Designation: A 6/A 6M – 05a

# Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling[1]

This standard is issued under the fixed designation A 6/A 6M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

## 1. Scope*

1.1 This general requirements specification[2] covers a group of common requirements that, unless otherwise specified in the applicable product specification, apply to rolled structural steel bars, plates, shapes, and sheet piling covered by each of the following product specifications issued by ASTM:

| ASTM Designation[3] | Title of Specification |
|---|---|
| A 36/A 36M | Carbon Structural Steel |
| A 131/A 131M | Structural Steel for Ships |
| A 242/A 242M | High-Strength Low-Alloy Structural Steel |
| A 283/A 283M | Low and Intermediate Tensile Strength Carbon Steel Plates |
| A 328/A 328M | Steel Sheet Piling |
| A 514/A 514M | High-Yield Strength, Quenched and Tempered Alloy Steel Plate Suitable for Welding |
| A 529/A 529M | High-Strength Carbon-Manganese Steel of Structural Quality |
| A 572/A 572M | High-Strength Low-Alloy Columbium-Vanadium Steel |
| A 573/A 573M | Structural Carbon Steel Plates of Improved Toughness |
| A 588/A 588M | High-Strength Low-Alloy Structural Steel with 50 ksi (345 MPa) Minimum Yield Point to 4 in. [100 mm] Thick |
| A 633/A 633M | Normalized High-Strength Low-Alloy Structural Steel Plates |
| A 656/A 656M | Hot-Rolled Structural Steel, High-Strength Low-Alloy Plate with Improved Formability |
| A 678/A 678M | Quenched-and-Tempered Carbon and High-Strength Low-Alloy Structural Steel Plates |
| A 690/A 690M | High-Strength Low-Alloy Steel H-Piles and Sheet Piling for Use in Marine Environments |
| A 709/A 709M | Carbon and High-Strength Low-Alloy Structural Steel Shapes, Plates, and Bars and Quenched-and-Tempered Alloy Structural Steel Plates for Bridges |
| A 710/A 710M | Age-Hardening Low-Carbon Nickel-Copper-Chromium-Molybdenum-Columbium Alloy Structural Steel Plates |
| A 769/A 769M | Carbon and High-Strength Electric Resistance Welded Steel Structural Shapes |
| A 786/A 786M | Rolled Steel Floor Plates |
| A 808/A 808M | High-Strength Low-Alloy Carbon, Manganese, Columbium, Vanadium Steel of Structural Quality with Improved Notch Toughness |
| A 827/A 827M | Plates, Carbon Steel, for Forging and Similar Applications |
| A 829/A 829M | Plates, Alloy Steel, Structural Quality |
| A 830/A 830M | Plates, Carbon Steel, Structural Quality, Furnished to Chemical Composition Requirements |
| A 852/A 852M | Quenched and Tempered Low-Alloy Structural Steel Plate with 70 ksi [485 Mpa] Minimum Yield Strength to 4 in. [100 mm] Thick |
| A 857/A 857M | Steel Sheet Piling, Cold Formed, Light Gage |
| A 871/A 871M | High-Strength Low Alloy Structural Steel Plate with Atmospheric Corrosion Resistance |
| A 913/A 913M | Specification for High-Strength Low-Alloy Steel Shapes of Structural Quality, Produced by Quenching and Self-Tempering Process (QST) |
| A 945/A 945M | Specification for High-Strength Low-Alloy Structural Steel Plate with Low Carbon and Restricted Sulfur for Improved Weldability, Formability, and Toughness |
| A 950/A 950M | Specification for Fusion Bonded Epoxy-Coated Structural Steel H-Piles and Sheet Piling |
| A 992/A 992M | Specification for Steel for Structural Shapes for Use in Building Framing |
| A 1026 | Specification for Alloy Steel Structural Shapes for Use in Building Framing |
| A 1043/A 1043M | Specification for Structural Steel with Low Yield to Tensile Ratio for Use in Buildings |

1.2 Annex A1 lists permitted variations in dimensions and mass (Note 1) in SI units. The values listed are not exact conversions of the values in Tables 1 to 31 inclusive but are, instead, rounded or rationalized values. Conformance to Annex A1 is mandatory when the "M" specification designation is used.

NOTE 1—The term "weight" is used when inch-pound units are the standard; however, under SI, the preferred term is "mass."

1.3 Annex A2 lists the dimensions of some shape profiles.

1.4 Appendix X1 provides information on coil as a source of structural products.

1.5 Appendix X2 provides information on the variability of tensile properties in plates and structural shapes.

1.6 Appendix X3 provides information on weldability.

1.7 Appendix X4 provides information on cold bending of plates, including suggested minimum inside radii for cold bending.

1.8 This general requirements specification also covers a group of supplementary requirements that are applicable to several of the above product specifications as indicated therein. Such requirements are provided for use where additional

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.02 on Structural Steel for Bridges, Buildings, Rolling Stock, and Ships.

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[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-6/SA-6M in Section II of that Code.

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

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testing or additional restrictions are required by the purchaser, and apply only where specified individually in the purchase order.

1.9 In case of any conflict in requirements, the requirements of the applicable product specification prevail over those of this general requirements specification.

1.10 Additional requirements that are specified in the purchase order and accepted by the supplier are permitted, provided that such requirements do not negate any of the requirements of this general requirements specification or the applicable product specification.

1.11 For purposes of determining conformance with this general requirements specification and the applicable product specification, values are to be rounded to the nearest unit in the right-hand place of figures used in expressing the limiting values in accordance with the rounding method of Practice E 29.

1.12 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system is to be used independently of the other, without combining values in any way.

1.13 This general requirements specification and the applicable product specification are expressed in both inch-pound units and SI units; however, unless the order specifies the applicable "M" specification designation (SI units), the structural product is furnished to inch-pound units.

1.14 The text of this general requirements specification contains notes and/or footnotes that provide explanatory material. Such notes and footnotes, excluding those in tables and figures, do not contain any mandatory requirements.

## 2. Referenced Documents

2.1 *ASTM Standards:* [3]

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

A 673/A 673M Specification for Sampling Procedure for Impact Testing of Structural Steel

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment

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

A 829 Specification for Plates, Alloy Steel, Structural Quality

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 112 Test Methods for Determining Average Grain Size

E 208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels

2.2 *American Welding Society Standards:*

A5.1 Mild Steel Covered Arc-Welding Electrodes[4]

A5.5 Low-Alloy Steel Covered Arc-Welding Electrodes[4]

2.3 *U.S. Military Standards:*

MIL-STD-129 Marking for Shipment and Storage[5]

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage[5]

2.4 *U.S. Federal Standard:*

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)[5]

2.5 *AIAG Standard:*

B-1 Bar Code Symbology Standard[6]

## 3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *Plates (other than floor plates)*—Flat, hot-rolled steel, ordered to thickness or weight [mass] and typically width and length, commonly classified as follows:

3.1.1.1 *When Ordered to Thickness*:

*(1)* Over 8 in. [200 mm] in width and 0.230 in. [6 mm] or over in thickness.

*(2)* Over 48 in. [1200 mm] in width and 0.180 in. [4.5 mm] or over in thickness.

3.1.1.2 *When Ordered to Weight [Mass]*:

*(1)* Over 8 in. [200 mm] in width and 9.392 lb/ft$^2$ [47.10 kg/m$^2$] or heavier.

*(2)* Over 48 in. [1200 mm] in width and 7.350 lb/ft$^2$ [35.32 kg/m$^2$] or heavier.

3.1.1.3 *Discussion*—Steel products are available in various thickness, width, and length combinations depending upon equipment and processing capabilities of various manufacturers and processors. Historic limitations of a product based upon dimensions (thickness, width, and length) do not take into account current production and processing capabilities. To qualify any product to a particular product specification requires all appropriate and necessary tests be performed and that the results meet the limits prescribed in that product specification. If the necessary tests required by a product specification cannot be conducted, the product cannot be qualified to that specification. This general requirement standard contains permitted variations for the commonly available sizes. Permitted variations for other sizes are subject to agreement between the customer and the manufacturer or processor, whichever is applicable.

3.1.1.4 Slabs, sheet bars, and skelp, though frequently falling in the foregoing size ranges, are not classed as plates.

3.1.1.5 Coils are excluded from qualification to the applicable product specification until they are decoiled, leveled or straightened, formed (if applicable), cut to length, and, if required, properly tested by the processor in accordance with ASTM specification requirements (see Sections 9, 10, 11, 12, 13, 14, 15, 18, and 19 and the applicable product specification).

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from the American Welding Society, 550 N.W. LaJeune Rd., Miami, FL 33135.

[5] Available from the procuring activity or as directed by the contracting office or from the Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094 Attn: NPODS.

[6] Available from the Automotive Industry Action Group, 26200 Lahser Road, Suite 200, Southfield, MI 48034.

3.1.2 *Shapes (Flanged Sections)*:

3.1.2.1 *structural-size shapes*—rolled flanged sections having at least one dimension of the cross section 3 in. [75 mm] or greater.

3.1.2.2 *bar-size shapes*—rolled flanged sections having a maximum dimension of the cross section less than 3 in. [75 mm].

3.1.2.3 *"W" shapes*—doubly-symmetric, wide-flange shapes with inside flange surfaces that are substantially parallel.

3.1.2.4 *"HP" shapes*—are wide-flange shapes generally used as bearing piles whose flanges and webs are of the same nominal thickness and whose depth and width are essentially the same.

3.1.2.5 *"S" shapes*—doubly-symmetric beam shapes with inside flange surfaces that have a slope of approximately 16⅔ %.

3.1.2.6 *"M" shapes*—doubly-symmetric shapes that cannot be classified as "W," " S," or "HP" shapes.

3.1.2.7 *"C" shapes*—channels with inside flange surfaces that have a slope of approximately 16⅔ %.

3.1.2.8 *"MC" shapes*—channels that cannot be classified as "C" shapes.

3.1.2.9 *"L" shapes*—shapes having equal-leg and unequal-leg angles.

3.1.3 *sheet piling*—rolled steel sections that are capable of being interlocked, forming a continuous wall when individual pieces are driven side by side.

3.1.4 *bars*—rounds, squares, and hexagons, of all sizes; flats 13⁄64 in. (0.203 in.) and over [over 5 mm] in specified thickness, not over 6 in. [150 mm] in specified width; and flats 0.230 in. and over [over 6 mm] in specified thickness, over 6 to 8 in. [150 to 200 mm] inclusive, in specified width.

3.1.5 *exclusive*—when used in relation to ranges, as for ranges of thickness in the tables of permissible variations in dimensions, is intended to exclude only the greater value of the range. Thus, a range from 60 to 72 in. [1500 to 1800 mm] exclusive includes 60 in. [1500 mm], but does not include 72 in. [1800 mm].

3.1.6 *rimmed steel*—steel containing sufficient oxygen to give a continuous evolution of carbon monoxide during solidification, resulting in a case or rim of metal virtually free of voids.

3.1.7 *semi-killed steel*—incompletely deoxidized steel containing sufficient oxygen to form enough carbon monoxide during solidification to offset solidification shrinkage.

3.1.8 *capped steel*—rimmed steel in which the rimming action is limited by an early capping operation. Capping is carried out mechanically by using a heavy metal cap on a bottle-top mold or chemically by an addition of aluminum or ferrosilicon to the top of the molten steel in an open-top mold.

3.1.9 *killed steel*—steel deoxidized, either by addition of strong deoxidizing agents or by vacuum treatment, to reduce the oxygen content to such a level that no reaction occurs between carbon and oxygen during solidification.

3.1.10 *mill edge*—the normal edge produced by rolling between horizontal finishing rolls. A mill edge does not conform to any definite contour. Mill edge plates have two mill edges and two trimmed edges.

3.1.11 *universal mill edge*—the normal edge produced by rolling between horizontal and vertical finishing rolls. Universal mill plates, sometimes designated UM Plates, have two universal mill edges and two trimmed edges.

3.1.12 *sheared edge*—the normal edge produced by shearing. Sheared edge plates are trimmed on all edges.

3.1.13 *gas cut edge*—the edge produced by gas flame cutting.

3.1.14 *special cut edge*—usually the edge produced by gas flame cutting involving special practices such as pre-heating or post-heating, or both, in order to minimize stresses, avoid thermal cracking and reduce the hardness of the gas cut edge. In special instances, special cut edge is used to designate an edge produced by machining.

3.1.15 *sketch*—when used to describe a form of plate, denotes a plate other than rectangular, circular, or semicircular. Sketch plates may be furnished to a radius or with four or more straight sides.

3.1.16 *normalizing*—a heat treating process in which a steel plate is reheated to a uniform temperature above the upper critical temperature and then cooled in air to below the transformation range.

3.1.17 *plate-as-rolled*—when used in relation to the location and number of tests, the term refers to the unit plate rolled from a slab or directly from an ingot. It does not refer to the condition of the plate.

3.1.18 *fine grain practice*—a steelmaking practice that is intended to produce a killed steel that is capable of meeting the requirements for fine austenitic grain size.

3.1.18.1 *Discussion*—It normally involves the addition of one or more austenitic grain refining elements in amounts that have been established by the steel producer as being sufficient. Austenitic grain refining elements include, but are not limited to, aluminum, columbium, titanium, and vanadium.

3.1.19 *structural product*—a hot-rolled steel plate, shape, sheet piling, or bar.

3.1.20 *coil*—hot-rolled steel in coiled form that is intended to be processed into a finished structural product.

3.1.21 *manufacturer*—the organization that directly controls the conversion of steel ingots, slabs, blooms, or billets, by hot-rolling, into an as-rolled structural product or into coil; and for structural products produced from as-rolled structural products, the organization that directly controls, or is responsible for, the operations involved in finishing the structural product.

3.1.21.1 *Discussion*—Such finishing operations include leveling or straightening, hot forming or cold forming (if applicable), welding (if applicable), cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

3.1.22 *processor*—the organization that directly controls, or is responsible for, the operations involved in the processing of coil into a finished structural product. Such processing operations include decoiling, leveling or straightening, hot-forming or cold-forming (if applicable), welding (if applicable), cutting

to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

3.1.22.1 *Discussion*—The processing operations need not be done by the organization that did the hot rolling of the coil. If only one organization is involved in the hot rolling and processing operations, that organization is termed the *manufacturer* for the hot rolling operation and the *processor* for the processing operations. If more than one organization is involved in the hot rolling and processing operations, the organization that did the hot rolling is termed the *manufacturer* and an organization that does one or more processing operations is termed a *processor*.

3.2 Refer to Terminology A 941 for additional definitions of terms used in this standard.

## 4. Ordering Information

4.1 Information items to be considered, if appropriate, for inclusion in purchase orders are as follows:

4.1.1 ASTM product specification designation (see 1.1) and year-date,

4.1.2 Name of structural product (plate, shape, bar, or sheet piling),

4.1.3 Shape designation, or size and thickness or diameter,

4.1.4 Grade, class, and type designation, if applicable,

4.1.5 Condition (see Section 6), if other than as-rolled,

4.1.6 Quantity (weight [mass] or number of pieces),

4.1.7 Length,

4.1.8 Exclusion of either structural product produced from coil or structural product produced from an as-rolled structural product (see 5.3 and Appendix X1), if applicable,

4.1.9 Heat treatment requirements (see 6.2 and 6.3), if any,

4.1.10 Testing for fine austenitic grain size (see 8.3.2),

4.1.11 Mechanical property test report requirements (see Section 14), if any,

4.1.12 Special packaging, marking, and loading for shipment requirements (see Section 19), if any,

4.1.13 Supplementary requirements, if any, including any additional requirements called for in the supplementary requirements,

4.1.14 End use, if there are any end-use-specific requirements (see 18.1, 11.3.4, Table 22 or Table A1.22, and Table 24 or Table A1.24)

4.1.15 Special requirements (see 1.10), if any, and

4.1.16 Repair welding requirements (see 9.5), if any.

## 5. Materials and Manufacture

5.1 The steel shall be made in an open-hearth, basic-oxygen, or electric-arc furnace, possibly followed by additionl refining in a ladle metallurgy furnace (LMF), or secondary melting by vacuum-arc remelting (VAR) or electroslag remelting (ESR).

5.2 The steel shall be strand cast or cast in stationary molds.

5.2.1 *Strand Cast*:

5.2.1.1 When heats of the same nominal chemical composition are consecutively strand cast at one time, the heat number assigned to the cast product need not be changed until all of the steel in the cast product is from the following heat.

5.2.1.2 When two consecutively strand cast heats have different nominal chemical composition ranges, the manufacturer shall remove the transition material by an established procedure that positively separates the grades.

5.3 Structural products shall be produced from an as-rolled structural product or from coil.

5.4 Where part of a heat is rolled into an as-rolled structural product and the balance of the heat is rolled into coil, each part shall be tested separately.

5.5 Structural products produced from coil shall not contain splice welds, unless previously approved by the purchaser.

## 6. Heat Treatment

6.1 Where th structural product is required to be heat treated, such heat treatment shall be performed by the manufacturer, the processor, or the fabricator, unless otherwise specified in the applicable product specification.

NOTE 2—When no heat treatment is required, the manufacturer or processor has the option of heat treating the structural product by normalizing, stress relieving, or normalizing then stress relieving to meet the applicable product specification.

6.2 Where the heat treatment is to be performed by other than the manufacturer, the order shall so state.

6.2.1 Where the heat treatment is to be performed by other than the manufacturer, the structural products shall be accepted on the basis of tests made on test specimens taken from full thickness test coupons heat treated in accordance with the requirements specified in the applicable product specification or in the purchase order. If the heat-treatment temperatures are not specified, the manufacturer or processor shall heat treat the test coupons under conditions he considers appropriate, provided that the purchaser is informed of the procedure followed in heat treating the test coupons.

6.3 Where the heat treatment is to be performed by the manufacturer or the processor, the structural product shall be heat treated as specified in the applicable product specification, or as specified in the purchase order, provided that the heat treatment specified by the purchaser is not in conflict with the requirements of the applicable product specification.

6.4 Where normalizing is to be performed by the fabricator, the structural product shall be either normalized or heated uniformly for hot forming, provided that the temperature to which the structural product is heated for hot forming does not significantly exceed the normalizing temperature.

6.5 The use of cooling rates that are faster than those obtained by cooling in air to improve the toughness shall be subject to approval by the purchaser, and structural products so treated shall be tempered subsequently in the range from 1100 to 1300 °F [595 to 705 °C].

## 7. Chemical Analysis

7.1 *Heat Analysis*:

7.1.1 Sampling for chemical analysis and methods of analysis shall be in accordance with Test Methods, Practices, and Terminolgy A 751.

7.1.2 For each heat, the heat analysis shall include determination of the content of carbon, manganese, phosphorus, sulfur, silicon, nickel, chromium, molybdenum, copper, vanadium, columbium; any other element that is specified or restricted by the applicable product specification for the applicable grade,

class, and type; and any austenitic grain refining element whose content is to be used in place of austenitic grain size testing of the heat (see 8.3.2).

7.1.3 Except as allowed by 7.1.4 for primary heats, heat analyses shall conform to the heat analysis requirements of the applicable product specification for the applicable grade, class, and type.

7.1.4 Where vacuum-arc remelting or electroslag remelting is used, a remelted heat is defined as all ingots remelted from a single primary heat. If the heat analysis of the primary heat conforms to the heat analysis requirements of the applicable product specification for the applicable grade, class, and type, the heat analysis for the remelted heat shall be determined from one test sample taken from one remelted ingot, or the product of one remelted ingot, from the primary heat. If the heat analysis of the primary heat does not conform to the heat analysis requirements of the applicable product specification for the applicable grade, type, and class, the heat analysis for the remelted heat shall be determined from one test sample taken from each remelted ingot, or the product of each remelted ingot, from the primary heat.

7.2 *Product Analysis*—For each heat, the purchaser shall have the option of analyzing representative samples taken from the finished structural product. Sampling for chemical analysis and methods of analysis shall be in accordance with Test Methods, Practices, and Terminology A 751. The product analyses so determined shall conform to the heat analysis requirements of the applicable product specification for the applicable grade, class, and type, subject to the permitted variations in product analysis given in Table A. If a range is specified, the determinations of any element in a heat shall not vary both above and below the specified range. Rimmed or capped steel is characterized by a lack of homogeneity in its composition, especially for the elements carbon, phosphorus, and sulfur. Therefore, the limitations for these elements shall not be applicable unless misapplication is clearly indicated.

7.3 *Referee Analysis*—For referee purposes, Test Methods, Practices, and Terminology A 751 shall be used.

7.4 *Grade Substitution*—Alloy steel grades that meet the chemical requirements of Table 1 of Specification A 829 shall not be substituted for carbon steel grades.

## 8. Metallurgical Structure

8.1 Where austenitic grain size testing is required, such testing shall be in accordance with Test Methods E 112 and at least 70 % of the grains in the area examined shall meet the specified grain size requirement.

8.2 *Coarse Austenitic Grain Size*—Where coarse austenitic grain size is specified, one austenitic grain size test per heat shall be made and the austenitic grain size number so determined shall be in the range of 1 to 5, inclusive.

8.3 *Fine Austenitic Grain Size*:

8.3.1 Where fine austenitic grain size is specified, except as allowed in 8.3.2, one austenitic grain size test per heat shall be made and the austenitic grain size number so determined shall be 5 or higher.

NOTE 3—Such austenitic grain size numbers may be achieved with lower contents of austenitic grain refining elemenst than 8.3.2 requires for austenitic grain size testing to be waived.

8.3.2 Unless testing for fine austenitic grain size is specified in the purchase order, an austenitic grain size test need not be made for any heat that has, by heat analysis, one or more of the following:

8.3.2.1 A total aluminum content of 0.020 % or more.

8.3.2.2 An acid soluble aluminum content of 0.015 % or more.

8.3.2.3 A content for an austenitic grain refining element that exceeds the minimum value agreed to by the purchaser as being sufficient for austenitic grain size testing to be waived, or

8.3.2.4 Contents for the combination of two or more austenitic grain refining elements that exceed the applicable minimum values agreed to by the purchaser as being sufficient for austenitic grain size testing to be waived.

## 9. Quality

9.1 *General*—Structural products shall be free of injurious defects and shall have a workmanlike finish.

NOTE 4—Unless otherwise specified, structural products are normally furnished in the as-rolled condition and are subjected to visual inspection by the manufacturer or processor. Non-injurious surface or internal imperfections, or both, may be present in the structural product as delivered and the structural product may require conditioning by the purchaser to improve its appearance or in preparation for welding, coating, or other further operations.

More restrictive requirements may be specified by invoking supplementary requirements or by agreement between the purchaser and the supplier.

Structural products that exhibit injurious defects during subsequent fabrication are deemed not to comply with the applicable product specification. (See 17.2.) Fabricators should be aware that cracks may initiate upon bending a sheared or burned edge during the fabrication process; this is not considered to be a fault of the steel but is rather a function of the induced cold-work or the heat-affected zone.

The conditioning requirements in 9.2, 9.3, and 9.4 limit the conditioning allowed to be performed by the manufacturer or processor. Conditioning of imperfections beyond the limits of 9.2, 9.3, and 9.4 may be performed by parties other than the manufacturer or processor at the discretion of the purchaser.

**TABLE A Permitted Variations in Product Analysis**

NOTE 1—Where "..." appears in this table, there is no requirement.

| Element | Upper Limit, or Maximum Specified Value, % | Permitted Variations, % | |
|---|---|---|---|
| | | Under Minimum Limit | Over Maximum Limit |
| Carbon | to 0.15 incl | 0.02 | 0.03 |
| | over 0.15 to 0.40 incl | 0.03 | 0.04 |
| | over 0.40 to 0.75 incl | 0.04 | 0.05 |
| | over 0.75 | 0.04 | 0.06 |
| Manganese[A] | to 0.60 incl | 0.05 | 0.06 |
| | over 0.60 to 0.90 incl | 0.06 | 0.08 |
| | over 0.90 to 1.20 incl | 0.08 | 0.10 |
| | over 1.20 to 1.35 incl | 0.09 | 0.11 |
| | over 1.35 to 1.65 incl | 0.09 | 0.12 |
| | over 1.65 to 1.95 incl | 0.11 | 0.14 |
| | over 1.95 | 0.12 | 0.16 |
| Phosphorus | to 0.04 incl | ... | 0.010 |
| | over 0.04 to 0.15 incl | ... | [B] |
| Sulfur | to 0.06 incl | ... | 0.010 |
| | over 0.06 | [B] | [B] |
| Silicon | to 0.30 incl | 0.02 | 0.03 |
| | over 0.30 to 0.40 incl | 0.05 | 0.05 |
| | over 0.40 to 2.20 incl | 0.06 | 0.06 |
| Nickel | to 1.00 incl | 0.03 | 0.03 |
| | over 1.00 to 2.00 incl | 0.05 | 0.05 |
| | over 2.00 to 3.75 incl | 0.07 | 0.07 |
| | over 3.75 to 5.30 incl | 0.08 | 0.08 |
| | over 5.30 | 0.10 | 0.10 |
| Chromium | to 0.90 incl | 0.04 | 0.04 |
| | over 0.90 to 2.00 incl | 0.06 | 0.06 |
| | over 2.00 to 4.00 incl | 0.10 | 0.10 |
| Molybdenum | to 0.20 incl | 0.01 | 0.01 |
| | over 0.20 to 0.40 incl | 0.03 | 0.03 |
| | over 0.40 to 1.15 incl | 0.04 | 0.04 |
| Copper | 0.20 minimum only | 0.02 | ... |
| | to 1.00 incl | 0.03 | 0.03 |
| | over 1.00 to 2.00 incl | 0.05 | 0.05 |
| Titanium | to 0.15 incl | 0.01[C] | 0.01 |
| Vanadium | to 0.10 incl | 0.01[C] | 0.01 |
| | over 0.10 to 0.25 incl | 0.02 | 0.02 |
| | over 0.25 | 0.02 | 0.03 |
| | minimum only specified | 0.01 | ... |
| Boron | any | [B] | [B] |
| Columbium | to 0.10 incl | 0.01[C] | 0.01 |
| Zirconium | to 0.15 incl | 0.03 | 0.03 |
| Nitrogen | to 0.030 incl | 0.005 | 0.005 |

[A] Permitted variations in manganese content for bars and bar size shapes shall be: to 0.90 incl ±0.03; over 0.90 to 2.20 incl± 0.06.
[B] Product analysis not applicable.
[C] 0.005, if the minimum of the range is 0.01 %.

**Index to Tables of Permitted Variations**

| Dimension | Table | |
|---|---|---|
| | Inch-Pound Units | SI Units |
| Camber | | |
| Plates, Carbon Steel; Sheared and Gas-Cut | 12 | A1.12 |
| Plates, Carbon Steel; Universal Mill | 11 | A1.11 |
| Plates, Other than Carbon Steel; Sheared, Gas-Cut and Universal Mill | 11 | A1.11 |
| Shapes, Rolled; S, M, C, MC, and L | 21 | A1.21 |
| Shapes, Rolled; W and HP | 24 | A1.24 |
| Shapes, Split; L and T | 25 | A1.25 |
| Cross Section of Shapes and Bars | | |
| Flats | 26 | A1.26 |
| Hexagons | 28 | A1.28 |
| Rounds and Squares | 27 | A1.27 |
| Shapes, Rolled; L, Bulb Angles, and Z | 17 | A1.17 |
| Shapes, Rolled; W, HP, S, M, C, and MC | 16 | A1.16 |
| Shapes, Rolled; T | 18 | A1.18 |
| Shapes, Split; L and T | 25 | A1.25 |
| Diameter | | |
| Plates, Sheared | 6 | A1.6 |
| Plates, Other than Alloy Steel, Gas-Cut | 7 | A1.7 |
| Plates, Alloy Steel, Gas-Cut | 10 | A1.10 |
| Rounds | 27 | A1.27 |
| End Out-of-Square | | |
| Shapes, Other than W | 20 | A1.20 |
| Shapes, W | 22 | A1.22 |
| Shapes, Milled, Other than W | 23 | A1.23 |
| Flatness | | |
| Plates, Carbon Steel | 13 | A1.13 |
| Plates, Other than Carbon Steel | 14 | A1.14 |
| Plates, Restrictive—Carbon Steel | S27.1 | S27.2 |
| Plates, Restrictive—Other than Carbon Steel | S27.3 | S27.4 |
| Length | | |
| Bars | 30 | A1.30 |
| Bars, Recut | 31 | A1.31 |
| Plates, Sheared and Universal Mill | 3 | A1.3 |
| Plates, Other than Alloy Steel, Gas-Cut | 9 | A1.9 |
| Plates, Alloy Steel, Gas-Cut | 8 | A1.8 |
| Plates, Mill Edge | 4 | A1.4 |
| Shapes, Rolled; Other than W | 19 | A1.19 |
| Shapes, Rolled; W and HP | 22 | A1.22 |
| Shapes, Split; L and T | 25 | A1.25 |
| Shapes, Milled | 23 | A1.23 |
| Straightness | | |
| Bars | 29 | A1.29 |
| Shapes, Other than W | 21 | A1.21 |
| Sweep | | |
| Shapes, W and HP | 24 | A1.24 |
| Thickness | | |
| Flats | 26 | A1.26 |
| Plates, Ordered to Thickness | 1 | A1.1 |
| Waviness | | |
| Plates | 15 | A1.15 |
| Weight [Mass] | | |
| Plates, Ordered to Weight [Mass] | 2 | A1.2 |
| Width | | |
| Flats | 26 | A1.26 |
| Plates, Sheared | 3 | A1.3 |
| Plates, Universal Mill | 5 | A1.5 |
| Plates, Other than Alloy Steel, Gas-Cut | 9 | A1.9 |
| Plates, Alloy Steel, Gas-Cut | 8 | A1.8 |
| Plates, Mill Edge | 4 | A1.4 |

9.2 *Plate Conditioning*:

9.2.1 The grinding of plates by the manufacturer or processor to remove imperfections on the top or bottom surface shall be subject to the limitations that the area ground is well faired without abrupt changes in contour and the grinding does not reduce the thickness of the plate by (*1*) more than 7 % under the nominal thickness for plates ordered to weight per square foot or mass per square metre, but in no case more than ⅛ in. [3 mm]; or (*2*) below the permissible minimum thickness for plates ordered to thickness in inches or millimetres.

9.2.2 The deposition of weld metal (see 9.5) following the removal of imperfections on the top or bottom surface of plates by chipping, grinding, or arc-air gouging shall be subject to the following limiting conditions:

9.2.2.1 The chipped, ground, or gouged area shall not exceed 2 % of the area of the surface being conditioned.

9.2.2.2 After removal of any imperfections preparatory to welding, the thickness of the plate at any location shall not be reduced by more than 30 % of the nominal thickness of the plate. (Specification A 131/A 131M restricts the reduction in thickness to 20 % maximum.)

9.2.3 The deposition of weld metal (see 9.5) following the removal of injurious imperfections on the edges of plates by grinding, chipping, or arc-air gouging by the manufacturer or processor shall be subject to the limitation that, prior to welding, the depth of the depression, measured from the plate edge inward, is not more than the thickness of the plate or 1 in. [25 mm], whichever is the lesser.

9.3 *Structural Size Shapes, Bar Size Shapes, and Sheet Piling Conditioning*:

9.3.1 The grinding, or chipping and grinding, of structural size shapes, bar size shapes, and sheet piling by the manufacturer or processor to remove imperfections shall be subject to the limitations that the area ground is well faired without abrupt changes in contour and the depression does not extend below the rolled surface by more than (*1*) 1⁄32 in. [1 mm], for material less than ⅜ in. [10 mm] in thickness; (*2*) 1⁄16 in. [2 mm], for material ⅜ to 2 in. [10 to 50 mm] inclusive in thickness; or (*3*) ⅛ in. [3 mm], for material over 2 in. [50 mm] in thickness.

9.3.2 The deposition of weld metal (see 9.5) following removal of imperfections that are greater in depth than the limits listed in 9.3.1 shall be subject to the following limiting conditions:

9.3.2.1 The total area of the chipped or ground surface of any piece prior to welding shall not exceed 2 % of the total surface area of that piece.

9.3.2.2 The reduction of thickness of the material resulting from removal of imperfections prior to welding shall not exceed 30 % of the nominal thickness at the location of the imperfection, nor shall the depth of depression prior to welding exceed 1¼ in. [32 mm] in any case except as noted in 9.3.2.3.

9.3.2.3 The deposition of weld metal (see 9.5) following grinding, chipping, or arc-air gouging of the toes of angles, beams, channels, and zees and the stems and toes of tees shall be subject to the limitation that, prior to welding, the depth of the depression, measured from the toe inward, is not more than the thickness of the material at the base of the depression or ½ in. [12.5 mm], whichever is the lesser.

9.3.2.4 The deposition of weld metal (see 9.5) and grinding to correct or build up the interlock of any sheet piling section at any location shall be subject to the limitation that the total surface area of the weld not exceed 2 % of the total surface area of the piece.

9.4 *Bar Conditioning*:

9.4.1 The conditioning of bars by the manufacturer or processor to remove imperfections by grinding, chipping, or some other means shall be subject to the limitations that the conditioned area is well faired and the affected sectional area is not reduced by more than the applicable permitted variations (see Section 12).

9.4.2 The deposition of weld metal (see 9.5) following chipping or grinding to remove imperfections that are greater in depth than the limits listed in 9.4.1 shall be subject to the following conditions:

9.4.2.1 The total area of the chipped or ground surface of any piece, prior to welding, shall not exceed 2 % of the total surface area of the piece.

9.4.2.2 The reduction of sectional dimension of a round, square, or hexagon bar, or the reduction in thickness of a flat bar, resulting from removal of an imperfection, prior to welding, shall not exceed 5 % of the nominal dimension or thickness at the location of the imperfection.

9.4.2.3 For the edges of flat bars, the depth of the conditioning depression prior to welding shall be measured from the edge inward and shall be limited to a maximum depth equal to the thickness of the flat bar or ½ in. [12.5 mm], whichever is less.

9.5 *Repair by Welding*:

9.5.1 *General Requirements*:

9.5.1.1 Repair by welding shall be in accordance with a welding procedure specification (WPS) using shielded metal arc welding (SMAW), gas metal arc welding (GMAW), flux cored arc welding (FCAW), or submerged arc welding (SAW) processes. Shielding gases used shall be of welding quality.

9.5.1.2 Electrodes and electrode-flux combinations shall be in accordance with the requirements of AWS Specification A5.1, A5.5, A5.17, A5.18, A5.20, A5.23, A5.28, or A5.29, whichever is applicable. For SMAW, low hydrogen electrodes shall be used.

9.5.1.3 Electrodes and electrode-flux combinations shall be selected so that the tensile strength of the deposited weld metal (after any required heat treatment) is consistent with the tensile strength specified for the base metal being repaired.

9.5.1.4 Welding electrodes and flux materials shall be dry and protected from moisture during storage and use.

9.5.1.5 Prior to repair welding, the surface to be welded shall be inspected to verify that the imperfections intended to be removed have been removed completely. Surfaces to be welded and surfaces adjacent to the weld shall be dry and free of scale, slag, rust, moisture, grease, and other foreign material that would prevent proper welding.

9.5.1.6 Welders and welding operators shall be qualified in accordance with the requirements of ANSI/AWS D1.1 or ASME Section IX, except that any complete joint penetration

groove weld qualification also qualifies the welder or welding operator to do repair welding.

9.5.1.7 Repair welding of structural products shall be in accordance with a welding procedure specification (WPS) that is in accordance with the requirements of ANSI/AWS D1.1 or ASME Section IX, with the following exceptions or clarifications:

*(a)* The WPS shall be qualified by testing a complete joint penetration groove weld or a surface groove weld.

*(b)* The geometry of the surface groove weld need not be described in other than a general way.

*(c)* An ANSI/AWS D1.1 prequalified complete joint penetration groove weld WPS is acceptable.

*(d)* Any material not listed in the prequalified base metal-filler metal combinations of ANSI/AWS D1.1 also is considered to be prequalified if its chemical composition and mechanical properties are comparable to those for one of the prequalified base metals listed in ANSI/AWS D1.1.

*(e)* Any material not listed in ASME Section IX also is considered to be a material with an S-number in ASME Section IX if its chemical composition and its mechanical properties are comparable to those for one of the materials listed in ASME Section IX with an S-number.

9.5.1.8 When so specified in the purchase order, the WPS shall include qualification by Charpy V-notch testing, with the test locations, test conditions, and the acceptance criteria meeting the requirements specified for repair welding in the purchase order.

9.5.1.9 When so specified in the purchase order, the welding procedure specification (WPS) shall be subject to approval by the purchaser prior to repair welding.

9.5.2 *Structural Products with a Specified Minimum Tensile Strength of 100 ksi [690 MPa] or Higher*—Repair welding of structural products with a specified minimum tensile strength of 100 ksi [690 MPa] or higher shall be subject to the following additional requirements:

9.5.2.1 When so specified in the purchase order, prior approval for repair by welding shall be obtained from the purchaser.

9.5.2.2 The surface to be welded shall be inspected using a magnetic particle method or a liquid penetrant method to verify that the imperfections intended to be removed have been completely removed. When magnetic particle inspection is employed, the surface shall be inspected both parallel and perpendicular to the length of the area to be repaired.

9.5.2.3 When weld repairs are to be post-weld heat-treated, special care shall be exercised in the selection of electrodes to avoid those compositions that embrittle as a result of such heat treatment.

9.5.2.4 Repairs on structural products that are subsequently heat-treated at the mill shall be inspected after heat treatment; repairs on structural products that are not subsequently heat-treated at the mill shall be inspected no sooner than 48 h after welding. Such inspection shall use a magnetic particle method or a liquid penetrant method; where magnetic particle inspection is involved, such inspection shall be both parallel to and perpendicular to the length of the repair.

9.5.2.5 The location of the weld repairs shall be marked on the finished piece.

9.5.3 *Repair Quality*—The welds and adjacent heat-affected zone shall be sound and free of cracks, the weld metal being thoroughly fused to all surfaces and edges without undercutting or overlap. Any visible cracks, porosity, lack of fusion, or undercut in any layer shall be removed prior to deposition of the succeeding layer. Weld metal shall project at least 1⁄16 in. (2 mm) above the rolled surface after welding, and the projecting metal shall be removed by chipping or grinding, or both, to make it flush with the rolled surface, and to produce a workmanlike finish.

9.5.4 *Inspection of Repair*—The manufacturer or processor shall maintain an inspection program to inspect the work to see that:

9.5.4.1 Imperfections have been completely removed.

9.5.4.2 The limitations specified above have not been exceeded.

9.5.4.3 Established welding procedures have been followed, and

9.5.4.4 Any weld deposit is of acceptable quality as defined above.

## 10. Test Methods

10.1 All tests shall be conducted in accordance with Test Methods and Definitions A 370.

10.2 Yield strength shall be determined either by the 0.2 % offset method or by the 0.5 % extension under load method, unless otherwise stated in the material specification.

10.3 *Rounding Procedures*—For purposes of determining conformance with the specification, a calculated value shall be rounded to the nearest 1 ksi [5 MPa] tensile and yield strength, and to the nearest unit in the right-hand place of figures used in expressing the limiting value for other values in accordance with the rounding method given in Practice E 29.

10.4 For full-section test specimens of angles, the cross-sectional area used for calculating the yield and tensile strengths shall be a theoretical area calculated on the basis of the weight of the test specimen (see 12.1).

## 11. Tension Tests

11.1 *Condition*—Test specimens for non-heat-treated structural products shall be taken from test coupons that are representative of the structural products in their delivered condition. Test specimens for heat-treated structural products shall be taken from test coupons that are representative of the structural products in their delivered condition, or from separate pieces of full thickness or full section from the same heat similarly heat treated.

11.1.1 Where the plate is heat treated with a cooling rate faster than still-air cooling from the austenitizing temperature, one of the following shall apply in addition to other requirements specified herein:

11.1.1.1 The gage length of the tension test specimen shall be taken at least 1*T* from any as-heat treated edge where *T* is the thickness of the plate and shall be at least ½ in. [12.5 mm] from flame cut or heat-affected-zone surfaces.

11.1.1.2 A steel thermal buffer pad, 1*T* by 1*T* by at least 3*T*, shall be joined to the plate edge by a partial penetration weld completely sealing the buffered edge prior to heat treatment.

11.1.1.3 Thermal insulation or other thermal barriers shall be used during the heat treatment adjacent to the plate edge where specimens are to be removed. It shall be demonstrated that the cooling rate of the tension test specimen is no faster than, and not substantially slower than, that attained by the method described in 11.1.1.2.

11.1.1.4 When test coupons cut from the plate but heat treated separately are used, the coupon dimensions shall be not less than 3*T* by 3*T* by *T* and each tension specimen cut from it shall meet the requirements of 11.1.1.1.

11.1.1.5 The heat treatment of test specimens separately in the device shall be subject to the limitations that (*1*) cooling rate data for the plate are available; (*2*) cooling rate control devices for the test specimens are available; and, (*3*) the method has received prior approval by the purchaser.

11.2 *Orientation*—For plates wider than 24 in. [600 mm], test specimens shall be taken such that the longitudinal axis of the test specimen is transverse to the final direction of rolling of the plate. Test specimens for all other structural products shall be taken such that the longitudinal axis of the test specimen is parallel to the final direction of rolling.

11.3 *Location*:

11.3.1 *Plates*—Test specimens shall be taken from a corner of the plate.

11.3.2 *W and HP Shapes with Flanges 6 in. [150 mm] or Wider*—Test specimens shall be selected from a point in the flange ⅔ of the way from the flange centerline to the flange toe.

11.3.3 *Shapes Other Than Those in 11.3.2*—Test specimens shall be selected from the webs of beams, channels, and zees; from the stems of rolled tees; and from the legs of angles and bulb angles, except where full-section test specimens for angles are used and the elongation acceptance criteria are increased accordingly. (See 11.6.2)

11.3.4 *Bars*:

11.3.4.1 Test specimens for bars to be used for pins and rollers shall be taken so that the axis is: midway between the center and the surface for pins and rollers less than 3 in. [75 mm] in diameter; 1 in. [25 mm] from the surface for pins and rollers 3 in. [75 mm] and over in diameter; or as specified in Annex A1 of Test Methods and Definitions A 370 if the applicable foregoing requirement is not practicable.

11.3.4.2 Test specimens for bars other than those to be used for pins and rollers shall be taken as specified in Annex A1 of Test Methods and Definitions A 370.

11.4 *Test Frequency*:

11.4.1 *Structural Products Produced from an As-Rolled Structural Product*—The minimum number of pieces or plates-as-rolled to be tested for each heat and strength gradation, where applicable, shall be as follows, except that it shall be permissible for any individual test to represent multiple strength gradations:

11.4.1.1 As given in Table B, or

11.4.1.2 One taken from the minimum thickness in the heat and one taken from the maximum thickness in the heat, where thickness means the specified thickness, diameter, or comparable dimension, whichever is appropriate for the applicable structural product rolled.

11.4.2 *Structural Products Produced from Coil and Furnished without Heat Treatment or with Stress Relieving Only*:

11.4.2.1 Except as allowed by 11.4.4, the minimum number of coils to be tested for each heat and strength gradation, where applicable, shall be as given in Table C, except that it shall be permissible for any individual coil to represent multiple strength gradations.

11.4.2.2 Except as required by 11.4.2.3, two tension test specimens shall be taken from each coil tested, with the first being taken immediately prior to the first structural product to be qualified, and the second being taken from the approximate center lap.

11.4.2.3 If, during decoiling, the amount of material decoiled is less than that required to reach the approximate center lap, the second test for the qualification of the decoiled portion of such a coil shall be taken from a location adjacent to the end of the innermost portion decoiled. For qualification of successive portions from such a coil, an additional test shall be taken adjacent to the innermost portion decoiled, until a test is obtained from the approximate center lap.

11.4.3 *Structural Products Produced from Coil and Furnished Heat Treated by other than Stress Relieving*—The minimum number of pieces to be tested for each heat and strength gradation, where applicable, shall be as follows, except that it shall be permissible for any individual test to represent multiple strength gradations:

11.4.3.1 As given in Table B, or

11.4.3.2 One taken from the minimum thickness in the heat and one taken from the maximum thickness in the heat, where thickness means the specified thickness, diameter, or comparable dimension, whichever is appropriate for the applicable structural product rolled.

11.4.4 *Structural Products Produced from Coil and Qualified Using Test Specimens Heat Treated by Other than Stress Relieving*—The minimum number of pieces to be tested for each heat and strength gradation, where applicable, shall be as follows, except that it shall be permissible for any individual test to represent multiple strength gradations:

11.4.4.1 As given in Table B, or

11.4.4.2 One taken from the minimum thickness in the heat, where thickness means the specified thickness, diameter, or comparable dimension, whichever is appropriate for the applicable structural product rolled.

11.5 *Preparation*:

11.5.1 *Plates*:

11.5.1.1 Tension test specimens for plates ¾ in. [20 mm] and under in thickness shall be the full thickness of the plates. The test specimens shall conform to the requirements shown in Fig. 3 of Test Methods and Definitions A 370 for either the 1½-in. [40-mm] wide test specimen or the ½-in. [12.5-mm] wide test specimen.

11.5.1.2 For plates up to 4 in. [100 mm], inclusive, in thickness, the use of 1½-in. [40-mm] wide test specimens, full thickness of the plate and conforming to the requirements

shown in Fig. 3 of Test Methods and Definitions A 370, shall be subject to the limitation that adequate testing machine capacity is available.

11.5.1.3 For plates over ¾ in. [20 mm] in thickness, except as permitted in 11.5.1.2, tension test specimens shall conform to the requirements shown in Fig. 4 of Test Methods and Definitions A 370 for the 0.500-in. [12.5-mm] diameter test specimen. The axis of such test specimens shall be located midway between the center of thickness and the top or bottom surface of the plate.

11.5.2 *Shapes*:

11.5.2.1 Except where angles are tested in full section, tension test specimens for shapes ¾ in. [20 mm] and under in thickness shall be the full thickness of the shape. Such test specimen shall conform to the requirements shown in Fig. 3 of Test Methods and Definitions A 370 for either the 1½-in. [40-mm] wide test specimen or the ½-in. [12.5-mm] wide test specimen.

11.5.2.2 For shapes up to 5 in. [125 mm], inclusive, in thickness, the use of 1½-in. [40-mm] wide test specimens, full thickness of the shape and conforming to the requirements shown in Fig. 3 of Test Methods and Definitions A 370, shall be subject to the limitation that adequate testing machine capacity is available.

**TABLE B Minimum Number of Tension Tests Required**

| Thickness[A] Range Rolled for the Heat | Thickness[A] Difference Between Pieces or Plates-as-rolled in the Thickness[A] Range | Minimum Number of Tension Tests Required |
|---|---|---|
| Under ⅜ in. [10 mm] | 1/16 in. [2 mm] or less | Two[B] tests per heat, taken from different pieces or plates-as-rolled having any thickness[A] in the thickness[A] range |
| | More than 1/16 in. [2 mm] | Two[B] tests per heat, one taken from the minimum thickness[A] in the thickness[A] range and one taken from the maximum thickness[A] in the thickness[A] range |
| ⅜ to 2 in. [10 to 50 mm], incl | Less than ⅜ in. [10 mm] | Two[B] tests per heat, taken from different pieces or plates-as-rolled having any thickness[A] in the thickness[A] range |
| | ⅜ in. [10 mm] or more | Two[B] tests per heat, one taken from the minimum thickness[A] in the thickness[A] range and one taken from the maximum thickness[A] in the thickness[A] range |
| Over 2 in. [50 mm] | Less than 1 in. [25 mm] | Two[B] tests per heat, taken from different pieces or plates-as-rolled having any thickness[A] in the thickness[A] range |
| | 1 in. [25 mm] or more | Two[B] tests per heat, one taken from the minimum thickness[A] in the thickness[A] range and one taken from the maximum thickness[A] in the thickness[A] range |

[A]Thickness means the specified thickness, diameter, or comparable dimension, whichever is appropriate for the specific structural product rolled.

[B]One test, if only one piece or plate-as-rolled is to be qualified.

**TABLE C Minimum Number of Coils Required to be Tension Tested**

NOTE—See 11.4.2.2 and 11.4.2.3 for the number of tests to be taken per coil.

| Thickness[A] Difference Between Coils in the Heat | Minimum Number of Coils Required to Be Tension Tested |
|---|---|
| Less than 1/16 in. [2 mm] | Two[B] coils per heat, at any thickness[A] in the heat |
| 1/16 in. [2 mm] or more | Two[B] coils per heat, one at the minimum thickness[A] in the heat and one at the maximum thickness[A] in the heat |

[A]Thickness means the specified thickness, diameter, or comparable dimension, whichever is appropriate for the specific structural product rolled.

[B]One coil, if the product of only one coil is to be qualified.

11.5.2.3 For shapes over ¾ in. [20 mm] in thickness, except as permitted in 11.5.2.2, tension test specimens shall conform to the requirements shown in Fig. 4 of Test Methods and Definitions A 370 for the 0.500–in. [12.5–mm] diameter test specimens. The axis of such test specimens shall be located midway between the center of thickness and the top or bottom surface of the shape.

11.5.3 *Bars*:

11.5.3.1 Except as otherwise provided below, test specimens for bars shall be in accordance with Annex A1 of Test Methods and Definitions A 370.

11.5.3.2 Except as provided in 11.5.3.5, test specimens for bars ¾ in. [20 mm] and under in thickness may conform to the requirements shown in Fig. 3 of Test Methods and Definitions A 370 for either the 1½-in. [40-mm] wide test specimen or the ½-in. [12.5-mm] wide specimen.

11.5.3.3 Except as provided in 11.5.3.4 and 11.5.3.5, test specimens for bars over ¾ in. [20 mm] in thickness or diameter shall conform either to the requirements for the 1½-in. [40-mm] or ½-in. [12.5-mm] wide test specimen shown in Fig. 3 of Test Methods and Definitions A 370, or to the requirements for the 0.500–in. [12.5–mm] diameter test specimen shown in Fig. 4 of Test Methods and Definitions A 370.

11.5.3.4 For bars other than those to be used for pins and rollers, the manufacturer or processor shall have the option of using test specimens that are machined to a thickness or diameter of at least ¾ in. [20 mm] for a length of at least 9 in. [230 mm].

11.5.3.5 Test specimens for bars to be used for pins and rollers shall conform to the requirements shown in Fig. 4 of Test Methods and Definitions A 370 for the 0.500–in. [12.5–mm] diameter test specimen.

11.6 *Elongation Requirement Adjustments*:

11.6.1 Due to the specimen geometry effect encountered when using the rectangular tension test specimen for testing thin material, adjustments in elongation requirements must be provided for thicknesses under 0.312 in. [8 mm]. Accordingly, the following deductions from the base elongation requirements shall apply:

| Nominal Thickness Range, in. [mm] | Elongation Deduction, % |
|---|---|
| 0.299—0.311 [7.60—7.89] | 0.5 |
| 0.286—0.298 [7.30—7.59] | 1.0 |
| 0.273—0.285 [7.00—7.29] | 1.5 |
| 0.259—0.272 [6.60—6.99] | 2.0 |
| 0.246—0.258 [6.20—6.59] | 2.5 |
| 0.233—0.245 [5.90—6.19] | 3.0 |
| 0.219—0.232 [5.50—5.89] | 3.5 |
| 0.206—0.218 [5.20—5.49] | 4.0 |
| 0.193—0.205 [4.90—5.19] | 4.5 |
| 0.180—0.192 [4.60—4.89] | 5.0 |
| 0.166—0.179 [4.20—4.59] | 5.5[A] |
| 0.153—0.165 [3.90—4.19] | 6.0[A] |
| 0.140—0.152 [3.60—3.89] | 6.5[A] |
| 0.127—0.139 [3.20—3.59] | 7.0[A] |
| < 0.127 [3.20] | 7.5[A] |

[A] Elongation deductions for thicknesses less than 0.180 in. [4.60 mm] apply to plates and structural shapes only.

11.6.2 Due to the specimen geometry effect encountered when using full-section test specimens for angles, the elongation requirements for structural-size angles shall be increased by six percentage points when full-section test specimens are used.

11.6.3 Due to the inherently lower elongation that is obtainable in thicker structural products, adjustments in elongation requirements shall be provided. For structural products over 3.5 in. [90 mm] in thickness, a deduction of 0.5 percentage point from the specified percentage of elongation in 2 in. [50 mm] shall be made for each 0.5–in. [12.5–mm] increment of thickness over 3.5 in. [90 mm], up to a maximum deduction of 3.0 percentage points. Accordingly, the following deductions from the base elongation requirements shall apply:

| Nominal Thickness Range, in. [mm] | Elongation Deduction,% |
|---|---|
| 3.500—3.999 [90.00—102.49] | 0.5 |
| 4.000—4.499 [102.50—114.99] | 1.0 |
| 4.500—4.999 [115.00—127.49] | 1.5 |
| 5.000—5.499 [127.50—139.99] | 2.0 |
| 5.500—5.999 [140.00—152.49] | 2.5 |
| 6.000 and thicker [152.50 and thicker] | 3.0 |

11.6.4 The tensile property requirements tables in many of the product specifications covered by this general requirements specification specify elongation requirements in both 8-in. [200–mm] and 2-in. [50–mm] gage lengths. Unless otherwise provided in the applicable product specification, both requirements are not required to be applied simultaneously and the elongation need only be determined in the gage length appropriate for the test specimen used. After selection of the appropriate gage length, the elongation requirement for the alternative gage length shall be deemed not applicable.

11.7 *Yield Strength Application*:

11.7.1 When test specimens do not exhibit a well-defined disproportionate yield point, yield strength shall be determined and substituted for yield point.

11.7.2 The manufacturer or processor shall have the option of substituting yield strength for yield point if the test specimen exhibits a well-defined disproportionate yield point.

11.7.3 Yield strength shall be determined either by the 0.2 % offset method or by the 0.5 % extension-under-load method.

11.8 *Product Tension Tests*—This specification does not provide requirements for product tension testing subsequent to shipment (see 15.1). Therefore, the requirements of 11.1 to 11.7 inclusive and Section 13 apply only for tests conducted at the place of manufacture prior to shipment.

NOTE 5—Compliance to Specification A 6/A 6M and the applicable product specification by a manufacturer or processor does not preclude the possibility that product tension test results might vary outside specified ranges. The tensile properties will vary within the same heat or piece, be it as-rolled, control-rolled, or heat-treated. Tension testing according to the requirements of Specification A 6/A 6M does not provide assurance that all products of a heat will be identical in tensile properties with the products tested. If the purchaser wishes to have more confidence than that provided by Specification A 6/A 6M testing procedures, additional testing or requirements, such as Supplementary Requirement S4, should be imposed.

11.8.1 Appendix X2 provides additional information on the variability of tensile properties in plates and structural shapes

## 12. Permitted Variations in Dimensions and Weight [Mass]

12.1 One cubic foot of rolled steel is assumed to weigh 490 lb. One cubic metre of rolled steel is assumed to have a mass of 7850 kg.

12.2 *Plates*—The permitted variations for dimensions and weight [mass] shall not exceed the applicable limits in Tables 1-15 [Annex A1, Tables A1.1 to A1.15], inclusive.

12.3 *Shapes*:

12.3.1 Annex A2 lists the designations and dimensions, in both inch-pound and SI units, of shapes that are most commonly available. Radii of fillets and toes of shape profiles vary with individual manufacturers and therefore are not specified.

12.3.2 The permitted variations in dimensions shall not exceed the applicable limits in Tables 16-25 [Annex A1, Tables A1.16 to A1.25], inclusive. Permitted variations for special shapes not listed in such tables shall be as agreed upon between the manufacturer and the purchaser.

**TABLE 1 Permitted Variations in Thickness for Rectangular, Carbon, High-Strength, Low-Alloy, and Alloy-Steel Plates, 15 in. and Under in Thickness When Ordered to Thickness**

NOTE 1—Tables 1-31, inclusive, contain permitted variations in dimensions and weight stated in inch-pound units.
NOTE 2—Permitted variation under specified thickness, 0.01 in.
NOTE 3—Thickness to be measured at ⅜ to ¾ in. from the longitudinal edge.
NOTE 4—For thicknesses measured at any location other than that specified in Note 3, the permitted variations over specified thickness shall be 1¾ times the amounts in this table, rounded to the nearest 0.01 in.
NOTE 5—Where "..." appears in this table, there is no requirement.

| Specified Thickness, in. | Permitted Variations Over Specified Thickness for Widths Given in Inches, in. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 48 and under | Over 48 to 60, excl | 60 to 72, excl | 72 to 84, excl | 84 to 96, excl | 96 to 108, excl | 108 to 120, excl | 120 to 132, excl | 132 to 144, excl | 144 to 168, excl | 168 to 182, excl | 182 and over |
| To ¼ , excl | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | ... | ... | ... |
| ¼ to 5/16 , excl | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | ... | ... | ... |
| 5/16 to ⅜ , excl | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.05 | ... | ... |
| ⅜ to 7/16 , excl | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.05 | 0.06 | 0.06 | ... |
| 7/16 to ½ , excl | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.05 | 0.06 | 0.06 | ... |
| ½ to 5/8 , excl | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.05 | 0.06 | 0.07 | ... |
| 5/8 to ¾ , excl | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 | 0.05 | 0.06 | 0.07 | 0.07 |
| ¾ to 1, excl | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.05 | 0.05 | 0.06 | 0.07 | 0.08 | 0.09 |
| 1 to 2, excl | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.07 | 0.08 | 0.10 | 0.10 | 0.11 | 0.13 | 0.16 |
| 2 to 3, excl | 0.09 | 0.09 | 0.09 | 0.10 | 0.10 | 0.11 | 0.12 | 0.13 | 0.14 | 0.15 | 0.15 | ... |
| 3 to 4, excl | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.13 | 0.14 | 0.14 | 0.14 | 0.15 | 0.17 | ... |
| 4 to 6, excl | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.20 | 0.20 | ... |
| 6 to 10, excl | 0.23 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.27 | 0.28 | ... |
| 10 to 12, excl | 0.29 | 0.29 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.35 | ... |
| 12 to 15, incl | 0.29 | 0.29 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | ... |

**TABLE 2 Permitted Variations in Weight for Rectangular Sheared Plates and Universal Mill Plates 613.0 lb/ft² and Under When Ordered to Weight**

NOTE 1—Permitted variations in overweight for lots of circular and sketch plates shall be 1¼ times the amounts in this table.
NOTE 2—Permitted variations in overweight for single plates shall be 1⅓ times the amounts in this table.
NOTE 3—Permitted variations in overweight for single circular and sketch plates shall be 1⅔ times the amounts in this table.
NOTE 4—The adopted standard density of rolled steel is 490 lb/ft³.
NOTE 5—Where "..." appears in this table, there is no requirement.

| Specified Weights, lb/ft² | Permitted Variations in Average Weight of Lots[A] for Widths Given in Inches, Expressed in Percentage of the Specified Weights per Square Foot | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 48 and under | | Over 48 to 60, excl | | 60 to 72, excl | | 72 to 84, excl | | 84 to 96, excl | | 96 to 108, excl | | 108 to 120, excl | | 120 to 132, excl | | 132 to 144, excl | | 144 to 168, excl | | 168 and over | |
| | Over | Under | Over | Under | Over | Under | Over | Under | Over | Under | Over | Under | Over | Under | Over | Under | Over | Under | Over | Under | Over | Under |
| To 10, excl | 4.0 | 3.0 | 4.5 | 3.0 | 5.0 | 3.0 | 5.5 | 3.0 | 6.0 | 3.0 | 7.5 | 3.0 | 9.0 | 3.0 | 11.0 | 3.0 | 13.0 | 3.0 | ... | ... | ... | ... |
| 10 to 12.5, excl | 4.0 | 3.0 | 4.5 | 3.0 | 4.5 | 3.0 | 5.0 | 3.0 | 5.5 | 3.0 | 6.5 | 3.0 | 7.0 | 3.0 | 8.0 | 3.0 | 9.0 | 3.0 | 12.0 | 3.0 | ... | ... |
| 12.5 to 15.0, excl | 4.0 | 3.0 | 4.0 | 3.0 | 4.5 | 3.0 | 4.5 | 3.0 | 5.0 | 3.0 | 5.5 | 3.0 | 6.0 | 3.0 | 7.5 | 3.0 | 8.0 | 3.0 | 11.0 | 3.0 | ... | ... |
| 15 to 17.5, excl | 3.5 | 3.0 | 3.5 | 3.0 | 4.0 | 3.0 | 4.5 | 3.0 | 4.5 | 3.0 | 5.0 | 3.0 | 5.5 | 3.0 | 6.0 | 3.0 | 7.0 | 3.0 | 9.0 | 3.0 | 10.0 | 3.0 |
| 17.5 to 20, excl | 3.5 | 2.5 | 3.5 | 2.5 | 3.5 | 3.0 | 4.0 | 3.0 | 4.5 | 3.0 | 4.5 | 3.0 | 5.0 | 3.0 | 5.5 | 3.0 | 6.0 | 3.0 | 8.0 | 3.0 | 9.0 | 3.0 |
| 20 to 25, excl | 3.5 | 2.5 | 3.5 | 2.5 | 3.5 | 3.0 | 3.5 | 3.0 | 4.0 | 3.0 | 4.0 | 3.0 | 4.5 | 3.0 | 5.0 | 3.0 | 5.5 | 3.0 | 7.0 | 3.0 | 8.0 | 3.0 |
| 25 to 30, excl | 3.0 | 2.5 | 3.5 | 2.5 | 3.5 | 2.5 | 3.5 | 3.0 | 3.5 | 3.0 | 3.5 | 3.0 | 4.0 | 3.0 | 4.5 | 3.0 | 5.0 | 3.0 | 6.5 | 3.0 | 7.0 | 3.0 |
| 30 to 40, excl | 3.0 | 2.0 | 3.0 | 2.0 | 3.0 | 2.0 | 3.0 | 2.0 | 3.5 | 2.0 | 3.5 | 2.5 | 3.5 | 2.5 | 4.0 | 3.0 | 4.5 | 3.0 | 6.0 | 3.0 | 6.5 | 3.0 |
| 40 to 81.7, excl | 2.5 | 2.0 | 3.0 | 2.0 | 3.0 | 2.0 | 3.0 | 2.0 | 3.5 | 2.0 | 3.5 | 2.0 | 3.5 | 2.5 | 3.5 | 3.0 | 4.0 | 3.0 | 5.5 | 3.0 | 6.0 | 3.0 |
| 81.7 to 122.6, excl | 2.5 | 2.0 | 3.0 | 2.0 | 3.0 | 2.0 | 3.0 | 2.0 | 3.5 | 2.0 | 3.5 | 2.0 | 3.5 | 2.5 | 3.5 | 3.0 | 3.5 | 3.0 | 4.0 | 3.0 | 4.5 | 3.0 |
| 122.6 to 163.4, excl | 2.5 | 1.5 | 2.5 | 1.5 | 2.5 | 1.5 | 2.5 | 1.5 | 2.5 | 2.0 | 2.5 | 2.0 | 2.5 | 2.0 | 2.5 | 2.0 | 2.5 | 2.0 | 3.0 | 2.0 | 3.5 | 2.0 |
| 163.4 to 245.1, excl | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 3.0 | 1.0 | 3.5 | 1.0 |
| 245.1 to 409.0, excl | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 3.0 | 1.0 |
| 409.0 to 490.1, excl | 2.0 | 1.0 | 2.0 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 |
| 490.1 to 613.0, excl | 2.0 | 1.0 | 2.0 | 1.0 | 2.0 | 1.0 | 2.0 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 |

[A] The term "lot" means all the plates of each tabular width and weight group represented in each shipment.

NOTE 6—Permitted variations are given in Tables 16 to 25 [Annex A1, Tables A1.16 to A1.25], inclusive, for some shapes that are not listed in Annex A2 (that is, bulb angles, tees, zees). Addition of such sections to Annex A2 will be considered by Subcommittee A01.02 when and if a need for such listing is shown.

**TABLE 3 Permitted Variations in Width and Length for Sheared Plates 1 ½ in. and Under in Thickness; Length Only of Universal Mill Plates 2 ½ in. and Under in Thickness**

| Specified Dimensions, in. | | Permitted Variations Over Specified Width and Length[A] for Thicknesses Given in Inches or Equivalent Weights Given in Pounds per Square Foot, in. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | To 3/8 , excl | | 3/8 to 5/8 , excl | | 5/8 to 1, excl | | 1 to 2, incl[B] | |
| Length | Width | To 15.3, excl | | 15.3 to 25.5, excl | | 25.5 to 40.8, excl | | 40.8 to 81.7, incl | |
| | | Width | Length | Width | Length | Width | Length | Width | Length |
| To 120, excl | To 60, excl | 3/8 | 1/2 | 7/16 | 5/8 | 1/2 | 3/4 | 5/8 | 1 |
| | 60 to 84, excl | 7/16 | 5/8 | 1/2 | 11/16 | 5/8 | 7/8 | 3/4 | 1 |
| | 84 to 108, excl | 1/2 | 3/4 | 5/8 | 7/8 | 3/4 | 1 | 1 | 1 1/8 |
| | 108 and over | 5/8 | 7/8 | 3/4 | 1 | 7/8 | 1 1/8 | 1 1/8 | 1 1/4 |
| 120 to 240, excl | To 60, excl | 3/8 | 3/4 | 1/2 | 7/8 | 5/8 | 1 | 3/4 | 1 1/8 |
| | 60 to 84, excl | 1/2 | 3/4 | 5/8 | 7/8 | 3/4 | 1 | 7/8 | 1 1/4 |
| | 84 to 108, excl | 9/16 | 7/8 | 11/16 | 15/16 | 13/16 | 1 1/8 | 1 | 1 3/8 |
| | 108 and over | 5/8 | 1 | 3/4 | 1 1/8 | 7/8 | 1 1/4 | 1 1/8 | 1 3/8 |
| 240 to 360, excl | To 60, excl | 3/8 | 1 | 1/2 | 1 1/8 | 5/8 | 1 1/4 | 3/4 | 1 1/2 |
| | 60 to 84, excl | 1/2 | 1 | 5/8 | 1 1/8 | 3/4 | 1 1/4 | 7/8 | 1 1/2 |
| | 84 to 108, excl | 9/16 | 1 | 11/16 | 1 1/8 | 7/8 | 1 3/8 | 1 | 1 1/2 |
| | 108 and over | 11/16 | 1 1/8 | 7/8 | 1 1/4 | 1 | 1 3/8 | 1 1/4 | 1 3/4 |
| 360 to 480, excl | To 60, excl | 7/16 | 1 1/8 | 1/2 | 1 1/4 | 5/8 | 1 3/8 | 3/4 | 1 5/8 |
| | 60 to 84, excl | 1/2 | 1 1/4 | 5/8 | 1 3/8 | 3/4 | 1 1/2 | 7/8 | 1 5/8 |
| | 84 to 108, excl | 9/16 | 1 1/4 | 3/4 | 1 3/8 | 7/8 | 1 1/2 | 1 | 1 7/8 |
| | 108 and over | 3/4 | 1 3/8 | 7/8 | 1 1/2 | 1 | 1 5/8 | 1 1/4 | 1 7/8 |
| 480 to 600, excl | To 60, excl | 7/16 | 1 1/4 | 1/2 | 1 1/2 | 5/8 | 1 5/8 | 3/4 | 1 7/8 |
| | 60 to 84, excl | 1/2 | 1 3/8 | 5/8 | 1 1/2 | 3/4 | 1 5/8 | 7/8 | 1 7/8 |
| | 84 to 108, excl | 5/8 | 1 3/8 | 3/4 | 1 1/2 | 7/8 | 1 5/8 | 1 | 1 7/8 |
| | 108 and over | 3/4 | 1 1/2 | 7/8 | 1 5/8 | 1 | 1 3/4 | 1 1/4 | 1 7/8 |
| 600 to 720, excl | To 60, excl | 1/2 | 1 3/4 | 5/8 | 1 7/8 | 3/4 | 1 7/8 | 7/8 | 2 1/4 |
| | 60 to 84, excl | 5/8 | 1 3/4 | 3/4 | 1 7/8 | 7/8 | 1 7/8 | 1 | 2 1/4 |
| | 84 to 108, excl | 5/8 | 1 3/4 | 3/4 | 1 7/8 | 7/8 | 1 7/8 | 1 1/8 | 2 1/4 |
| | 108 and over | 7/8 | 1 3/4 | 1 | 2 | 1 1/8 | 2 1/4 | 1 1/4 | 2 1/2 |
| 720 and over | To 60, excl | 9/16 | 2 | 3/4 | 2 1/8 | 7/8 | 2 1/4 | 1 | 2 3/4 |
| | 60 to 84, excl | 3/4 | 2 | 7/8 | 2 1/8 | 1 | 2 1/4 | 1 1/8 | 2 3/4 |
| | 84 to 108, excl | 3/4 | 2 | 7/8 | 2 1/8 | 1 | 2 1/4 | 1 1/4 | 2 3/4 |
| | 108 and over | 1 | 2 | 1 1/8 | 2 3/8 | 1 1/4 | 2 1/2 | 1 3/8 | 3 |

[A] Permitted variation under specified width and length, 1/4 in.
[B] Permitted variations in length apply also to Universal Mill plates up to 12 in. in width for thicknesses over 2 to 2½ in., incl, except for alloy steel up to 2 in. thick.

**TABLE 4 Permitted Variations in Width for Mill Edge Carbon and High-Strength, Low-Alloy Plates Produced on Strip Mills (Applies to Plates Produced from Coil and to Plates Produced from an As-Rolled Structural Product)**

| Specified Width, in. | Permitted Variation Over Specified Width, in.[A] |
|---|---|
| To 14, excl | 7/16 |
| 14 to 17, excl | 1/2 |
| 17 to 19, excl | 9/16 |
| 19 to 21, excl | 5/8 |
| 21 to 24, excl | 11/16 |
| 24 to 26, excl | 13/16 |
| 26 to 28, excl | 15/16 |
| 28 to 35, excl | 1 1/8 |
| 35 to 50, excl | 1 1/4 |
| 50 to 60, excl | 1 1/2 |
| 60 to 65, excl | 1 5/8 |
| 65 to 70, excl | 1 3/4 |
| 70 to 80, excl | 1 7/8 |
| 80 and over | 2 |

[A] No permitted variation under specified width.

**TABLE 5 Permitted Variations in Rolled Width for Universal Mill Plates 15 in. and Under in Thickness**

| Specified Width, in. | Permitted Variations Over Specified Width[A] for Thicknesses Given in Inches or Equivalent Weights Given in Pounds per Square Foot, in. | | | | | |
|---|---|---|---|---|---|---|
| | To 3/8 , excl | 3/8 to 5/8 , excl | 5/8 to 1, excl | 1 to 2, incl | Over 2 to 10, incl | Over 10 to 15, incl |
| | To 15.3, excl | 15.3 to 25.5, excl | 25.5 to 40.8, excl | 40.8 to 81.7, incl | 81.7 to 409.0, incl | 409.0 to 613.0, incl |
| Over 8 to 20, excl | 1/8 | 1/8 | 3/16 | 1/4 | 3/8 | 1/2 |
| 20 to 36, excl | 3/16 | 1/4 | 5/16 | 3/8 | 7/16 | 9/16 |
| 36 and over | 5/16 | 3/8 | 7/16 | 1/2 | 9/16 | 5/8 |

[A] Permitted variation under specified width, 1/8 in.

12.3.3 *Shapes Having One Dimension of the Cross Section 3 in. [75 mm] or Greater (Structural-Size Shapes)*—The cross-sectional area or weight [mass] of each shape shall not vary more than 2.5 % from the theoretical or specified amounts.

**TABLE 6 Permitted Variations in Diameter for Sheared Circular Plates 1 in. and Under in Thickness**

| Specified Diameters, in. | Permitted Variations Over Specified Diameter for Thicknesses Given in Inches, in.[A] | | |
|---|---|---|---|
| | To 3/8, excl | 3/8 to 5/8, excl | 5/8 to 1, incl |
| To 32, excl | 1/4 | 3/8 | 1/2 |
| 32 to 84, excl | 5/16 | 7/16 | 9/16 |
| 84 to 108, excl | 3/8 | 1/2 | 5/8 |
| 108 to 130, excl | 7/16 | 9/16 | 11/16 |
| 130 and over | 1/2 | 5/8 | 3/4 |

[A]No permitted variation under specified diameter.

**TABLE 7 Permitted Variations in Diameter for Gas-Cut Circular Plates (Not Applicable to Alloy Steel)**

| Specified Diameter, in. | Permitted Variation Over Specified Diameter for Thicknesses Given in Inches, in.[A] | | | | | |
|---|---|---|---|---|---|---|
| | to 1, excl | 1 to 2, excl | 2 to 4, excl | 4 to 6, excl | 6 to 8, excl | 8 to 15, incl |
| To 32, excl | 3/8 | 3/8 | 1/2 | 1/2 | 5/8 | 3/4 |
| 32 to 84, excl | 3/8 | 1/2 | 1/2 | 5/8 | 3/4 | 7/8 |
| 84 to 108, excl | 1/2 | 9/16 | 5/8 | 3/4 | 7/8 | 1 |
| 108 to 130, excl | 1/2 | 9/16 | 11/16 | 7/8 | 1 | 1 1/8 |
| 130 and over | 5/8 | 3/4 | 7/8 | 1 | 1 1/8 | 1 1/4 |

[A]No permitted variation under specified diameter.

**TABLE 8 Permitted Variations in Width and Length for Rectangular Plates When Gas Cuttings is Specified or Required (Applies to Alloy Steel Specifications Only).**

NOTE 1—These permitted variations shall be taken all under or divided over and under, if so specified.

NOTE 2—Plates with universal rolled edges will be gas cut to length only.

| Specified Thickness, in. | Permitted Variation Over Specified Width and Length, in. |
|---|---|
| To 2, excl | 3/4 |
| 2 to 4, excl | 1 |
| 4 to 6, excl | 1 1/8 |
| 6 to 8, excl | 1 5/16 |
| 8 to 15, incl | 1 1/2 |

**TABLE 9 Permitted Variations in Width and Length for Rectangular Plates When Gas Cutting is Specified or Required (Not Applicable to Alloy Steel)**

NOTE 1—These permitted variations may be taken all under or divided over and under, if so specified.

NOTE 2—Plates with universal rolled edges will be gas cut to length only.

| Specified Thickness, in. | Permitted Variation Over Specified Width and Length, in. |
|---|---|
| To 2, excl | 1/2 |
| 2 to 4, excl | 5/8 |
| 4 to 6, excl | 3/4 |
| 6 to 8, excl | 7/8 |
| 8 to 15, incl | 1 |

12.4 *Sheet Piling*—The weight [mass] of each steel sheet pile shall not vary more than 2.5 % from the theoretical or specified weight [mass]. The length of each steel sheet pile shall be not less than the specified length, and not more than 5 in. [125 mm] over the specified length..

**TABLE 10 Permitted Variations in Diameter for Gas-Cut Circular Plates (Applies to Alloy Steel Specifications Only)**

| Specified Diameter, in. | Permitted Variations Over Specified Diameter for Specified Thicknesses Given in Inches, in.[A] | | | | | |
|---|---|---|---|---|---|---|
| | to 1, excl | 1 to 2, excl | 2 to 4, excl | 4 to 6, excl | 6 to 8, excl | 8 to 15, incl |
| To 32, excl | 1/2 | 1/2 | 3/4 | 3/4 | 1 | 1 |
| 32 to 84, excl | 1/2 | 5/8 | 7/8 | 1 | 1 1/8 | 1 1/4 |
| 84 to 108, excl | 5/8 | 3/4 | 1 | 1 1/8 | 1 1/4 | 1 3/8 |
| 108 to 130, incl | 7/8 | 1 | 1 1/8 | 1 1/4 | 1 3/8 | 1 1/2 |

[A]No permitted variation under specified diameter.

**TABLE 11 Permitted Camber[A] for Carbon Steel, High-Strength Low-Alloy Steel, and Alloy Steel Universal Mill Plates and High-Strength Low-Alloy Steel and Alloy Steel Sheared, Special-Cut, or Gas-Cut Rectangular Plates**

| Specified Thickness, in. | Specified Weight, lb/ft$^2$ | Specified Width, in. | Permitted Camber, in. |
|---|---|---|---|
| To 2, incl | to 81.7, incl | all | 1/8 × (no. of feet of length/5) |
| Over 2 to 15, incl | 81.7 to 613.0, incl | to 30, incl | 3/16 × (no. of feet of length/5) |
| Over 2 to 15, incl | 81.7 to 613.0, incl | over 30 | 1/4 × (no. of feet of length/5) |

[A]Camber as it relates to plates is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

**TABLE 12 Permitted Camber[A] for Sheared Plates and Gas-Cut Rectangular Plates, All Thicknesses (Applies to Carbon Steel Only)**

| Permitted camber, in. = 1/8 × (number of feet of length/5) |
|---|

[A]Camber as it relates to plates is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

12.5 *Hot-Rolled Bars*—The permitted variations in dimensions shall not exceed the applicable limits in Tables 26-31 [Annex A1, Tables A1.26 to A1.31], inclusive.

## 13. Retests

13.1 If any test specimen shows defective machining or develops flaws, the manufacturer or processor shall have the option of discarding it and substituting another test specimen.

13.2 If the percentage of elongation of any tension test specimen is less than that specified and any part of the fracture is more than 3/4 in. [20 mm] from the center of the gage length of a 2-in. [50-mm] specimen or is outside the middle half of the gage length of an 8-in. [200-mm] specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

13.3 Except as provided in 13.3.1, if the results from an original tension specimen fails to meet the specified requirements, but are within 2 ksi [14 MPa] of the required tensile strength, within 1 ksi [7 MPa] of the required yield strength or yield point, or within 2 percentage points of the required elongation, a retest shall be permitted to replace the failing test. A retest shall be performed for the failing original test, with the specimen being randomly selected from the heat. If the results of the retest meet the specified requirements, the heat or lot shall be approved.

13.3.1 For structural products that are tested as given in Table C, both tests from each coil tested to qualify a heat are

**TABLE 13 Permitted Variations From a Flat Surface for Standard Flatness Carbon Steel Plates**

NOTE 1—When the longer dimension is under 36 in., the permitted variation from a flat surface shall not exceed ¼ in. When the longer dimension is from 36 to 72 in., incl, the permitted variation from a flat surface shall not exceed 75 % of the tabular amount for the specified width, but in no case less than ¼ in.

NOTE 2—These permitted variations apply to plates that have a specified minimum tensile strength of not more than 60 ksi or comparable chemical composition or hardness. The limits in this table are increased 50 % for plates that have a higher specified minimum tensile strength or comparable chemical composition or hardness.

NOTE 3—This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of such plates.

NOTE 4—Where "..." appears in this table, there is no requirement.

NOTE 5—Plates must be in a horizontal position on a flat surface when flatness is measured.

| Specified Thickness, in. | Specified Weight, lb/ft$^2$ | Permitted Variations from a Flat Surface for Specified Widths Given in Inches, in.[A,B] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | To 36, excl | 36 to 48, excl | 48 to 60, excl | 60 to 72, excl | 72 to 84, excl | 84 to 96, excl | 96 to 108, excl | 108 to 120, excl | 120 to 144, excl | 144 to 168, excl | 168 and Over |
| To ¼ , excl | To 10.2, excl | 9/16 | ¾ | 15/16 | 1¼ | 1⅜ | 1½ | 1⅝ | 1¾ | 1⅞ | ... | ... |
| ¼ to ⅜ , excl | 10.2 to 15.3, excl | ½ | ⅝ | ¾ | 15/16 | 1⅛ | 1¼ | 1⅜ | 1½ | 1⅝ | ... | ... |
| ⅜ to ½ , excl | 15.3 to 20.4, excl | ½ | 9/16 | ⅝ | ⅝ | ¾ | ⅞ | 1 | 1⅛ | 1¼ | 1⅞ | 2⅛ |
| ½ to ¾ , excl | 20.4 to 30.6, excl | 7/16 | ½ | 9/16 | ⅝ | ⅝ | ¾ | 1 | 1 | 1⅛ | 1½ | 2 |
| ¾ to 1, excl | 30.6 to 40.8, excl | 7/16 | ½ | 9/16 | ⅝ | ⅝ | ⅝ | ¾ | ⅞ | 1 | 1⅜ | 1¾ |
| 1 to 2, excl | 40.8 to 81.7, excl | ⅜ | ½ | ½ | 9/16 | 9/16 | ⅝ | ⅝ | ⅝ | 11/16 | 1⅛ | 1½ |
| 2 to 4, excl | 81.7 to 163.4, excl | 5/16 | ⅜ | 7/16 | ½ | ½ | ½ | ½ | 9/16 | ⅝ | ⅞ | 1⅛ |
| 4 to 6, excl | 163.4 to 245.1, excl | ⅜ | 7/16 | ½ | ½ | 9/16 | 9/16 | ⅝ | ¾ | ⅞ | ⅞ | 1 |
| 6 to 8, excl | 245.1 to 326.8, excl | 7/16 | ½ | ½ | ⅝ | 11/16 | ¾ | ⅞ | ⅞ | 1 | 1 | 1 |
| 8 to 10, excl | 326.8 to 409.0, excl | ½ | ½ | ⅝ | 11/16 | ¾ | 13/16 | ⅞ | 15/16 | 1 | 1 | 1 |
| 10 to 12, excl | 409.0 to 490.1, excl | ½ | ⅝ | ¾ | 13/16 | ⅞ | 15/16 | 1 | 1 | 1 | 1 | 1 |
| 12 to 15, excl | 490.1 to 613.0, incl | ⅝ | ¾ | 13/16 | ⅞ | 15/16 | 1 | 1 | 1 | 1 | 1 | ... |

[A] *Permitted Variation from a Flat Surface for Length*—The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width for plates up to 12 ft in length, or in any 12 ft for longer plates.

[B] *Permitted Variation from a Flat Surface for Width*—The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

**TABLE 14 Permitted Variations From a Flat Surface for Standard Flatness High-Strength Low-Alloy Steel and Alloy Steel Plates, Hot Rolled or Thermally Treated**

NOTE 1—When the longer dimension is under 36 in., the permitted variation from a flat surface shall not exceed ⅜ in. When the longer dimension is from 36 to 72 in. incl, the permitted variation from a flat surface shall not exceed 75 % of the tabular amount for the specified width.

NOTE 2—This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of such plates.

NOTE 3—Where "..." appears in this table, there is no requirement.

NOTE 4—Plates must be in a horizontal position on a flat surface when flatness is measured.

| Specified Thickness, in. | Specified Weight, lb/ft$^2$ | Permitted Variations from a Flat Surface for Specified Widths, in.[A,B] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | To 36, excl | 36 to 48, excl | 48 to 60, excl | 60 to 72, excl | 72 to 84, excl | 84 to 96, excl | 96 to 108, excl | 108 to 120, excl | 120 to 144, excl | 144 to 168, excl | 168 and Over |
| To ¼ , excl | To 10.2 excl | 13/16 | 1⅛ | 1⅜ | 1⅞ | 2 | 2¼ | 2⅜ | 2⅝ | 2¾ | ... | ... |
| ¼ to ⅜ , excl | 10.2 to 15.3, excl | ¾ | 15/16 | 1⅛ | 1⅜ | 1¾ | 1⅞ | 2 | 2¼ | 2⅜ | ... | ... |
| ⅜ to ½ , excl | 15.3 to 20.4, excl | ¾ | ⅞ | 15/16 | 15/16 | 1⅛ | 1 5/16 | 1½ | 1⅝ | 1⅞ | 2¾ | 3⅛ |
| ½ to ¾ , excl | 20.4 to 30.6, excl | ⅝ | ¾ | 13/16 | ⅞ | 1 | 1⅛ | 1¼ | 1⅜ | 1⅝ | 2¼ | 3 |
| ¾ to 1, excl | 30.6 to 40.8, excl | ⅝ | ¾ | ⅞ | ⅞ | 15/16 | 1 | 1⅛ | 1 5/16 | 1½ | 2 | 2⅝ |
| 1 to 2, excl | 40.8 to 81.7, excl | 9/16 | ⅝ | ¾ | 13/16 | ⅞ | 15/16 | 1 | 1 | 1 | 1⅝ | 2¼ |
| 2 to 4, excl | 81.7 to 163.4, excl | ½ | 9/16 | 11/16 | ¾ | ¾ | ¾ | ¾ | ⅞ | 1 | 1¼ | 1⅝ |
| 4 to 6, excl | 163.4 to 245.1, excl | 9/16 | 11/16 | ¾ | ¾ | ⅞ | ⅞ | 15/16 | 1⅛ | 1¼ | 1¼ | 1½ |
| 6 to 8, excl | 245.1 to 326.8, excl | ⅝ | ¾ | ¾ | 15/16 | 1 | 1⅛ | 1¼ | 1 5/16 | 1½ | 1½ | 1½ |
| 8 to 10, excl | 326.8 to 409.0, excl | ¾ | 13/16 | 15/16 | 1 | 1⅛ | 1¼ | 1 5/16 | 1⅜ | 1½ | 1½ | 1½ |
| 10 to 12, excl | 409.0 to 490.1, excl | ¾ | 15/16 | 1⅛ | 1¼ | 1 5/16 | 1⅜ | 1½ | 1½ | 1½ | 1½ | 1½ |
| 12 to 15, incl | 490.1 to 613.0, incl | ⅞ | 1 | 1 3/16 | 1 5/16 | 1⅜ | 1½ | 1½ | 1½ | 1½ | 1½ | 1½ |

[A] *Permitted Variation from a Flat Surface for Length*—The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft for longer plates.

[B] *Permitted Variation from a Flat Surface for Width*—The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

required to meet all mechanical property requirements. Should either test fail to do so, then that coil shall not be used to qualify the heat; however, the portion of that individual coil that is bracketed by acceptable tests (see 11.4.2.3) is considered to be qualified.

13.4 Quenched and tempered steel plates shall be subject to any additional retest requirements contained in the applicable product specification.

**TABLE 15 Permitted Variations in Waviness for Standard Flatness Plates**

NOTE 1—Waviness denotes the maximum deviation of the surface of the plate from a plane parallel to the surface of the point of measurement and contiguous to the surface of the plate at each of the two adjacent wave peaks, when the plate is resting on a flat horizontal surface, as measured in an increment of less than 12 ft of length. The permitted variation in waviness is a function of the permitted variation from a flat surface as obtained from Table 13 or 14, whichever is applicable.

NOTE 2—Plates must be in a horizontal position on a flat surface when waviness is measured.

| Permitted Variation from a Flat Surface (from Table 13 or 14), in. | Permitted Variation in Waviness, in., When Number of Waves in 12 ft is | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 5/16 | 5/16 | 1/4 | 3/16 | 1/8 | 1/8 | 1/16 | 1/16 |
| 3/8 | 3/8 | 5/16 | 3/16 | 3/16 | 1/8 | 1/16 | 1/16 |
| 7/16 | 7/16 | 5/16 | 1/4 | 3/16 | 1/8 | 1/8 | 1/16 |
| 1/2 | 1/2 | 3/8 | 5/16 | 3/16 | 3/16 | 1/8 | 1/16 |
| 9/16 | 9/16 | 7/16 | 5/16 | 1/4 | 3/16 | 1/8 | 1/8 |
| 5/8 | 5/8 | 1/2 | 3/8 | 1/4 | 3/16 | 1/8 | 1/8 |
| 11/16 | 11/16 | 1/2 | 3/8 | 5/16 | 3/16 | 3/16 | 1/8 |
| 3/4 | 3/4 | 9/16 | 7/16 | 5/16 | 1/4 | 3/16 | 1/8 |
| 13/16 | 13/16 | 5/8 | 7/16 | 5/16 | 1/4 | 3/16 | 1/8 |
| 7/8 | 7/8 | 11/16 | 1/2 | 3/8 | 1/4 | 3/16 | 1/8 |
| 15/16 | 15/16 | 11/16 | 1/2 | 3/8 | 5/16 | 1/4 | 3/16 |
| 1 | 1 | 3/4 | 9/16 | 7/16 | 5/16 | 1/4 | 3/16 |
| 1 1/8 | 1 1/8 | 7/8 | 5/8 | 1/2 | 3/8 | 1/4 | 3/16 |
| 1 1/4 | 1 1/4 | 15/16 | 11/16 | 1/2 | 3/8 | 5/16 | 1/4 |
| 1 3/8 | 1 3/8 | 1 1/16 | 3/4 | 9/16 | 7/16 | 5/16 | 1/4 |
| 1 1/2 | 1 1/2 | 1 1/8 | 7/8 | 5/8 | 1/2 | 3/8 | 1/4 |
| 1 5/8 | 1 5/8 | 1 1/4 | 15/16 | 11/16 | 1/2 | 3/8 | 5/16 |
| 1 3/4 | 1 3/4 | 1 5/16 | 1 | 3/4 | 9/16 | 7/16 | 5/16 |
| 1 7/8 | 1 7/8 | 1 7/16 | 1 1/16 | 13/16 | 9/16 | 7/16 | 5/16 |
| 2 | 2 | 1 1/2 | 1 1/8 | 7/8 | 5/8 | 1/2 | 3/8 |
| 2 1/8 | 2 1/8 | 1 5/8 | 1 3/16 | 7/8 | 11/16 | 1/2 | 3/8 |
| 2 1/4 | 2 1/4 | 1 11/16 | 1 1/4 | 15/16 | 11/16 | 9/16 | 3/8 |
| 2 3/8 | 2 3/8 | 1 13/16 | 1 5/16 | 1 | 3/4 | 9/16 | 7/16 |
| 2 1/2 | 2 1/2 | 1 7/8 | 1 7/16 | 1 1/16 | 13/16 | 9/16 | 7/16 |
| 2 5/8 | 2 5/8 | 2 | 1 1/2 | 1 1/8 | 13/16 | 5/8 | 7/16 |
| 2 3/4 | 2 3/4 | 2 1/16 | 1 9/16 | 1 1/8 | 7/8 | 5/8 | 1/2 |
| 2 7/8 | 2 7/8 | 2 3/16 | 1 5/8 | 1 3/16 | 15/16 | 11/16 | 1/2 |
| 3 | 3 | 2 1/4 | 1 11/16 | 1 1/4 | 15/16 | 11/16 | 9/16 |
| 3 1/8 | 3 1/8 | 2 3/8 | 1 3/4 | 1 5/16 | 1 | 3/4 | 9/16 |

13.5 When the full-section option of 11.3.3 is used and the elongation falls below the specified requirement, the manufacturer or processor shall have the option of making another test using a test specimen permitted in 11.5.2.

## 14. Test Reports

14.1 Test reports for each heat supplied are required and they shall report the following:

14.1.1 The applicable product specification designation, including year-date and whichever of grade, class, and type are specified in the purchase order, to which the structural product is furnished.

14.1.2 The heat number, heat analysis (see 7.1), and nominal sizes.

NOTE 7—If the amount of copper, chromium, nickel, molybdenum, or silicon is less than 0.02 %, the heat analysis for that element may be reported as <0.02 %. If the amount of columbium or vanadium is less than 0.008 %, the heat analysis for that element may be reported as <0.008%.

14.1.3 For structural products that are tested as given in Table B, two tension test results appropriate to qualify the shipment (see 11.4), except that only one tension test result need be reported if the shipment consists of a single piece or plate-as-rolled.

14.1.3.1 In reporting elongation values, both the percentage increase and the original gage length shall be stated.

14.1.4 For structural products that are required to be heat treated, either by the applicable product specification or by the purchase order, all heat treatments, including temperature ranges and times at temperature, unless the purchaser and the supplier have agreed to the supply of a heat treatment procedure in place of the actual temperatures and times.

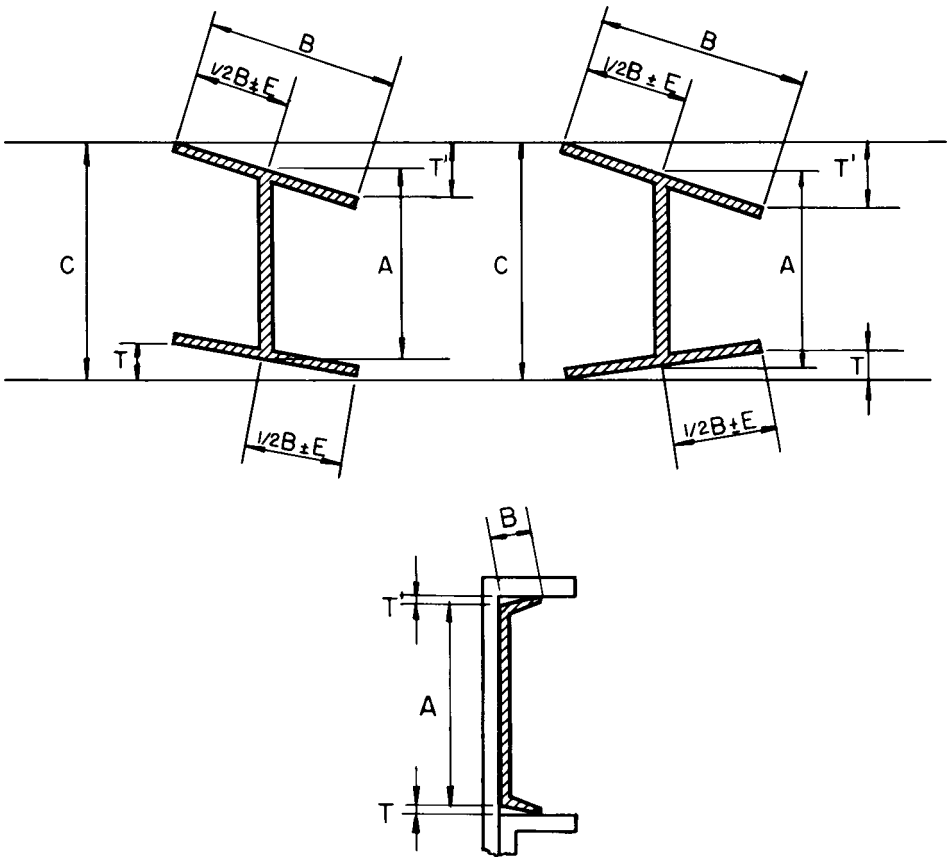
14.1.4.1 Subcritical heat treatment to soften thermally cut edges need not be reported, except for structural products having a specified minimum tensile strength of 95 ksi [655 MPa] or higher, unless such subcritical heating is accomplished at temperatures at least 75 °F [40 °C] lower than the minimum tempering temperature.

14.1.5 The results of any required austenitic grain size tests (see 8.2 or 8.3, whichever is applicable).

**TABLE 16 Permitted Variations in Cross Section for W, HP, S, M, C, and MC Shapes**

NOTE 1—*A* is measured at center line of web for S, M, and W and HP shapes; at back of web for C and MC shapes. Measurement is overall for C shapes under 3 in. *B* is measured parallel to flange. *C* is measured parallel to web.

NOTE 2—Where "..." appears in this table, there is no requirement.




| Shape | Section Nominal Sizes, in. | Permitted Variations in Sectional Dimensions Given, in. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *A*, Depth | | *B*, Flange Width | | $T + T'$ [A] Flanges Out-of-Square[B] | *E*, Web off Center[C] | *C*, Maximum Depth at any Cross Section over Theoretical Depth, in. | Permitted Variations Over or Under Theoretical Web Thickness for Thicknesses Given in Inches, in. | |
| | | Over Theoretical | Under Theoretical | Over Theoretical | Under Theoretical | | | | 3/16 and under | Over 3/16 |
| W and HP | Up to 12, incl | 1/8 | 1/8 | 1/4 | 3/16 | 1/4 | 3/16 | 1/4 | ... | ... |
| | Over 12 | 1/8 | 1/8 | 1/4 | 3/16 | 5/16 | 3/16 | 1/4 | ... | ... |
| S and M | 3 to 7, incl | 3/32 | 1/16 | 1/8 | 1/8 | 1/32 | 3/16 | ... | ... | ... |
| | Over 7 to 14, incl | 1/8 | 3/32 | 5/32 | 5/32 | 1/32 | 3/16 | ... | ... | ... |
| | Over 14 to 24, incl | 3/16 | 1/8 | 3/16 | 3/16 | 1/32 | 3/16 | ... | ... | ... |
| C and MC | 1½ and under | 1/32 | 1/32 | 1/32 | 1/32 | 1/32 | ... | ... | 0.010 | 0.015 |
| | Over 1½ to 3, excl | 1/16 | 1/16 | 1/16 | 1/16 | 1/32 | ... | ... | 0.015 | 0.020 |
| | 3 to 7, incl | 3/32 | 1/16 | 1/8 | 1/8 | 1/32 | ... | ... | ... | ... |
| | Over 7 to 14, incl | 1/8 | 3/32 | 1/8 | 5/32 | 1/32 | ... | ... | ... | ... |
| | Over 14 | 3/16 | 1/8 | 1/8 | 3/16 | 1/32 | ... | ... | ... | ... |

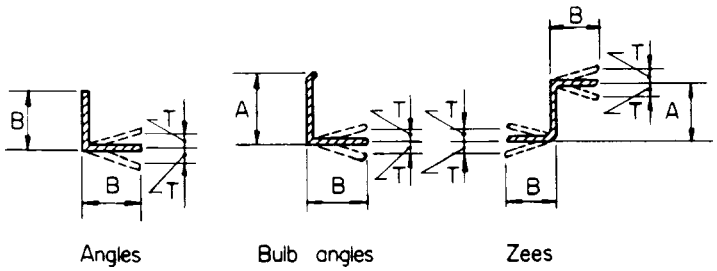
[A] $T + T'$ applies when flanges of channels are toed in or out. For channels 5/8 in. and under in depth, the permitted out-of-square is 3/64 in./in. of depth.
[B] Permitted variation is per inch of flange width for S, M, C, and MC shapes.
[C] Permitted variation of 5/16 in. max for sections over 426 lb/ft.

14.1.6 The results of any other test required by the applicable product specification, the applicable supplementary requirements, and the purchase order.

14.2 The thickness of the structural product tested is not necessarily the same as an individual ordered thickness, given that it is the heat that is tested, rather than each ordered item.

**TABLE 17 Permitted Variations in Cross Section for Angles (L Shapes), Bulb Angles, and Zees**

NOTE 1—Where "..." appears in this table, there is no requirement.

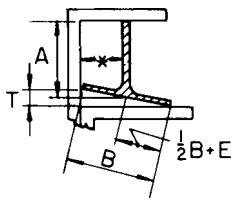



| Section | Nominal Size, in. | Permitted Variations in Sectional Dimensions Given, in. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *A*, Depth | | *B*, Flange Width or Length of Leg | | *T*, Out-of-Square per Inch of *B* | Permitted Variations Over or Under Theoretical Thickness for Thicknesses Given in Inches, in. | | |
| | | Over Theoretical | Under Theoretical | Over Theoretical | Under Theoretical | | 3/16 and under | Over 3/16 to 3/8, incl | Over 3/8 |
| Angles[A] (L Shapes) | 1 and under | ... | ... | 1/32 | 1/32 | 3/128[B] | 0.008 | 0.010 | ... |
| | Over 1 to 2, incl | ... | ... | 3/64 | 3/64 | 3/128[B] | 0.010 | 0.010 | 0.012 |
| | Over 2 to 3, excl | ... | ... | 1/16 | 1/16 | 3/128[B] | 0.012 | 0.015 | 0.015 |
| | 3 to 4, incl | ... | ... | 1/8 | 3/32 | 3/128[B] | ... | ... | ... |
| | Over 4 to 6, incl | ... | ... | 1/8 | 1/8 | 3/128[B] | ... | ... | ... |
| | Over 6 | ... | ... | 3/16 | 1/8 | 3/128[B] | ... | ... | ... |
| Bulb angles | (Depth) 3 to 4, incl | 1/8 | 1/16 | 1/8 | 3/32 | 3/128[B] | ... | ... | ... |
| | Over 4 to 6, incl | 1/8 | 1/16 | 1/8 | 1/8 | 3/128[B] | ... | ... | ... |
| | Over 6 | 1/8 | 1/16 | 3/16 | 1/8 | 3/128[B] | ... | ... | ... |
| Zees | 3 to 4, incl | 1/8 | 1/16 | 1/8 | 3/32 | 3/128[B] | ... | ... | ... |
| | Over 4 to 6, incl | 1/8 | 1/16 | 1/8 | 1/8 | 3/128[B] | ... | ... | ... |

[A] For unequal leg angles, longer leg determines classification.
[B] 3/128 in./in. = 1½ °.

**TABLE 18 Permitted Variations in Sectional Dimensions for Rolled Tees**

NOTE 1—*Back of square and center line of stem are to be parallel when measuring "out-of-square."
NOTE 2—Where "..." appears in this table, there is no requirement.




| Nominal Size,[A] | Permitted Variations in Sectional Dimensions Givev, in. Tees | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *A*, Depth[B] | | *B*, Width[B] | | *T*, Out-of-Square per Inch of *B* | *E*, Web-off-Center | Stem Out-of-Square[C] | Thickness of Flange | | Thickness of Stem | |
| | Over | Under | Over | Under | | | | Over | Under | Over | Under |
| 1¼ and under | 3/64 | 3/64 | 3/64 | 3/64 | ... | ... | 1/32 | 0.010 | 0.010 | 0.005 | 0.020 |
| Over 1¼ to 2, incl | 1/16 | 1/16 | 1/16 | 1/16 | ... | ... | 1/16 | 0.012 | 0.012 | 0.010 | 0.020 |
| Over 2 to 3, excl | 3/32 | 3/32 | 3/32 | 3/32 | ... | ... | 3/32 | 0.015 | 0.015 | 0.015 | 0.020 |
| 3 to 5, incl | 3/32 | 1/16 | 1/8 | 1/8 | 1/32 | 3/32 | ... | ... | ... | ... | ... |
| Over 5 to 7, incl | 3/32 | 1/16 | 1/8 | 1/8 | 1/32 | 1/8 | ... | ... | ... | ... | ... |

[A] The longer member of an unequal tee determines the size for permitted variations.
[B] Measurements for both depth and width are overall.
[C] Stem-out-of-square is the permitted variation from its true position of the center line of stem, measured at the point.

Tests from specified thicknesses in accordance with 11.4 and encompassing the thicknesses in a shipment shall be sufficient for qualifying the structural product in the shipment. Such test thicknesses are not required to be within previously tested and shipped thicknesses from the same heat.

**TABLE 19 Permitted Variations in Length for S, M, C, MC, L, T, Z, and Bulb Angle Shapes**

NOTE 1—Where "..." appears in this table, there is no requirement.

| Nominal Size,[A] in. | Permitted Variations from Specified Length for Lengths Given in Feet, in. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 to 10, excl | | 10 to 20,excl | | 20 to 30, incl | | Over 30 to 40, incl | | Over 40 to 50, incl | | Over 50 to 65, incl | | Over 65 ft | |
| | Over | Under | Over | Under | Over | Under | Over | Under | Over | Under | Over | Under | Over | Under |
| Under 3 | 5/8 | 0 | 1 | 0 | 1½ | 0 | 2 | 0 | 2½ | 0 | 2½ | 0 | ... | ... |
| 3 and over | 1 | 0 | 1½ | 0 | 1¾ | 0 | 2¼ | 0 | 2¾ | 0 | 2¾ | 0 | ... | ... |

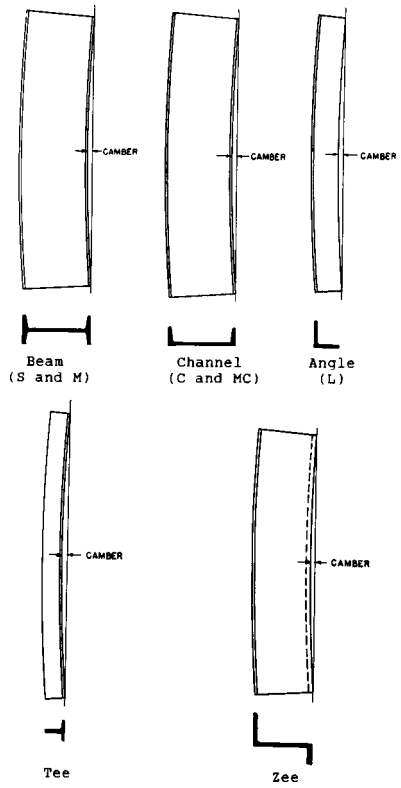
[A]Greatest cross-sectional dimension.

**TABLE 20 Permitted Variations in End Out-Of-Square for S, M, C, MC, L, T, Z, and Bulb Angle Shapes**

| Shapes | Permitted Variation |
|---|---|
| S, M, C, and MC | 1/64 in. per inch of depth |
| L[A] | 3/128 in. per inch of leg length or 1½ ° |
| Bulb angles | 3/128 in. per inch of depth or 1½ ° |
| Rolled Tees[A] | 1/64 in. per inch of flange or stem |
| Zees | 3/128 in. per inch of sum of both flange lengths |

[A]Permitted variations in end out-of-square are determined on the longer members of the shape.

**TABLE 21 Permitted Variations in Straightness for S, M, C, MC, L, T, Z, and Bulb Angle Shapes**




Positions for Measuring Camber of Shapes

| Variable | Nominal Size,[A] in. | Permitted Variation, in. |
|---|---|---|
| Camber | under 3 | ¼ in. in any 5 ft, or ¼ × (number of feet of total length/5) |
| | 3 and over | ⅛ × (number of feet of total length/5) |
| Sweep | all | Due to the extreme variations in flexibility of these shapes, permitted variations for sweep are subject to negotiations between the manufacturer and the purchaser for the individual sections involved. |

[A]Greatest cross-sectional dimension.

14.3 For structural products produced from coil that are supplied in the as-rolled condition or have been heat treated by stress relieving only, the test report shall state "Produced from Coil." Both test results shall be reported for each qualifying coil, and the location within the coil for each test shall be stated.

**TABLE 22 Permitted Variations in Length for W and HP Shapes**

| W and HP Shapes | Permitted Variations from Specified Length for Lengths Given in Feet, in.[A,B] | | | |
|---|---|---|---|---|
| | 30 and under | | Over 30 | |
| | Over | Under | Over | Under |
| Beams 24 in. and under in nominal depth | 3/8 | 3/8 | 3/8 plus 1/16 for each additional 5 ft or fraction thereof | 3/8 |
| Beams over 24 in. in nominal depth and all columns | 1/2 | 1/2 | 1/2 plus 1/16 for each additional 5 ft or fraction thereof | 1/2 |

[A]For HP and W shapes specified in the order for use as bearing piles, the permitted variations in length are plus 5 in. and minus 0 in. These permitted variations in length also apply to sheet piles.

[B]The permitted variations in end out-of-square for W and HP shapes shall be 1/64 in. per inch of depth, or per inch of flange width if the flange width is larger than the depth.

**TABLE 23 Permitted Variations in Length and End Out-of-Square, Milled Shapes**

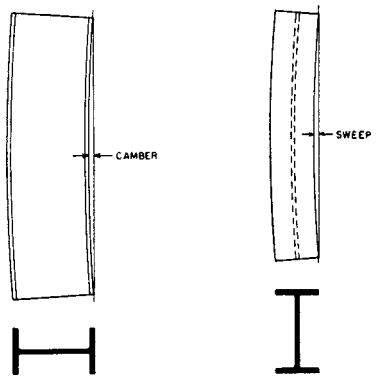
| Nominal Depth, in. | Length, ft[B] | Permitted Variations in Length and End Out-of-Square, in.[A] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Milled Both Ends[C] | | | Milled One-End[C] | | |
| | | Length | | End Out-of-Square | Length | | End Out-of-Square (for Milled End) |
| | | Over | Under | | Over | Under | |
| 6 to 36 | 6 to 70 | 1/32 | 1/32 | 1/32 | 1/4 | 1/4 | 1/32 |

[A]Length is measured along center line of web. Measurements are made with the steel and tape at the same temperature.

[B]The permitted variations in length and end out-of-square are additive.

[C]End out-of-square is measured by (*a*) squaring from the center line of the web and (*b*) squaring from the center line of the flange. The measured variation from true squareness in either plane shall not exceed the total tabular amount.

**TABLE 24 Permitted Variations in Straightness for W and HP Shapes**




Positions for Measuring Camber and Sweep of W and HP Shapes

| | Permitted Variation in Straightness, in. |
|---|---|
| Camber and sweep | 1/8 × (number of feet of total length/10)[A] |
| When certain sections[B] with a flange width approximately equal to depth are specified in the order for use as columns: | |
| Lengths of 45 ft and under | 1/8 × (number of feet of total length/10) but not over 3/8 |
| Lengths over 45 ft | 3/8 + [1/8 × ([number of feet of total length − 45]/10)] |

[A]Sections with a flange width less than 6 in., permitted variation for sweep, in. = 1/8 × (number of feet of total length/5).

[B]Applies only to:
8-in. deep sections 31 lb/ft and heavier,
10-in. deep sections 49 lb/ft and heavier,
12-in. deep sections 65 lb/ft and heavier, and
14-in. deep sections 90 lb/ft and heavier.
For other sections specified in the order for use as columns, the permitted variation is subject to negotiation with the manufacturer.

14.4 For structural products produced from coil, both the manufacturer and the processor shall be identified on the test report.

14.5 When full-section test specimens have been used for the qualification of angles, that information shall be stated on the test report.

14.6 A signature is not required on the test report; however, the document shall clearly identify the organization submitting the report. Notwithstanding the absence of a signature, the organization submitting the report is responsible for the content of the report.

14.7 For structural products finished by other than the original manufacturer, the supplier of the structural product shall also provide the purchaser with a copy of the original manufacturer's test report.

14.8 A test report, certficate of inspection, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document shall meet the requirements of the applicable product specification and shall conform to any existing EDI agreement

**TABLE 25 Permitted Variations in Dimensions for Split Tees and Split Angles (L Shapes)[A]**

| Specified Depth, in. | Permitted Variation Over or Under Specified Depth,[B] in. |
|---|---|
| To 6, excl (beams and channels) | 1/8 |
| 6 to 16, excl (beams and channels) | 3/16 |
| 16 to 20, excl (beams and channels) | 1/4 |
| 20 to 24, excl (beams) | 5/16 |
| 24 and over (beams) | 3/8 |

[A]The permitted variations in length for split tees or angles are the same as those applicable to the section from which the tees or angles are split.

[B]The above permitted variations in depth of tees or angles include the permitted variations in depth for the beams or channels before splitting. Permitted variations in dimensions and straightness, as set up for the beams or channels from which these tees or angles are cut, apply, except:
straightness = 1/8 in. × (length in feet/5)

**TABLE 26 Permitted Variations in Sectional Dimensions for Square-Edge and Round-Edge Flat Bars**

NOTE 1—Where "..." appears in this table, there is no requirement.

| Specified Widths, in. | Permitted Variations Over or Under Specified Thickness, for Thicknesses Given in Inches, in. | | | | | | | Permitted Variations From Specified Width, in. | |
|---|---|---|---|---|---|---|---|---|---|
| | 0.203 to 0.230, excl | 0.230 to 1/4, excl | 1/4 to 1/2, incl | Over 1/2 to 1, incl | Over 1 to 2, incl | Over 2 to 3, incl | Over 3 | Over | Under |
| To 1, incl | 0.007 | 0.007 | 0.008 | 0.010 | ... | ... | ... | 1/64 | 1/64 |
| Over 1 to 2, incl | 0.007 | 0.007 | 0.012 | 0.015 | 1/32 | ... | ... | 1/32 | 1/32 |
| Over 2 to 4, incl | 0.008 | 0.008 | 0.015 | 0.020 | 1/32 | 3/64 | 3/64 | 1/16 | 1/32 |
| Over 4 to 6, incl | 0.009 | 0.009 | 0.015 | 0.020 | 1/32 | 3/64 | 3/64 | 3/32 | 1/16 |
| Over 6 to 8, incl | [A] | 0.015 | 0.016 | 0.025 | 1/32 | 3/64 | 1/16 | 1/8[B] | 3/32[B] |

[A]Flats over 6 to 8 in., incl, in width are not available as hot-rolled carbon steel bars in thickness under 0.230 in.

[B]For flats over 6 to 8 in., in width, and to 3 in. incl in thickness.

**TABLE 27 Permitted Variations in Sectional Dimensions for Round and Square Bars and Round-Cornered Squares**

| Specified Size, in. | Permitted Variations from Specified Size, in. | | Permitted Out-of-Round or Out-of-Square, in.[A] |
|---|---|---|---|
| | Over | Under | |
| To 5/16 | 0.005 | 0.005 | 0.008 |
| Over 5/16 to 7/16, incl | 0.006 | 0.006 | 0.009 |
| Over 7/16 to 5/8, incl | 0.007 | 0.007 | 0.010 |
| Over 5/8 to 7/8, incl | 0.008 | 0.008 | 0.012 |
| Over 7/8 to 1, incl | 0.009 | 0.009 | 0.013 |
| Over 1 to 1 1/8, incl | 0.010 | 0.010 | 0.015 |
| Over 1 1/8 to 1 1/4, incl | 0.011 | 0.011 | 0.016 |
| Over 1 1/4 to 1 3/8, incl | 0.012 | 0.012 | 0.018 |
| Over 1 3/8 to 1 1/2, incl | 0.014 | 0.014 | 0.021 |
| Over 1 1/2 to 2, incl | 1/64 | 1/64 | 0.023 |
| Over 2 to 2 1/2, incl | 1/32 | 0 | 0.023 |
| Over 2 1/2 to 3 1/2, incl | 3/64 | 0 | 0.035 |
| Over 3 1/2 to 4 1/2, incl | 1/16 | 0 | 0.046 |
| Over 4 1/2 to 5 1/2, incl | 5/64 | 0 | 0.058 |
| Over 5 1/2 to 6 1/2, incl | 1/8 | 0 | 0.070 |
| Over 6 1/2 to 8 1/4, incl | 5/32 | 0 | 0.085 |
| Over 8 1/4 to 9 1/2, incl | 3/16 | 0 | 0.100 |
| Over 9 1/2 to 10, incl | 1/4 | 0 | 0.120 |

[A]Out-of-round is the difference between the maximum and minimum diameters of the bar, measured at the same transverse cross section. Out-of-square section is the difference in perpendicular distance between opposite faces, measured at the same transverse cross section.

between the purchaser and the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission shall be responsible for the content of the report.

NOTE 8—The industry definition as invoked here is: EDI is the computer to computer exchange of business information in a standard format such as ANSI ASC X12.

## 15. Inspection and Testing

15.1 The inspector representing the purchaser shall have free entry, at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the structural product

**TABLE 28 Permitted Variations in Sectional Dimensions for Hexagons**

| Specified Sizes Between Opposite Sides, in. | Permitted Variations from Specified Size, in. | | Permitted Out-of-Hexagon Section, Three Measurements, in.[A] |
|---|---|---|---|
| | Over | Under | |
| ½ and under | 0.007 | 0.007 | 0.011 |
| Over ½ to 1, incl | 0.010 | 0.010 | 0.015 |
| Over 1 to 1½ , incl | 0.021 | 0.013 | 0.025 |
| Over 1½ to 2, incl | 1/32 | 1/64 | 1/32 |
| Over 2 to 2½ , incl | 3/64 | 1/64 | 3/64 |
| Over 2½ to 3½ , incl | 1/16 | 1/64 | 1/16 |

[A]Out-of-hexagon section is the greatest difference in distance between any two opposite faces measured at the same transverse cross section.

**TABLE 29 Permitted Variations in Straightness for Bars**

| Permitted Variations in Straightness, in.[A] |
|---|
| ¼ in any 5 ft and ¼ × (number of feet of total length/5) |

[A]Permitted variations in straightness do not apply to hot-rolled bars if any subsequent heating operation has been performed.

**TABLE 30 Permitted Variations in Length for Hot-Cut Steel Bars[A]**

NOTE 1—Where "..." appears in this table, there is no requirement.

| Specified Sizes of Rounds, Squares, and Hexagons, in. | Specified Sizes of Flats, in. | | Permitted Variations Over Specified Length Given in Feet, in. (No Variation Under) | | | | |
|---|---|---|---|---|---|---|---|
| | Thickness | Width | 5 to 10, excl | 10 to 20, excl | 20 to 30, excl | 30 to 40, excl | 40 to 60, incl |
| To 1, incl | To 1, incl | To 3, incl | ½ | ¾ | 1¼ | 1¾ | 2¼ |
| Over 1 to 2, incl | Over 1 | To 3, incl | ⅝ | 1 | 1½ | 2 | 2½ |
| Over 1 to 2, incl | To 1, incl | Over 3 to 6, incl | ⅝ | 1 | 1½ | 2 | 2½ |
| Over 2 to 5, incl | Over 1 | Over 3 to 6, incl | 1 | 1½ | 1¾ | 2¼ | 2¾ |
| Over 5 to 10, incl | ... | ... | 2 | 2½ | 2¾ | 3 | 3¼ |
| | 0.230 to 1, incl | Over 6 to 8, incl | ¾ | 1¼ | 1¾ | 3½ | 4 |
| | Over 1 to 3, incl | Over 6 to 8, incl | 1¼ | 1¾ | 2 | 3½ | 4 |
| | | Hot Sawing | | | | | |
| 2 to 5, incl[B] | 1 and over | 3 and over | [B] | 1½ | 1¾ | 2¼ | 2¾ |
| Over 5 to 10, incl | ... | ... | [B] | 2½ | 2¾ | 3 | 3¼ |

[A]For flats over 6 to 8 in., incl, in width and over 3 in. in thickness, consult the manufacturer for permitted variations in length.
[B]Smaller sizes and shorter lengths are not commonly hot sawed.

**TABLE 31 Permitted Variations in Length for Bars Recut Both Ends After Straightening[AB]**

| Sizes of Rounds, Squares, Hexagons, Width of Flats and Maximum Dimension of Other Sections, in. | Permitted Variations from Specified Lengths Given in Feet, in. | | | |
|---|---|---|---|---|
| | To 12, incl | | Over 12 | |
| | Over | Under | Over | Under |
| To 3, incl | 3/16 | 1/16 | ¼ | 1/16 |
| Over 3 to 6, incl | ¼ | 1/16 | ⅜ | 1/16 |
| Over 6 to 8, incl | ⅜ | 1/16 | ½ | 1/16 |
| Rounds over 8 to 10, incl | ½ | 1/16 | ⅝ | 1/16 |

[A]For flats over 6 to 8 in., incl, in width, and over 3 in. in thickness, consult the manufacturer or processor for permitted variations in length.
[B]Permitted variations are sometimes required all over or all under the specified length, in which case the sum of the two permitted variations applies.

ordered. The manufacturer shall afford the inspector all reasonable facilities to be satisfied that the structural product is being furnished in accordance with this general requirements specification, the applicable product specification, and the purchase order. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere with the operation of the manufacturer's works.

15.2 Where structural products are produced from coil, 15.1 shall apply to the processor instead of the manufacturer, and the place of process shall apply instead of the place of manufacture. Where structural products are produced from coil and the processor is different from the manufacturer, the inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed to all parts of the manufacturer's works that concern the manufacture of the structural product ordered.

## 16. Retreatment

16.1 If any heat-treated structural product fails to meet the mechanical property requirements of the applicable product

specification, the manufacturer or the processor shall have the option of heat treating the structural product again. All mechanical property tests shall be repeated and the structural product shall be reexamined for surface defects when it is resubmitted for inspection.

## 17. Rejection

17.1 Any rejection based upon product analysis made in accordance with the applicable product specification shall be reported to the supplier and samples that represent the rejected structural product shall be preserved for 2 weeks from the date of notification of such rejection. In case of dissatisfaction with the results of the tests, the supplier shall have the option of making claim for a rehearing within that time.

17.2 The purchaser shall have the option of rejecting structural product that exhibits injurious defects subsequent to its acceptance at the manufacturer's or processor's works, and so notifying the manufacturer or processor.

## 18. Identification of Structural Products

18.1 *Required Plate Markings*:

18.1.1 Except as allowed by 18.1.4.2 and 18.6, plates shall be legibly marked with the following: applicable ASTM designation (see 1.1) (year-date not required); "G" or "MT" if applicable (see 18.1.2); applicable grade; heat number; size and thickness; and name, brand, or trademark of the manufacturer (for plates produced from an as-rolled structural product) or the processor (for plates produced from coil).

18.1.2 Plates that are required to be heat treated, but have not been so heat treated, shall be marked, by the manufacturer or processor, with the letter "G" (denoting green) following the required ASTM designation mark, except that "G" marking is not necessary if such plates are for shipment, for the purpose of obtaining the required heat treatment, to an organization under the manufacturer's control. Such plates shall have been qualified for shipment on the basis of test specimens that have been so heat treated. Plates that are required to be heat treated, and have been so heat treated, shall be marked, by the party that performed the heat treatment, with the letter "MT" (denoting material treated) following the required ASTM designation mark.

18.1.3 Except as allowed by 18.1.4.2 and 18.6, the required markings for plates shall be by steel die stamping, paint marking, or by means of permanently affixed, colorfast, weather-resistant labels or tags. It shall be the responsibility of the supplier that all required markings be intact and fully legible upon receipt by the purchaser.

18.1.4 *Location of Markings*:

18.1.4.1 The required markings for plates shall be in at least one place on each finished plate.

18.1.4.2 For secured lifts of all sizes of plates ⅜ in. [10 mm] (or 5⁄16 in. [8 mm] for material specified for bridge construction end use) or under in thickness, and for secured lifts of all thicknesses of plates 36 in. [900 mm] or under in width, the manufacturer or processor shall have the option of placing such markings on only the top piece of each lift, or of showing such markings on a substantial tag attached to each lift, unless otherwise specified.

18.2 *Shapes*:

18.2.1 Except as allowed by 18.2.2 and 18.6, shapes shall be marked with the heat number, size of section, length, and mill identification marks on each piece. Shapes with the greatest cross-sectional dimension greater than 6 in. [150 mm] shall have the manufacturer's name, brand, or trademark shown in raised letters at intervals along the length. In addition, shapes shall be identified with the ASTM designation (year-date not required) and grade, either by marking each piece individually, by permanently affixing a colorfast, weather-resistant label or tag, or, if bundled, by attaching a substantial tag to the bundle.

18.2.2 Bundling for shipment of small shapes with the greatest cross-sectional dimension not greater than 6 in. [150 mm] is permissible. Each lift or bundle shall be marked or substantially tagged showing the identification information listed in 18.2.1.

18.2.3 It shall be permissible for the manufacturer to make a full size bundle at the end of a heat by adding product from a consecutively rolled heat of the same nominal chemical composition. The manufacturer shall identify a bundle consisting of product from two heats with the number of the first heat rolled or identify both heats. The manufacturer shall maintain records of the heats contained in each bundle.

18.3 *Steel Sheet Piling*—Steel sheet piling shall be marked with the heat number, size of section, length, and mill identification marks on each piece, either by marking, or by permanently affixing colorfast, weather-resistant label or tag. The manufacturer's name, brand, or trademark shall be shown in raised letters at intervals along the length.

18.4 *Bars*—Bars of all sizes, when loaded for shipment, shall be properly identified with the name or brand of manufacturer, purchaser's name and order number, the ASTM designation number (year-date not required), grade number where appropriate, size and length, weight [mass] of lift, and the heat number for identification. Unless otherwise specified, the method of marking is at the manufacturer's option and shall be made by hot stamping, cold stamping, painting, or marking tags attached to the lifts of bars. Bars are not required to be die-stamped.

18.4.1 It shall be permissible for the manufacturer to make a full size bundle at the end of a heat by adding product from a consecutively rolled heat of the same nominal chemical composition. The manufacturer shall identify a bundle consisting of product from two heats with the number of the first heat rolled or identify both heats. The manufacturer shall maintain records of the heats contained in each bundle.

18.5 *Bar Coding*—In addition to the requirements of 18.1 to 18.4 inclusive, the manufacturer or processor shall have the option of using bar coding as a supplementary identification method.

NOTE 9—Bar coding should be consistent with AIAG Standards.

18.6 *Subdivided Material*:

18.6.1 Except as allowed by 18.6.2, pieces separated from a master structural product by an organization other than the original manufacturer shall be identified with the ASTM designation (year-date not required), grade, heat number, and the heat treatment identification, if applicable, along with the trademark, brand, or name of the organization subdividing the structural product. The identification methods shall be in

accordance with the requirements of 18.1 to 18.4 inclusive, except that the raised letters method for shapes and steel sheet piling is not required. If the original manufacturer's identification remains intact, the structural product need not be additionally identified by the organization supplying the structural product.

18.6.2 It shall be permissible for pieces from the same heat of structural product to be bundled or placed in secured lifts, with the identification specified in 18.6.1 placed on the top piece of each lift or shown on a substantial tag attached to each bundle or lift.

## 19. Packaging, Marking, and Loading for Shipment

19.1 Packaging, marking, and loading for shipment shall be in accordance with Practices A 700.

19.2 When Level A is specified, and when specified in the contract or order, and for direct procurement by or direct shipment to the U.S. government, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163.

19.3 When specified in the contract or order, and for direct procurement by or direct shipment to the U.S.government, marking for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for military agencies and with Fed. Std. No. 123 for civil agencies.

## 20. Keywords

20.1 bars; general requirements; plates; rolled; shapes; sheet piling; structural steel

## SUPPLEMENTARY REQUIREMENTS

The following standardized supplementary requirements are for use when desired by the purchaser. Those that are considered suitable for use with each material specification are listed in the specification. Other tests may be performed by agreement between the supplier and the purchaser. These additional requirements shall apply only when specified in the order, in which event the specified tests shall be made by the manufacturer or processor before shipment of the material.

## S1. Vacuum Treatment

S1.1 The steel shall be made by a process that includes vacuum degassing while molten. Unless otherwise agreed upon with the purchaser, it is the responsibility of the manufacturer to select suitable process procedures.

## S2. Product Analysis

S2.1 Product analyses shall be made for those elements specified or restricted by the applicable product specification for the applicable grade, class, and type. Specimens for analysis shall be taken adjacent to or from the tension test specimen, or from a sample taken from the same relative location as that from which the tension test specimen was taken.

## S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons

S3.1 Prior to testing, the test specimens representing the structural product for acceptance purposes for mechanical properties shall be thermally treated to simulate a post-weld heat treatment below the critical temperature ($Ac_3$), using the heat treatment parameters (such as temperature range, time, and cooling rates) specified in the order. The test results for such heat-treated test specimens shall meet the applicable product specification requirements.

## S4. Additional Tension Test

S4.1 *Plate*—One tension test shall be made from each unit plate rolled from a slab or directly from an ingot, except that for quenched and tempered plates, a test shall be taken from each unit plate heat treated. The results obtained shall be reported on the mill test reports when such tests are required by the order.

## S5. Charpy V-Notch Impact Test

S5.1 Charpy V-notch impact tests shall be conducted in accordance with Specification A 673/A 673M.

S5.2 The frequency of testing, the test temperature to be used, and the absorbed energy requirements shall be as specified on the order.

## S6. Drop-Weight Test (for Material 0.625 in. [16 mm] and over in Thickness)

S6.1 Drop-weight tests shall be made in accordance with Test Method E 208. The specimens shall represent the material in the final condition of heat treatment. Agreement shall be reached between the purchaser and the manufacturer or processor as to the number of pieces to be tested and whether a maximum nil-ductility transition (NDT) temperature is mandatory or if the test results are for information only.

### S8. Ultrasonic Examination

S8.1 The material shall be ultrasonically examined in accordance with the requirements specified on the order.

### S15. Reduction of Area Measurement

S15.1 The reduction of area, as determined on the 0.500-in. [12.5-mm] diameter round tension test specimen in accordance with Methods and Definitions A 370, shall not be less than 40 %.

### S18. Maximum Tensile Strength

S18.1 Steel having a specified minimum tensile strength of less than 70 ksi [485 MPa] shall not exceed the minimum specified tensile strength by more than 30 ksi [205 MPa].

S18.2 Steel having a minimum specified tensile strength of 70 ksi [485 MPa] or higher shall not exceed the minimum specified tensile strength by more than 25 ksi [170 MPa].

### S23. Copper-Bearing Steel (for improved atmospheric corrosion resistance)

S23.1 The copper content shall be a minimum of 0.20 % on heat analysis, 0.18 on product analysis.

### S26. Subdivided Material—Marking of Individual Pieces

S26.1 Subdivided pieces shall be individually identified by marking, stenciling, or die stamping the applicable product specification designation (year-date not required), grade, heat number, and the heat treatment identification, if applicable, along with the trademark, brand, or name of the organization that subdivided the structural product. As an alternative, individual subdivided pieces shall be identified by a code traceable to the original required identification, provided that the trademark, name, or brand of the organization that subdivided the structural product is also placed on the structural product and the original required identification, cross referenced on the code, is furnished with the structural product.

### S27. Restrictive Plate Flatness

S27.1As-rolled or normalized carbon steel plates ordered to restrictive flatness shall conform to the permitted variations from a flat surface given in Table S27.1 or Table S27.2, whichever is applicable.

S27.2 As-rolled or normalized high-strength low-alloy steel plates ordered to restrictive flatness shall conform to the permitted variations from a flat surface given in Table S27.3 or Table S27.4, whichever is applicable.

### S28. Fine Grain Practice

S28.1 The steel shall be made to fine grain practice.

### S29. Fine Austenitic Grain Size

S29.1 The requirements for fine austenitic grain size (see 8.1 and 8.3) shall be met.

### S30. Charpy V-Notch Impact Test for Structural Shapes: Alternate Core Location

S30.1 For shapes with a flange thickness equal to or greater than 1½ in. [38.1 mm] that are specified in the purchase order to be tested in accordance with this supplementary requirement, Charpy V-notch impact tests shall be conducted in accordance with Specification A 673/A 673M, using specimens taken from the alternate core location. Unless otherwise specified in the purchase order, the minimum average absorbed energy for each test shall be 20 ft·lbf [27 J] and the test temperature shall be 70 °F [21 °C].

S30.2 The frequency of testing shall be Frequency (H), except that, for rolled shapes produced from ingots, the frequency shall be Frequency (P) and the specimens shall be taken from a location representing the top of an ingot or part of an ingot used to produce the product represented by such specimens.

### S31. Maximum Carbon Equivalent for Weldability

S31.1 Plates and shapes shall be supplied with a specific maximum carbon equivalent value as specified by the purchaser. This value shall be based upon heat analysis. The required chemical analysis as well as the carbon equivalent shall be reported.

S31.2 The carbon equivalent shall be calculated using the following formula:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S31.3 For additional information on the weldability of steel, see Appendix X3.

### S32. Single Heat Bundles

S32.1 Bundles containing shapes or bars shall be from a single heat of steel.

**TABLE S27.1 Permitted Variations From a Flat Surface for As-Rolled or Normalized Carbon Steel Plates Ordered to Half-Standard Flatness**

NOTE 1—*Permitted Variation From a Flat Surface Along the Length*—The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft. in length, or in any 12 ft. of longer plates.

NOTE 2—*Permitted Variation From a Flat Surface Across the Width*—The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 36 in., the permitted variation from a flat surface shall not exceed ¼ in. in each direction. When the longer dimension is from 36 to 72 in., incl., the permitted variation from a flat surface shall not exceed 75 % of the tabular amount for the specified width, but in no case less than ¼ in.

NOTE 4—The permitted variations given in this table apply to plates that have a minimum specified tensile strength not over 60 ksi or comparable chemistry or hardness. For plates specified to a higher minimum tensile strength or compatible chemistry or hardness, the permitted variations are 1½ times the amounts in this table.

NOTE 5—This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of such plates.

NOTE 6—Permitted variations in waviness do not apply.

NOTE 7—Plates must be in a horizontal position on a flat surface when flatness is measured.

| Specified Thickness, in. | Specified Weights, lb/ft$^2$ | Permitted Variations From a Flat Surface for Specified Widths Given in Inches, in. | | | | | |
|---|---|---|---|---|---|---|---|
| | | 48 to 60, excl. | 60 to 72, excl. | 72 to 84, excl. | 84 to 96, excl. | 96 to 108, excl. | 108 to 120, incl. |
| To ¼ , excl. | To 10.2, excl. | 15/32 | 5/8 | 11/16 | 3/4 | 13/16 | 7/8 |
| ¼ to ⅜ , excl. | 10.2 to 15.3, excl. | 3/8 | 15/32 | 9/16 | 5/8 | 11/16 | 3/4 |
| ⅜ to ½ , excl. | 15.3 to 20.4, excl. | 5/16 | 5/16 | 3/8 | 7/16 | ½ | 9/16 |
| ½ to ¾ , excl. | 20.4 to 30.6, excl. | 9/32 | 5/16 | 5/16 | 3/8 | ½ | ½ |
| ¾ to 1, excl. | 30.6 to 40.8, excl. | 9/32 | 5/16 | 5/16 | 5/16 | 3/8 | 7/16 |
| 1 to 2, incl. | 40.8 to 51.7, incl. | ¼ | 9/32 | 9/32 | 5/16 | 5/16 | 5/16 |

**TABLE S27.2 Permitted Variations From a Flat Surface for As-Rolled or Normalized Carbon Steel Plates Ordered to Half-Standard Flatness**

NOTE 1—*Permitted Variation From a Flat Surface Along the Length*—The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 3700 mm in length, or in any 3700 mm of longer plates.

NOTE 2—*Permitted Variation From a Flat Surface Across the Width*—The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 900 mm, the permitted variation from a flat surface shall not exceed 6 mm in each direction. When the longer dimension is from 900 to 1800 mm, incl., the permitted flatness variation should not exceed 75 % of the tabular amount for the specified width, but in no case less than 6 mm.

NOTE 4—The permitted variations given in this table apply to plates that have a minimum specified tensile strength not over 415 MPa or comparable chemistry or hardness. For plates specified to a higher minimum tensile strength or compatible chemistry or hardness, the permitted variations are 1½ times the amounts in this table.

NOTE 5—This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of such plates.

NOTE 6—Permitted variations in waviness do not apply.

NOTE 7—Plates must be in a horizontal position on a flat surface when flatness is measured.

| Specified Thickness, mm | Specified Weights, kg/m$^2$ | Permitted Variations From a Flat Surface for Specified Widths Given in Millimetres, mm | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1200 to 1500, excl. | 1500 to 1800, excl. | 1800 to 2100, excl. | 2100 to 2400, excl. | 2400 to 2700, excl. | 2700 to 3000, incl. |
| To 6, excl. | To 47.1 excl. | 12 | 16 | 17 | 19 | 20 | 22 |
| 6 to 10, excl. | 47.1 to 78.5, excl. | 9 | 12 | 14 | 16 | 17 | 19 |
| 10 to 12, excl. | 78.5 to 94.2, excl. | 8 | 8 | 9 | 11 | 12 | 14 |
| 12 to 20, excl. | 94.2 to 157.0, excl. | 7 | 8 | 8 | 9 | 12 | 12 |
| 20 to 25, excl. | 157.0 to 196.2, excl. | 7 | 8 | 8 | 8 | 9 | 11 |
| 25 to 50, incl. | 196.2 to 392.5, incl. | 6 | 7 | 7 | 8 | 8 | 8 |

**TABLE S27.3 Permitted Variations From a Flat Surface for As-Rolled or Normalized High-Strength Low-Alloy Steel Plates Ordered to Half-Standard Flatness**

NOTE 1—*Permitted Variation From a Flat Surface Along the Length*—The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft. in length, or in any 12 ft. of longer plates.

NOTE 2—*Permitted Variation From a Flat Surface Across the Width*—The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 36 in., the permitted variation from a flat surface shall not exceed ⅜ in. in each direction. When the larger dimension is from 36 to 72 in., incl., the permitted variation from a flat surface shall not exceed 75 % of the tabular amount for the specified width, but in no case less than ⅜ in.

NOTE 4—This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of those plates.

NOTE 5—Permitted variations in waviness do not apply.

NOTE 6—Plates must be in a horizontal position on a flat surface when flatness is measured.

| Specified Thickness, in. | Specified Weights, lb/ft$^2$ | Permitted Variations From a Flat Surface for Specified Widths Given in Inches, in. | | | | | |
|---|---|---|---|---|---|---|---|
| | | 48 to 60, excl. | 60 to 72, excl. | 72 to 84, excl. | 84 to 96, excl. | 96 to 108, excl. | 108 to 120, incl. |
| To ¼ , excl. | To 10.2 excl. | 11/16 | 15/16 | 1 | 1 1/8 | 1 3/16 | 1 5/16 |
| ¼ to ⅜ , excl. | 10.2 to 15.3, excl. | 9/16 | 11/16 | 7/8 | 15/16 | 1 | 1 1/8 |
| ⅜ to ½ , excl. | 15.3 to 20.4, excl. | 15/32 | 15/32 | 9/16 | 21/32 | ¾ | 13/16 |
| ½ to ¾ , excl. | 20.4 to 30.6, excl. | 13/32 | 7/16 | ½ | 9/16 | ⅝ | 11/16 |
| ¾ to 1, excl. | 30.6 to 40.8, excl. | 7/16 | 7/16 | 15/32 | ½ | 9/16 | 21/32 |
| 1 to 2, incl. | 40.8 to 51.7, incl. | ⅜ | 13/32 | 7/16 | 15/32 | ½ | ½ |

**TABLE S27.4 Permitted Variations From a Flat Surface for As-Rolled or Normalized High-Strength Low-Alloy Steel Plates Ordered to Half-Standard Flatness**

NOTE 1— *Permitted Variation From a Flat Surface Along the Length*—The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 3700 mm in length, or in any 3700 mm of longer plates.

NOTE 2—*Permitted Variation From a Flat Surface Across the Width*—The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 900 mm, the permitted variation from a flat surface shall not exceed 10 mm in each direction. When the larger dimension is from 900 to 1800 mm, incl., the permitted variation from a flat surface shall not exceed 75 % of the tabular amount for the specified width but in no case less than 10 mm.

NOTE 4—This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of such plates.

NOTE 5—Permitted variations in waviness do not apply.

NOTE 6—Plates must be in a horizontal position on a flat surface when flatness is measured.

| Specified Thickness, mm | Specified Weights, kg/m$^2$ | Permitted Variations From a Flat Surface for Specified Widths Given in Millimetres, mm | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1200 to 1500, excl. | 1500 to 1800, excl. | 1800 to 2100, excl. | 2100 to 2400, excl. | 2400 to 2700, excl. | 2700 to 3000, incl. |
| To 6, excl. | To 47.1 excl. | 17 | 24 | 25 | 28 | 30 | 33 |
| 6 to 10, excl. | 47.1 to 78.5, excl. | 14 | 17 | 22 | 24 | 25 | 28 |
| 10 to 12, excl. | 78.5 to 94.2, excl. | 12 | 12 | 14 | 16 | 19 | 20 |
| 12 to 20, excl. | 94.2 to 157.0, excl. | 11 | 11 | 12 | 14 | 16 | 17 |
| 20 to 25, excl. | 157.0 to 196.2, excl. | 11 | 11 | 12 | 12 | 14 | 16 |
| 25 to 50, incl. | 196.2 to 392.5, incl. | 9 | 10 | 11 | 12 | 12 | 12 |

## ANNEXES

**(Mandatory Information)**

### A1. PERMITTED VARIATIONS IN DIMENSIONS AND MASS IN SI UNITS

A1.1 Tables A1.1 to A1.31 inclusive, contain permitted variations in dimensions and mass stated in SI Units.

**TABLE A1.1 Permitted Variations in Thickness for Rectangular Carbon, High-Strength Low Alloy, and Alloy Steel Plates, 300 mm and Under in Thickness When Ordered to Thickness**

NOTE 1—Permitted variation under specified thickness, 0.3 mm.

NOTE 2—Thickness to be measured at 10 to 20 mm from the longitudinal edge.

NOTE 3—For specified thicknesses not listed in this table, the permitted variations in thickness shall be as given for the next higher value of specified thickness that is listed in this table.

NOTE 4—For thickness measured at any location other than that specified in Note 4, the permitted variations over specified thickness shall be 1 ¾ times the amounts in this table, rounded to the nearest 0.1 mm.

NOTE 5— Where "..." appears in this table, there is no requirement.

| Specified Thickness, mm | Permitted Variations Over Specified Thickness for Widths Given in Millimetres, mm | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1200 and Under | Over 1200 to 1500, excl | 1500 to 1800, excl | 1800 to 2100, excl | 2100 to 2400, excl | 2400 to 2700, excl | 2700 to 3000, excl | 3000 to 3300, excl | 3300 to 3600, excl | 3600 to 4200, excl | 4200 and Over |
| 5.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 1.0 | ... | ... |
| 5.5 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 1.0 | ... | ... |
| 6.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 1.0 | 1.1 | ... | ... |
| 7.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 1.0 | 1.2 | 1.4 | ... |
| 8.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 1.0 | 1.2 | 1.4 | ... |
| 9.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 1.0 | 1.0 | 1.3 | 1.5 | ... |
| 10.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 1.0 | 1.0 | 1.3 | 1.5 | 1.7 |
| 11.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 1.0 | 1.0 | 1.3 | 1.5 | 1.7 |
| 12.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 1.0 | 1.0 | 1.3 | 1.5 | 1.8 |
| 14.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 0.9 | 1.0 | 1.1 | 1.3 | 1.5 | 1.8 |
| 16.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 0.9 | 1.0 | 1.1 | 1.3 | 1.5 | 1.8 |
| 18.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.4 | 1.6 | 2.0 |
| 20.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 1.0 | 1.2 | 1.2 | 1.4 | 1.6 | 2.0 |
| 22.0 | 0.8 | 0.9 | 0.9 | 0.9 | 1.0 | 1.1 | 1.3 | 1.3 | 1.5 | 1.8 | 2.0 |
| 25.0 | 0.9 | 0.9 | 1.0 | 1.0 | 1.0 | 1.2 | 1.3 | 1.5 | 1.5 | 1.8 | 2.2 |
| 28.0 | 1.0 | 1.0 | 1.1 | 1.1 | 1.1 | 1.3 | 1.4 | 1.8 | 1.8 | 2.0 | 2.2 |
| 30.0 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.4 | 1.5 | 1.8 | 1.8 | 2.1 | 2.4 |
| 32.0 | 1.2 | 1.2 | 1.3 | 1.3 | 1.3 | 1.5 | 1.6 | 2.0 | 2.0 | 2.3 | 2.6 |
| 35.0 | 1.3 | 1.3 | 1.4 | 1.4 | 1.4 | 1.6 | 1.7 | 2.3 | 2.3 | 2.5 | 2.8 |
| 38.0 | 1.4 | 1.4 | 1.5 | 1.5 | 1.5 | 1.7 | 1.8 | 2.3 | 2.3 | 2.7 | 3.0 |
| 40.0 | 1.5 | 1.5 | 1.6 | 1.6 | 1.6 | 1.8 | 2.0 | 2.5 | 2.5 | 2.8 | 3.3 |
| 45.0 | 1.6 | 1.6 | 1.7 | 1.8 | 1.8 | 2.0 | 2.3 | 2.8 | 2.8 | 3.0 | 3.5 |
| 50.0 | 1.8 | 1.8 | 1.8 | 2.0 | 2.0 | 2.3 | 2.5 | 3.0 | 3.0 | 3.3 | 3.8 |
| 55.0 | 2.0 | 2.0 | 2.0 | 2.2 | 2.2 | 2.5 | 2.8 | 3.3 | 3.3 | 3.5 | 3.8 |
| 60.0 | 2.3 | 2.3 | 2.3 | 2.4 | 2.4 | 2.8 | 3.0 | 3.4 | 3.4 | 3.8 | 4.0 |
| 70.0 | 2.5 | 2.5 | 2.5 | 2.6 | 2.6 | 3.0 | 3.3 | 3.5 | 3.6 | 4.0 | 4.0 |
| 80.0 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 3.3 | 3.5 | 3.5 | 3.6 | 4.0 | 4.0 |
| 90.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.5 | 3.5 | 3.5 | 3.6 | 4.0 | 4.4 |
| 100.0 | 3.3 | 3.3 | 3.3 | 3.3 | 3.5 | 3.8 | 3.8 | 3.8 | 3.8 | 4.4 | 4.4 |
| 110.0 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.8 | 3.8 | 3.8 | 3.8 | 4.4 | 4.4 |
| 120.0 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 4.8 | 4.8 |
| 130.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.2 | 5.2 |
| 140.0 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 5.6 | 5.6 |
| 150.0 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 5.6 | 5.6 |
| 160.0 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 5.6 | 5.6 |
| 180.0 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 6.3 | 6.3 |
| 200.0 | 5.8 | 5.8 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 7.0 | 7.0 |
| 250.0 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 8.8 |
| 300.0 | 7.5 | 7.5 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 |

**TABLE A1.2 Permitted Variations in Mass for Rectangular Sheared Plates and Universal Mill Plates 2983 kg/m² and Under When Ordered to Mass**

NOTE 1—Permitted variations in excess mass for lots of circular and sketch plates shall be 1¼ times the amounts in this table.
NOTE 2—Permitted variations in excess mass for single plates shall be 1⅓ times the amounts in this table.
NOTE 3—Permitted variations in excess mass for single circular and sketch plates shall be 1⅔ times the amounts in this table.
NOTE 4—The adopted standard density for rolled steel is 7850 kg/m³.
NOTE 5—Where " ..." appears in this table, there is no requirement.

| Specified Mass, kg/m² | Permitted Variations in Average Mass of Lots[A] for Widths Given in Millimetres, Expressed in Percentage of the Specified Masses per Square Metre | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1200 and Under | | Over 1200 to 1500, excl | | 1500 to 1800, excl | | 1800 to 2100, excl | | 2100 to 2400, excl | | 2400 to 2700, excl | | 2700 to 3000, excl | | 3000 to 3300, excl | | 3300 to 3600, excl | | 3600 to 4200, excl | | 4200 and Over | |
| | Over | Under | Over | Under | Over | Under | Over | Under | Over | Under | Over | Under | Over | Under | Over | Under | Over | Under | Over | Under | Over | Under |
| To 51.02, excl | 4.0 | 3.0 | 4.5 | 3.0 | 5.0 | 3.0 | 5.5 | 3.0 | 6.0 | 3.0 | 7.5 | 3.0 | 9.0 | 3.0 | ... | ... | ... | ... | ... | ... | ... | ... |
| 51.02 to 62.80, excl | 4.0 | 3.0 | 4.5 | 3.0 | 5.0 | 3.0 | 5.5 | 3.0 | 6.0 | 3.0 | 6.5 | 3.0 | 7.0 | 3.0 | 8.0 | 3.0 | 9.0 | 3.0 | ... | ... | ... | ... |
| 62.80 to 74.58, excl | 4.0 | 3.0 | 4.0 | 3.0 | 4.5 | 3.0 | 5.0 | 3.0 | 5.5 | 3.0 | 5.5 | 3.0 | 6.0 | 3.0 | 7.5 | 3.0 | 8.0 | 3.0 | 11 | 3.0 | ... | ... |
| 74.58 to 86.35, excl | 3.5 | 3.0 | 3.5 | 3.0 | 4.0 | 3.0 | 4.5 | 3.0 | 5.0 | 3.0 | 5.0 | 3.0 | 5.5 | 3.0 | 6.0 | 3.0 | 7.0 | 3.0 | 9.0 | 3.0 | 10 | 3.0 |
| 86.35 to 102.0, excl | 3.5 | 2.5 | 3.5 | 2.5 | 3.5 | 3.0 | 4.0 | 3.0 | 4.5 | 3.0 | 4.5 | 3.0 | 5.0 | 3.0 | 5.5 | 3.0 | 6.0 | 3.0 | 8.0 | 3.0 | 9.0 | 3.0 |
| 102.0 to 125.6, excl | 3.5 | 2.5 | 3.5 | 2.5 | 3.5 | 3.0 | 3.5 | 3.0 | 4.0 | 3.0 | 4.0 | 3.0 | 4.5 | 3.0 | 5.0 | 3.0 | 5.5 | 3.0 | 7.0 | 3.0 | 8.0 | 3.0 |
| 125.6 to 149.2, excl | 3.0 | 2.5 | 3.5 | 2.5 | 3.5 | 2.5 | 3.5 | 3.0 | 3.5 | 3.0 | 3.5 | 3.0 | 4.0 | 3.0 | 4.5 | 3.0 | 5.0 | 3.0 | 6.5 | 3.0 | 7.0 | 3.0 |
| 149.2 to 196.2, excl | 3.0 | 2.0 | 3.0 | 2.0 | 3.0 | 2.0 | 3.0 | 2.0 | 3.5 | 2.0 | 3.5 | 2.5 | 3.5 | 2.5 | 4.0 | 3.0 | 4.5 | 3.0 | 6.0 | 3.0 | 6.5 | 3.0 |
| 196.2 to 392.5, excl | 2.5 | 2.0 | 3.0 | 2.0 | 3.0 | 2.0 | 3.0 | 2.0 | 3.5 | 2.0 | 3.5 | 2.0 | 3.5 | 2.5 | 3.5 | 3.0 | 4.0 | 3.0 | 5.5 | 3.0 | 6.0 | 3.0 |
| 392.5 to 588.8, excl | 2.5 | 2.0 | 3.0 | 2.0 | 3.0 | 2.0 | 3.0 | 2.0 | 3.5 | 2.0 | 3.5 | 2.0 | 3.5 | 2.5 | 3.5 | 3.0 | 3.5 | 3.0 | 4.0 | 3.0 | 4.5 | 3.0 |
| 588.8 to 785.0, excl | 2.5 | 1.5 | 2.5 | 1.5 | 2.5 | 1.5 | 2.5 | 1.5 | 2.5 | 2.0 | 2.5 | 2.0 | 2.5 | 2.0 | 2.5 | 2.0 | 2.5 | 2.0 | 3.0 | 2.0 | 3.5 | 2.0 |
| 785.0 to 1178, excl | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 3.0 | 1.0 | 3.5 | 1.0 |
| 1178 to 1962, excl | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 3.0 | 1.0 |
| 1962 to 2355, excl | 2.0 | 1.0 | 2.0 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 |
| 2355 to 2983, incl | 2.0 | 1.0 | 2.0 | 1.0 | 2.0 | 1.0 | 2.0 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 | 2.5 | 1.0 |

[A]The term "lot" means all the plates of each tabular width and mass group represented in each shipment.

**TABLE A1.3 Permitted Variations in Width and Length for Sheared Plates 40 mm and Under in Thickness; Length Only of Universal Mill Plates 65 mm and Under in Thickness**

| Specified Dimensions, mm | | Permitted Variations Over Specified Width and Length[A] for Thicknesses Given in Millimetres and Equivalent Masses Given in Kilograms per Square Metre, mm | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | To 10.5, excl | | 10.5 to 16, excl | | 16 to 25, excl | | 25 to 50, incl[B] | |
| Length | Width | To 78.50, excl | | 78.50 to 125.6, excl | | 125.6 to 196.2, excl | | 196.2 to 392.5, excl | |
| | | Width | Length | Width | Length | Width | Length | Width | Length |
| To 3000, excl | To 1500, excl | 10 | 13 | 11 | 16 | 13 | 19 | 16 | 25 |
| | 1500 to 2100, excl | 11 | 16 | 13 | 18 | 16 | 22 | 19 | 25 |
| | 2100 to 2700, excl | 13 | 19 | 16 | 22 | 19 | 25 | 25 | 29 |
| | 2700 and over | 16 | 22 | 19 | 25 | 22 | 29 | 29 | 32 |
| 3000 to 6000, excl | To 1500, excl | 10 | 19 | 13 | 22 | 16 | 25 | 19 | 29 |
| | 1500 to 2100, excl | 13 | 19 | 16 | 22 | 19 | 25 | 22 | 32 |
| | 2100 to 2700, excl | 14 | 22 | 18 | 24 | 21 | 29 | 25 | 35 |
| | 2700 and over | 16 | 25 | 19 | 29 | 22 | 32 | 29 | 35 |
| 6000 to 9000, excl | To 1500, excl | 10 | 25 | 13 | 29 | 16 | 32 | 19 | 38 |
| | 1500 to 2100, excl | 13 | 25 | 16 | 29 | 19 | 32 | 22 | 38 |
| | 2100 to 2700, excl | 14 | 25 | 18 | 32 | 22 | 35 | 25 | 38 |
| | 2700 and over | 18 | 29 | 22 | 32 | 25 | 35 | 32 | 44 |
| 9000 to 12 000, excl | To 1500, excl | 11 | 29 | 13 | 32 | 16 | 35 | 19 | 41 |
| | 1500 to 2100, excl | 13 | 32 | 16 | 35 | 19 | 38 | 22 | 41 |
| | 2100 to 2700, excl | 14 | 32 | 19 | 35 | 22 | 38 | 25 | 48 |
| | 2700 and over | 19 | 35 | 22 | 38 | 25 | 41 | 32 | 48 |
| 12 000 to 15 000, excl | To 1500, excl | 11 | 32 | 13 | 38 | 16 | 41 | 19 | 48 |
| | 1500 to 2100, excl | 13 | 35 | 16 | 38 | 19 | 41 | 22 | 48 |
| | 2100 to 2700, excl | 16 | 35 | 19 | 38 | 22 | 41 | 25 | 48 |
| | 2700 and over | 19 | 38 | 22 | 41 | 25 | 44 | 32 | 48 |
| 15 000 to 18 000, excl | To 1500, excl | 13 | 44 | 16 | 48 | 19 | 48 | 22 | 57 |
| | 1500 to 2100, excl | 16 | 44 | 19 | 48 | 22 | 48 | 25 | 57 |
| | 2100 to 2700, excl | 16 | 44 | 19 | 48 | 22 | 48 | 29 | 57 |
| | 2700 and over | 22 | 44 | 25 | 51 | 29 | 57 | 32 | 64 |
| 18 000 and over | To 1500, excl | 14 | 51 | 19 | 54 | 22 | 57 | 25 | 70 |
| | 1500 to 2100, excl | 19 | 51 | 22 | 54 | 25 | 57 | 29 | 70 |
| | 2100 to 2700, excl | 19 | 51 | 22 | 54 | 25 | 57 | 32 | 70 |
| | 2700 and over | 25 | 51 | 29 | 60 | 32 | 64 | 35 | 76 |

[A]Permitted variations under specified width and length, 6 mm.
[B]Permitted variations in length apply also to Universal Mill plates up to 300 mm in width for thicknesses over 50 to 65 mm, incl, except for alloy steel up to 50 mm thick.

**TABLE A1.4 Permitted Variations in Width for Mill Edge Carbon and High Strength Low-Alloy Plates Produced on Strip Mills (Applies to Plates Produced from Coil and to Plates Produced from an As-Rolled Structural Product)**

| Specified Width, mm | Permitted Variation Over Specified Width, mm[A] |
|---|---|
| To 360, excl | 11 |
| 360 to 430, excl | 13 |
| 430 to 480, excl | 14 |
| 480 to 530, excl | 16 |
| 530 to 610, excl | 17 |
| 610 to 660, excl | 21 |
| 660 to 710, excl | 24 |
| 710 to 890, excl | 29 |
| 890 to 1270, excl | 32 |
| 1270 to 1520, excl | 38 |
| 1520 to 1650, excl | 41 |
| 1650 to 1780, excl | 44 |
| 1780 to 2030, excl | 47 |
| 2030 and over | 51 |

[A]No permitted variation under specified width.

**TABLE A1.5 Permitted Variations in Rolled Width for Universal Mill Plates 380 mm and Under in Thickness**

| Specified Width, mm | Permitted Variations Over Specified Width[A] for Thickness Given in Millimetres or Equivalent Masses Given in Kilograms per Square Metre, mm | | | | | |
|---|---|---|---|---|---|---|
| | To 10, excl | 10 to 16, excl | 16 to 25, incl | 25 to 50, incl | Over 50 to 250, incl | Over 250 to 400, incl |
| | To 78.50, excl | 78.50 to 125.6, excl | 125.6 to 196.2, excl | 196.2 to 392.5, incl | Over 392.5 to 1962, incl | Over 1962 to 3140, incl |
| Over 200 to 500, excl | 3 | 3 | 5 | 6 | 10 | 13 |
| 500 to 900, excl | 5 | 6 | 8 | 10 | 11 | 14 |
| 900 and over | 8 | 10 | 11 | 13 | 14 | 16 |

[A]Permitted variation under specified width, 3 mm.

**TABLE A1.6 Permitted Variations in Diameter for Sheared Circular Plates 25 mm and Under in Thickness**

| Specified Diameters, mm | Permitted Variations Over Specified Diameter for Thicknesses Given in Millimetres, mm[A] | | |
|---|---|---|---|
| | To 10, excl | 10 to 16, excl | 16 to 25, incl |
| To 800, excl | 6 | 10 | 13 |
| 800 to 2100, excl | 8 | 11 | 14 |
| 2100 to 2700, excl | 10 | 13 | 16 |
| 2700 to 3300, excl | 11 | 14 | 17 |
| 3300 and over | 13 | 16 | 19 |

[A]No permitted variation under specified diameter.

**TABLE A1.7 Permitted Variations in Diameter for Gas-Cut Circular Plates (Not Applicable to Alloy Steel)**

| Specified Diameters, mm | Permitted Variation Over Specified Diameter for Thicknesses Given, mm[A] | | | | | |
|---|---|---|---|---|---|---|
| | To 25, excl | 25 to 50, excl | 50 to 100, excl | 100 to 150, excl | 150 to 200, excl | 200 to 400, incl |
| To 800, excl | 10 | 10 | 13 | 13 | 16 | 19 |
| 800 to 2100, excl | 10 | 13 | 13 | 16 | 19 | 22 |
| 2100 to 2700, excl | 13 | 14 | 16 | 19 | 22 | 25 |
| 2700 to 3300, excl | 13 | 14 | 17 | 22 | 25 | 29 |
| 3300 and over | 16 | 19 | 22 | 25 | 29 | 32 |

[A]No permitted variations under specified diameter.

**TABLE A1.8 Permitted Variations in Width and Length for Rectangular Plates When Gas Cutting is Specified or Required (Applies to Alloy Steel Specifications Only).**

NOTE 1—Plates with universal rolled edges will be gas cut to length only.
NOTE 2—These permitted variations shall be taken all under or divided over and under, if so specified.

| Specified Thickness, mm | Permitted Variation Over Specified Width and Length, mm |
|---|---|
| To 50, excl | 19 |
| 50 to 100, excl | 25 |
| 100 to 150, excl | 29 |
| 150 to 200, excl | 33 |
| 200 to 400, excl | 38 |

**TABLE A1.9 Permitted Variations in Width and Length for Rectangular Plates When Gas Cutting is Specified or Required (Not Applicable to Alloy Steel)**

NOTE 1—Plates with universal rolled edges will be gas cut to length only.

| Specified Thickness, mm | Permitted Variation Over Specified Width and Length, mm[A] |
|---|---|
| To 50, excl | 13 |
| 50 to 100, excl | 16 |
| 100 to 150, excl | 19 |
| 150 to 200, excl | 22 |
| 200 to 400, incl | 25 |

[A]These permitted variations shall be taken all under or divided over and under, if so specified.

**TABLE A1.10 Permitted Variations in Diameter for Gas-Cut Circular Plates (Applies to Alloy Steel Specifications Only)**

| Specified Diameter, mm | Permitted Variations Over Specified Diameter for Specified Thicknesses Given in Millimetres, mm[A] | | | | | |
|---|---|---|---|---|---|---|
| | To 25, excl | 25 to 50, excl | 50 to 100, excl | 100 to 150, excl | 150 to 200, excl | 200 to 400, incl |
| To 800, excl | 13 | 13 | 19 | 19 | 25 | 25 |
| 800 to 2100, excl | 13 | 16 | 22 | 25 | 29 | 32 |
| 2100 to 2700, excl | 16 | 19 | 25 | 29 | 32 | 35 |
| 2700 to 3300, incl | 22 | 25 | 29 | 32 | 35 | 38 |

[A]No permitted variations under specified diameter.

**TABLE A1.11 Permitted Camber[A] for Carbon Steel, High-Strength Low-Alloy Steel, and Alloy Steel Universal Mill Plates and High-Strength Low-Alloy Steel and Alloy Steel Sheared or Gas-Cut Rectangular Plates**

| Specified Width, mm | Permitted Camber, mm |
|---|---|
| To 750, incl | Length in millimetres/300 |
| Over 750 to 1500 | Length in millimetres/250 |

[A] Camber as it relates to plates is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

**TABLE A1.12 Permitted Camber[A] for Sheared Plates and Gas-Cut Rectangular Plates, All Thicknesses (Applies to Carbon Steel Only)**

| Permitted camber, mm = length in millimetres/500 |
|---|

[A] Camber as it relates to plates is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

**TABLE A1.13 Permitted Variations From a Flat Surface for Standard Flatness Carbon Steel Plates**

NOTE 1—When the longer dimension is under 900 mm, the permitted variation from a flat surface shall not exceed 6 mm. When the longer dimension is from 900 to 1800 mm, incl, the permitted variation from a flat surface shall not exceed 75 % of the tabular amount for the specified width, but in no case less than 6 mm.

NOTE 2—These permitted variations apply to plates that have a specified minimum tensile strength of not more than 415 MPa or comparable chemical composition or hardness. The limits in this table are increased 50 % for plates that have a higher specified minimum tensile strength or comparable chemical composition or hardness.

NOTE 3—This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of such plates.

NOTE 4—Where "..." appears in this table, there is no requirement.

NOTE 5—Plates must be in a horizontal position on a flat surface when flatness is measured.

| Specified Thickness, mm | Specified Mass, kg/m$^2$ | Permitted Variations From a Flat Surface for Specified Widths Given in Millimetres, mm[A,B] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | To 900, excl | 900 to 1200, excl | 1200 to 1500, excl | 1500 to 1800, excl | 1800 to 2100, excl | 2100 to 2400, excl | 2400 to 2700, excl | 2700 to 3000, excl | 3000 to 3600, excl | 3600 to 4200, excl | 4200 and over |
| To 6, excl | To 47.1, excl | 14 | 19 | 24 | 32 | 35 | 38 | 41 | 44 | 48 | ... | ... |
| 6 to 10, excl | 47.1 to 78.5, excl | 13 | 16 | 19 | 24 | 29 | 32 | 35 | 38 | 41 | ... | ... |
| 10 to 12, excl | 78.5 to 94.2, excl | 13 | 14 | 16 | 16 | 19 | 22 | 25 | 29 | 32 | 48 | 54 |
| 12 to 20, excl | 94.2 to 157.0, excl | 11 | 13 | 14 | 16 | 16 | 19 | 25 | 25 | 29 | 38 | 51 |
| 20 to 25, excl | 157.0 to 196.2, excl | 11 | 13 | 14 | 16 | 16 | 16 | 19 | 22 | 25 | 35 | 44 |
| 25 to 50, excl | 196.2 to 392.5, excl | 10 | 13 | 13 | 14 | 14 | 16 | 16 | 16 | 18 | 29 | 38 |
| 50 to 100, excl | 392.5 to 785.0, excl | 8 | 10 | 11 | 13 | 13 | 13 | 13 | 14 | 16 | 22 | 29 |
| 100 to 150, excl | 785.0 to 1178, excl | 10 | 11 | 13 | 13 | 14 | 14 | 16 | 19 | 22 | 22 | 25 |
| 150 to 200, excl | 1178 to 1570, excl | 11 | 13 | 13 | 16 | 18 | 19 | 22 | 22 | 25 | 25 | 25 |
| 200 to 250, excl | 1570 to 1962, excl | 13 | 13 | 16 | 18 | 19 | 21 | 22 | 24 | 25 | 25 | 25 |
| 250 to 300, excl | 1962 to 2355, excl | 13 | 16 | 19 | 21 | 22 | 24 | 25 | 25 | 25 | 25 | 25 |
| 300 to 400, incl | 2355 to 3140, incl | 16 | 19 | 21 | 22 | 24 | 25 | 25 | 25 | 25 | 25 | ... |

[A]*Permitted Variation From a Flat Surface Along the Length*—The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width for plates up to 4000 mm in length, or in any 4000 mm for longer plates.

[B]*Permitted Variation From a Flat Surface Across the Width*—The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

**TABLE A1.14 Permitted Variations From a Flat Surface for Standard Flatness High-Strength Low-Alloy Steel and Alloy Steel Plates, Hot Rolled or Thermally Treated**

NOTE 1—When the longer dimension is under 900 mm, the permitted variation from a flat surface shall not exceed 10 mm. When the longer dimension is from 900 to 1800 mm, incl, the permitted variation from a flat surface shall not exceed 75 % of the tabular amount for the specified width.

NOTE 2—This table and these notes cover the permitted variations from a flat surface for circular and sketch plates, based upon the maximum dimensions of such plates.

NOTE 3—Where "..." appears in this table, there is no requirement.

NOTE 4—Plates must be in a horizontal position on a flat surface when flatness is measured.

| Specified Thickness, mm | Specified Mass, kg/m$^2$ | Permitted Variations from a Flat Surface for Specified Widths Given in Millimetres, mm[A,B] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | To 900, excl | 900 to 1200, excl | 1200 to 1500, excl | 1500 to 1800, excl | 1800 to 2100, excl | 2100 to 2400, excl | 2400 to 2700, excl | 2700 to 3000, excl | 3000 to 3600, excl | 3600 to 4200, excl | 4200 and over |
| To 6, excl | To 47.1, excl | 21 | 29 | 35 | 48 | 51 | 57 | 60 | 67 | 70 | ... | ... |
| 6 to 10, excl | 47.1 to 78.5, excl | 19 | 24 | 29 | 35 | 44 | 48 | 51 | 57 | 60 | ... | ... |
| 10 to 12, excl | 78.5 to 94.2, excl | 19 | 22 | 24 | 24 | 29 | 33 | 38 | 41 | 48 | 70 | 79 |
| 12 to 20, excl | 94.2 to 157.0, excl | 16 | 19 | 22 | 22 | 25 | 29 | 32 | 35 | 41 | 57 | 76 |
| 20 to 25, excl | 157.0 to 196.2, excl | 16 | 19 | 22 | 22 | 24 | 25 | 29 | 33 | 38 | 51 | 67 |
| 25 to 50, excl | 196.2 to 392.5, excl | 14 | 16 | 19 | 21 | 22 | 24 | 25 | 25 | 25 | 41 | 57 |
| 50 to 100, excl | 392.5 to 785.0, excl | 13 | 14 | 18 | 19 | 19 | 19 | 19 | 22 | 25 | 32 | 41 |
| 100 to 150, excl | 785.0 to 1178, excl | 14 | 18 | 19 | 19 | 22 | 22 | 24 | 29 | 32 | 32 | 38 |
| 150 to 200, excl | 1178 to 1570, excl | 16 | 19 | 19 | 24 | 25 | 29 | 32 | 33 | 38 | 38 | 38 |
| 200 to 250, excl | 1570 to 1962, excl | 19 | 21 | 24 | 25 | 29 | 32 | 33 | 35 | 38 | 38 | 38 |
| 250 to 300, excl | 1962 to 2355, excl | 19 | 24 | 29 | 32 | 33 | 35 | 38 | 38 | 38 | 38 | 38 |
| 300 to 400, incl | 2355 to 3140, incl | 22 | 25 | 30 | 33 | 35 | 38 | 38 | 38 | 38 | 38 | 38 |

[A] *Permitted Variation From a Flat Surface Along the Length*—The longer dimension specified is considered the length, and the permitted variation from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 4000 mm in length, or in any 4000 mm for longer plates.

[B] *Permitted Variation From a Flat Surface Across the Width*—The permitted variation from a flat surface across the width shall not exceed the tabular amount for the specified width.

**TABLE A1.15 Permitted Variations in Waviness for Standard Flatness Plates**

NOTE 1—Waviness denotes the maximum deviation of the surface of the plate from a plane parallel to the surface of the point of measurement and contiguous to the surface of the place at each of the two adjacent wave peaks, when the plate is resting on a flat horizontal surface, as measured in an increment of less than 4000 mm of length. The permitted variation in waviness is a function of the permitted variation from a flat surface as obtained from Table A1.13 or A1.14, whichever is applicable.

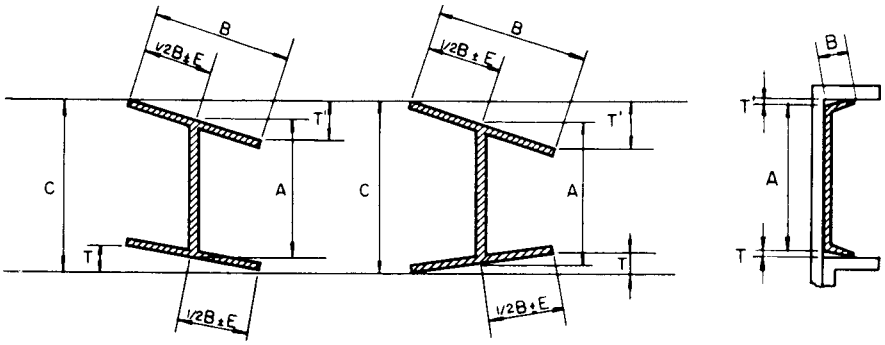
NOTE 2—Plates must be in a horizontal position on a flat surface when waviness is measured.

| Permitted Variation from a Flat Surface (from Table A1.13 or A1.14), mm | Permitted Variations in Waviness, mm, When Number of Waves in 4000 mm is | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 8 | 6 | 5 | 3 | 3 | 2 | 2 |
| 10 | 10 | 8 | 5 | 5 | 3 | 2 | 2 |
| 11 | 11 | 8 | 6 | 5 | 3 | 3 | 2 |
| 13 | 13 | 10 | 8 | 5 | 5 | 3 | 2 |
| 14 | 14 | 11 | 8 | 6 | 5 | 3 | 2 |
| 16 | 16 | 13 | 10 | 6 | 5 | 3 | 2 |
| 17 | 17 | 13 | 10 | 8 | 5 | 5 | 2 |
| 19 | 19 | 14 | 11 | 8 | 6 | 5 | 2 |
| 21 | 21 | 16 | 11 | 8 | 6 | 5 | 2 |
| 22 | 22 | 17 | 13 | 10 | 6 | 5 | 2 |
| 24 | 24 | 17 | 13 | 10 | 8 | 6 | 5 |
| 25 | 25 | 19 | 14 | 11 | 8 | 6 | 5 |
| 29 | 29 | 22 | 16 | 13 | 10 | 6 | 5 |
| 32 | 32 | 24 | 17 | 13 | 10 | 8 | 6 |
| 35 | 35 | 27 | 19 | 14 | 11 | 8 | 6 |
| 38 | 38 | 29 | 22 | 16 | 13 | 10 | 6 |
| 41 | 41 | 32 | 24 | 17 | 13 | 10 | 8 |
| 44 | 44 | 33 | 25 | 19 | 14 | 11 | 8 |
| 48 | 48 | 37 | 27 | 21 | 14 | 11 | 8 |
| 51 | 51 | 38 | 29 | 22 | 16 | 13 | 10 |
| 54 | 54 | 41 | 30 | 22 | 17 | 13 | 10 |
| 57 | 57 | 43 | 32 | 24 | 17 | 14 | 10 |
| 60 | 60 | 46 | 33 | 25 | 19 | 14 | 11 |
| 64 | 64 | 48 | 37 | 27 | 21 | 14 | 11 |
| 67 | 67 | 51 | 38 | 29 | 21 | 16 | 11 |
| 70 | 70 | 52 | 40 | 29 | 22 | 16 | 13 |
| 73 | 73 | 56 | 41 | 30 | 24 | 17 | 13 |
| 76 | 76 | 57 | 43 | 32 | 24 | 17 | 14 |
| 79 | 79 | 60 | 44 | 33 | 25 | 19 | 14 |

**TABLE A1.16 Permitted Variations in Cross Section for W, HP, S, M, C, and MC Shapes**

NOTE 1—*A* is measured at center lines of web for S, M, W, and HP shapes; at back of web for C and MC shapes. Measurement is overall for C shapes under 75 mm. *B* is measured parallel to flange. *C* is measured parallel to web.

NOTE 2—Where "..." appears in this table, there is no requirement.




| Shape | Section Nominal Size, mm | Permitted Variations in Sectional Dimensions Given, mm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *A,* Depth | | *B,* Flange Width | | $T + T'$[A] Flanges Out-of-Square[B] | *E,* Web off Center[C] | *C,* Maximum Depth at any Cross Section over Theoretical Depth | Permitted Variations Over or Under Theoretical Web Thickness for Thicknesses Given in Millimetres, mm | |
| | | Over Theoretical | Under Theoretical | Over Theoretical | Under Theoretical | | | | 5 and Under | Over 5 |
| W and HP | up to 310, incl | 4 | 3 | 6 | 5 | 6 | 5 | 6 | ... | ... |
| | over 310 | 4 | 3 | 6 | 5 | 8 | 5 | 6 | ... | ... |
| S and M | 75 to 180, incl | 2 | 2 | 3 | 3 | 0.03 | 5 | ... | ... | ... |
| | over 180 to 360, incl. | 3 | 2 | 4 | 4 | 0.03 | 5 | ... | ... | ... |
| | over 360 to 610, incl | 5 | 3 | 5 | 5 | 0.03 | 5 | ... | ... | ... |
| C and MC | 40 and under | 1 | 1 | 1 | 1 | 0.03 | ... | ... | 0.2 | 0.4 |
| | over 40 to 75, excl | 2 | 2 | 2 | 2 | 0.03 | ... | ... | 0.4 | 0.5 |
| | 75 to 180, incl | 3 | 2 | 3 | 3 | 0.03 | ... | ... | ... | ... |
| | over 180 to 360, incl | 3 | 3 | 3 | 4 | 0.03 | ... | ... | ... | ... |
| | over 360 | 5 | 4 | 3 | 5 | 0.03 | ... | ... | ... | ... |

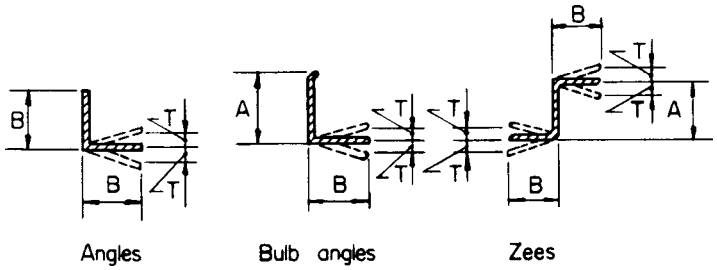
[A] $T + T'$ applies when flanges of channels are toed in or out. For channels 16 mm and under in depth, the permitted out-of-square is 0.05 mm/mm of depth. The permitted variation shall be rounded to the nearest millimetre after calculation.

[B] Permitted variation is per millimetre of flange width for S, M, C, and MC shapes.

[C] Permitted variation of 8 mm max for sections over 634 kg/m.

**TABLE A1.17 Permitted Variations in Cross Section for Angles (L Shapes), Bulb Angles, and Zees**

NOTE 1—Where "..." appears in this table, there is no requirement.

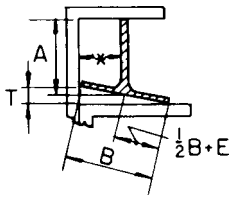



| Section | Nominal Size, mm | Permitted Variations in Sectional Dimensions Given, mm | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *A*, Depth | | *B*, Flange Width, or Length of Leg | | *T*, Out-of-Square per Millimetre of *B* | Permitted Variations Over or Under Theoretical Thickness for Thicknesses Given in Millimetres, mm | | |
| | | Over Theoretical | Under Theoretical | Over Theoretical | Under Theoretical | | 5 and Under | Over 5 to 10 | Over 10 |
| Angles[A] (L shapes) | 25 and under | ... | ... | 1 | 1 | 0.026[B] | 0.2 | 0.2 | ... |
| | over 25 to 50, incl | ... | ... | 1 | 1 | 0.026[B] | 0.2 | 0.2 | 0.3 |
| | over 50 to 75, excl | ... | ... | 2 | 2 | 0.026[B] | 0.3 | 0.4 | 0.4 |
| | 75 to 100, incl | ... | ... | 3 | 2 | 0.026[B] | ... | ... | ... |
| | over 100 to 150 incl | ... | ... | 3 | 3 | 0.026[B] | ... | ... | ... |
| | over 150 | ... | ... | 5 | 3 | 0.026[B] | ... | ... | ... |
| Bulb angles | (depth) 75 to 100, incl | 3 | 2 | 4 | 2 | 0.026[B] | ... | ... | ... |
| | over 100 to 150, incl | 3 | 2 | 4 | 3 | 0.026[B] | ... | ... | ... |
| | over 150 | 3 | 2 | 5 | 3 | 0.026[B] | ... | ... | ... |
| Zees | 75 to 100, incl | 3 | 2 | 4 | 2 | 0.026[B] | ... | ... | ... |
| | over 100 to 150, incl | 3 | 2 | 4 | 3 | 0.026[B] | ... | ... | ... |

[A]For unequal leg angles, longer leg determines classification.
[B]0.026 mm/mm = 1½ °. The permitted variation shall be rounded to the nearest millimetre after calculation.

**TABLE A1.18 Permitted Variations in Sectional Dimensions for Rolled Tees**

NOTE 1—*Back of square and center line of stem are to be parallel when measuring "out-of-square."
NOTE 2—Where "..." appears in this table, there is no requirement.




| Nominal Size[A] | Permitted Variations in Sectional Dimensions Given, mm | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *A*, Depth[B] | | *B*, Width[B] | | *T*, Out-of-Square per Millimetre of *B* | *E*, Web Off-Center, max | Stem Out-of-Square[C] | Thickness of Flange | | Thickness of Stem | |
| | Over | Under | Over | Under | | | | Over | Under | Over | Under |
| 30 and under | 1 | 1 | 1 | 1 | ... | ... | 1 | 0.2 | 0.2 | 0.1 | 0.5 |
| Over 30 to 50, incl | 2 | 2 | 2 | 2 | ... | ... | 2 | 0.3 | 0.3 | 0.2 | 0.5 |
| Over 50 to 75, excl | 2 | 2 | 2 | 2 | ... | ... | 2 | 0.4 | 0.4 | 0.4 | 0.5 |
| 75 to 125, incl | 2 | 2 | 3 | 3 | 0.03 | 2 | ... | ... | ... | ... | ... |
| Over 125 to 180, incl | 2 | 2 | 3 | 3 | 0.03 | 3 | ... | ... | ... | ... | ... |

[A]The longer member of an unequal tee determines the size for Permitted variations.
[B]Measurements for both depth and width are overall.
[C]Stem out-of-square is the permitted variation from its true position of the center line of stem, measured at the point.

**TABLE A1.19 Permitted Variations in Length for S, M, C, MC, L, T, Z, and Bulb Angle Shapes**

NOTE 1—Where "..." appears in this table, there is no requirement.

| Nominal Size,[A] mm | Permitted Variations From Specified Length for Lengths Given in Metres, mm | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.5 to 3, excl | | 3 to 6, excl | | 6 to 9, incl | | Over 9 to 12, incl | | Over 12 to 15, incl | | Over 15 to 20, incl | | Over 20 m | |
| | Over | Under | Over | Under | Over | Under | Over | Under | Over | Under | Over | Under | Over | Under |
| Under 75 | 16 | 0 | 25 | 0 | 38 | 0 | 51 | 0 | 64 | 0 | 64 | 0 | ... | ... |
| 75 and over | 25 | 0 | 38 | 0 | 45 | 0 | 57 | 0 | 70 | 0 | 70 | 0 | ... | ... |

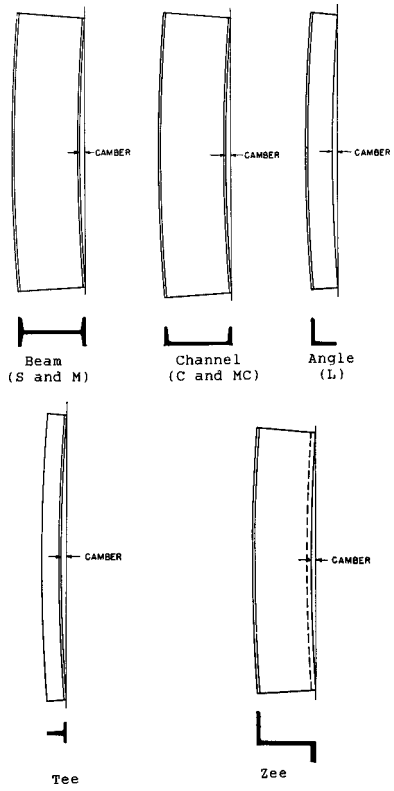
[A] Greatest cross-sectional dimension.

**TABLE A1.20 Permitted Variations in End Out-of-Square for S, M, C, MC, L, T, Z, and Bulb Angle Shapes**

| Shapes | Permitted Variation |
|---|---|
| S, M, C, and MC | 0.017 mm per millimetre of depth |
| L[A] | 0.026 mm per millimetre of leg length or 1½ ° |
| Bulb angles | 0.026 mm per millimetre of depth or 1½ ° |
| Rolled tees[A] | 0.017 mm per millimetre of flange or stem |
| Zees | 0.026 mm per millimetre of sum of both flange lengths |

[A] Permitted variations in ends out-of-square are determined on the longer members of the shape.

**TABLE A1.21 Permitted Variations in Straightness for S, M, C, MC, L, T, Z, and Bulb Angle Shapes**




Positions for Measuring Camber of Shapes

| Variable | Nominal Size,[A] mm | Permitted Variation, mm |
|---|---|---|
| Camber | under 75 | 4 × number of metres of total length |
| | 75 and over | 2 × number of metres of total length |
| Sweep | all | Due to the extreme variations in flexibility of these shapes, permitted variations for sweep are subject to negotiations between the manufacturer and the purchaser for the individual sections involved. |

[A] Greatest cross-sectional dimension.

**TABLE A1.22 Permitted Variations in Length for W and HP Shapes**

| W Shapes | Permitted Variations From Specified Length for Lengths Given in Metres, mm[A,B] | | | |
|---|---|---|---|---|
| | 9 and Under | | Over 9 | |
| | Over | Under | Over | Under |
| Beams 610 mm and under in nominal depth | 10 | 10 | 10 plus 1 for each additional 1 m or fraction thereof | 10 |
| Beams over 610 mm in nominal depth and all columns | 13 | 13 | 13 plus 1 for each additional 1 m or fraction thereof | 13 |

[A]For HP and W shapes specified in the order for use as bearing piles, the permitted variations in length are plus 125 and minus 0 mm. These permitted variations in length also apply to sheet piles.

[B]The permitted variations in end out-of-square for W and HP shapes shall be 0.016 mm per millimetre of depth, or per millimetre of flange width if the flange width is larger than the depth. The permitted variations shall be rounded to the nearest millimetre after calculation.

**TABLE A1.23 Permitted Variations for Length and End Out-of-Square, Milled Shapes**

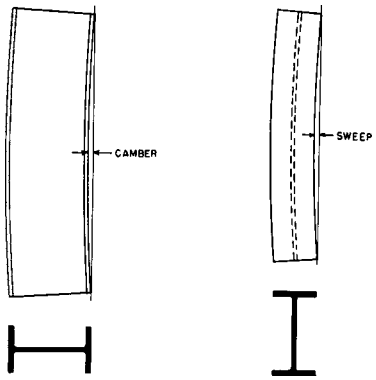
| Nominal Depth, mm | Length,[B]m | Permitted Variations in Length and End Out-of-Square, mm[A] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Milled Both Ends[C] | | | Milled One End[C] | | |
| | | Length | | End Out-of-Square | Length | | End Out-of-Square-(for Milled End) |
| | | Over | Under | | Over | Under | |
| 150 to 920 | 2 to 21 | 1 | 1 | 1 | 6 | 6 | 1 |

[A]The permitted variations in length and end out-of-square are additive.

[B]Length is measured along center line of web. Measurements are made with the steel and tape at the same temperature.

[C]End out-of-square is measured by (*a*) squaring from the center line of the web and (*b*) squaring from the center line of the flange. The measured variation from true squareness in either plane shall not exceed the total tabular amount.

**TABLE A1.24 Permitted Variations in Straightness for W and HP Shapes**




Positions for Measuring Camber and Sweep of W and HP Shapes

| | Permitted Variation in Straightness, mm |
|---|---|
| Camber and sweep | 1 × number of metres of total length[A] |
| When certain sections[B] with a flange width approximately equal to depth are specified in the order for use as columns: | |
| Lengths of 14 m and under | 1 × number of metres of total length, but not over 10 |
| Lengths over 14 m | 10 + [1 × (number of metres of total length − 14 m)] |

[A]Sections with a flange width less than 150 mm, permitted variation for sweep, mm = 2 × number of metres of total length.

[B]Applies only to:
200-mm deep sections—46.1 kg/m and heavier,
250-mm deep sections—73 kg/m and heavier,
310-mm deep sections—97 kg/m and heavier, and
360-mm deep sections—116 kg/m and heavier.
For other sections specified in the order for use as columns, the permitted variation is subject to negotiation with the manufacturer.

**TABLE A1.25 Permitted Variations in Dimensions for Split Tees and Split Angles (L Shapes)[A]**

| Specified Depth, mm | Permitted Variation Over or Under Specified Depth,[B] mm |
|---|---|
| To 150, excl (beams and channels) | 3 |
| 150 to 410, excl (beams and channels) | 5 |
| 410 to 510, excl (beams and channels) | 6 |
| 510 to 610, excl (beams) | 8 |
| 610 and over (beams) | 10 |

[A]The permitted variations in length for split tees or angles are the same as those applicable to the section from which the tees or angles are split.

[B]The above permitted variations in depth of tees or angles include the permitted variations in depth for the beams or channels before splitting. Permitted variations in dimensions and straightness, as set up for the beams or channels from which these tees or angles are cut, apply, except

straightness = 2 mm × length in metres

**TABLE A1.26 Permitted Variations in Sectional Dimensions for Square-Edge and Round-Edge Flat Bars**

NOTE 1—Where "..." appears in this table, there is no requirement.

| Specified Widths, mm | Permitted Variations Over or Under Specified Thickness, for Thicknesses Given in Millimetres, mm | | | | | | Permitted Variations from Specified Width, mm | |
|---|---|---|---|---|---|---|---|---|
| | Over 5 to 6, incl | Over 6 to 12, incl | Over 12 to 25, incl | Over 25 to 50, incl | Over 50 to 75 | Over 75 | Over | Under |
| To 25, incl | 0.18 | 0.20 | 0.25 | ... | ... | ... | 0.5 | 0.5 |
| Over 25 to 50, incl | 0.18 | 0.30 | 0.40 | 0.8 | ... | ... | 1.0 | 1.0 |
| Over 50 to 100, incl | 0.20 | 0.40 | 0.50 | 0.8 | 1.2 | 1.2 | 1.5 | 1.0 |
| Over 100 to 150, incl | 0.25 | 0.40 | 0.50 | 0.8 | 1.2 | 1.2 | 2.5 | 1.5 |
| Over 150 to 200, incl | [A] | 0.40 | 0.65 | 0.8 | 1.2 | 1.6 | 3.0 | 2.5 |

[A]Flats over 150 to 200 mm, incl, in width are not available as hot-rolled bars in thickness 6 mm and under.

**TABLE A1.27 Permitted Variations in Sectional Dimensions for Round and Square Bars and Round-Cornered Squares**

NOTE 1—Where "..." appears in this table, there is no requirement.

| Specified Sizes, mm | Permitted Variation Over or Under Specified Size | | Permitted Out-of-Round or Out-of-Square Section[A] | |
|---|---|---|---|---|
| | mm | % | mm | % |
| Up to 7.0, incl | 0.13 | ... | 0.20 | ... |
| Over 7.0 to 11.0, incl | 0.15 | ... | 0.22 | ... |
| Over 11.0 to 15.0, incl | 0.18 | ... | 0.27 | ... |
| Over 15.0 to 19.0, incl | 0.20 | ... | 0.30 | ... |
| Over 19.0 to 250, incl | ... | 1[B] | ... | 1½[B] |

[A]Out-of-round is the difference between the maximum and minimum diameters of the bar, measured at the same transverse cross section. Out-of-square section is the difference in perpendicular distance between opposite faces, measured at the same transverse cross section.

[B]The permitted variation shall be rounded to the nearest tenth of a millimetre after calculation.

**TABLE A1.28 Permitted Variations in Sectional Dimensions for Hexagons**

| Specified Sizes Between Opposite Sides, mm | Permitted Variations from Specified Size, mm | | Out-of-Hexagon Section, mm[A] |
|---|---|---|---|
| | Over | Under | |
| To 13 incl | 0.18 | 0.18 | 0.3 |
| Over 13 to 25 incl | 0.25 | 0.25 | 0.4 |
| Over 25 to 40 incl | 0.55 | 0.35 | 0.6 |
| Over 40 to 50 incl | 0.8 | 0.40 | 0.8 |
| Over 50 to 65 incl | 1.2 | 0.40 | 1.2 |
| Over 65 to 80 incl | 1.6 | 1.6 | |

[A]Out-of-hexagon section is the greatest difference in distance between any two opposite faces, measured at the same transverse cross section.

**TABLE A1.29 Permitted Variations in Straightness for Bars**

| Maximum Permitted Variation in Straightness, mm[A] |
|---|
| 6 mm in any 1500 mm and (length in millimetres/250)[B] |

[A]Permitted variations in straightness do not apply to hot-rolled bars if any subsequent heating operation has been performed.
[B]Round to the nearest whole millimetre.

**TABLE A1.30 Permitted Variations in Length for Hot-Cut Steel Bars[A]**

NOTE 1—Where "..." appears in this table, there is no requirement.

| Specified Sizes of Rounds, Squares, and Hexagons, mm | Specified Sizes of Flats, mm | | Permitted Variations Over Specified Lengths Given in Metres, mm (No Variation Under) | | | | |
|---|---|---|---|---|---|---|---|
| | Thickness | Width | 1.5 to 3, excl | 3 to 6, excl | 6 to 9, excl | 9 to 12, excl | 12 to 18, incl |
| To 25, incl | to 25, incl | to 75, incl | 15 | 20 | 35 | 45 | 60 |
| Over 25 to 50, incl | over 25 | to 75, incl | 15 | 25 | 40 | 50 | 65 |
| | to 25, incl | over 75 to 150, incl | 15 | 25 | 40 | 50 | 65 |
| Over 50 to 125, incl | over 25 | over 75 to 150, incl | 25 | 40 | 45 | 60 | 70 |
| Over 125 to 250, incl | ... | ... | 50 | 65 | 70 | 75 | 85 |
| | over 6 to 25, incl | over 150 to 200, incl | 20 | 30 | 45 | 90 | 100 |
| | over 25 to 75, incl | over 150 to 200, incl | 30 | 45 | 50 | 90 | 100 |
| Bar size sections | ... | ... | 15 | 25 | 40 | 50 | 65 |
| | | Hot Sawing | | | | | |
| 50 to 125, incl | 25 and over | 75 and over | [B] | 40 | 45 | 60 | 70 |
| Over 125 to 250, incl | ... | ... | [B] | 65 | 70 | 75 | 85 |

[A]For flats over 150 to 200 mm, incl, in width and over 75 mm in thickness, consult the manufacturer for permitted variations in length.
[B]Smaller sizes and shorter lengths are not commonly hot sawed.

**TABLE A1.31 Permitted Variations in Length for Bars Recut Both Ends After Straightening[A,B]**

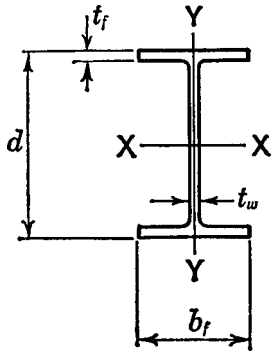
| Sizes of Rounds, Squares, Hexagons, Widths of Flats and Maximum Dimensions of Other Sections, mm | Permitted Variations Over Specified Length Given in Metres, mm (No Variation Under) | |
|---|---|---|
| | to 3.7, incl | over 3.7 |
| To 75, incl | 6 | 8 |
| Over 75 to 150, incl | 8 | 11 |
| Over 150 to 200, incl | 11 | 14 |
| Rounds over 200 to 250, incl | 14 | 18 |

[A]For flats over 150 to 200 mm, incl, in width, and over 75 mm in thickness, consult the manufacturer or the processor for permitted variations in length.
[B]Permitted variations are sometimes required all over or all under the specified length, in which case the sum of the two permitted variations applies.

## A2. DIMENSIONS OF STANDARD SHAPE PROFILES

A2.1 Listed herein are dimensions and weight [mass] of some standard shape profiles. The values stated in inch-pound units are independent of the values stated in SI units, and the values from the two systems are not to be combined in any way. Unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

**TABLE A2.1 "W" Shapes**




| Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot) | Area *A*, in.$^2$ | Depth *d*, in. | Flange | | Web Thickness $t_w$, in.[A] | Designation [Nominal Depth in Millimetres and Mass in Kilograms per Metre] | Area *A*, mm$^2$ | Depth *d*, mm | Flange | | Web Thickness $t_w$, mm[A] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Width $b_f$, in. | Thickness $t_f$, in.[A] | | | | | Width $b_f$, mm | Thickness, $t_f$, mm[A] | |
| W44 X 335 | 98.7 | 44.02 | 15.945 | 1.770 | 1.025 | W1100 X 499 | 63 500 | 1 118 | 405 | 45.0 | 26.0 |
| X 290 | 85.8 | 43.62 | 15.825 | 1.575 | 0.865 | X 433 | 55 100 | 1 108 | 402 | 40.0 | 22.0 |
| X 262 | 77.2 | 43.31 | 15.750 | 1.415 | 0.785 | X 390 | 49 700 | 1 100 | 400 | 36.0 | 20.0 |
| X 230 | 67.9 | 42.91 | 15.750 | 1.220 | 0.710 | X 343 | 43 600 | 1 090 | 400 | 31.0 | 18.0 |
| W40 X 593 | 174.4 | 42.99 | 16.690 | 3.230 | 1.790 | W1000 X 883 | 112 500 | 1 092 | 424 | 82.0 | 45.5 |
| X 503 | 147.8 | 42.05 | 16.415 | 2.755 | 1.535 | X 748 | 95 300 | 1 068 | 417 | 70.0 | 39.0 |
| X 431 | 126.7 | 41.26 | 16.220 | 2.360 | 1.340 | X 642 | 81 800 | 1 048 | 412 | 60.0 | 34.0 |
| X 397 | 117.0 | 40.95 | 16.120 | 2.200 | 1.220 | X 591 | 75 300 | 1 040 | 409 | 55.9 | 31.0 |
| X 372 | 109.4 | 40.63 | 16.065 | 2.045 | 1.160 | X 554 | 70 600 | 1 032 | 408 | 52.0 | 29.5 |
| X 362 | 107.0 | 40.55 | 16.020 | 2.010 | 1.120 | X 539 | 68 700 | 1 030 | 407 | 51.1 | 28.4 |
| X 324 | 95.3 | 40.16 | 15.910 | 1.810 | 1.000 | X 483 | 61 500 | 1 020 | 404 | 46.0 | 25.4 |
| X 297 | 87.4 | 39.84 | 15.825 | 1.650 | 0.930 | X 443 | 56 400 | 1 012 | 402 | 41.9 | 23.6 |
| X 277 | 81.3 | 39.69 | 15.830 | 1.575 | 0.830 | X 412 | 52 500 | 1 008 | 402 | 40.0 | 21.1 |
| X 249 | 73.3 | 39.38 | 15.750 | 1.420 | 0.750 | X 371 | 47 300 | 1 000 | 400 | 36.1 | 19.0 |
| X 215 | 63.3 | 38.98 | 15.750 | 1.220 | 0.650 | X 321 | 40 800 | 990 | 400 | 31.0 | 16.5 |
| X 199 | 58.4 | 38.67 | 15.750 | 1.065 | 0.650 | X 296 | 37 700 | 982 | 400 | 27.1 | 16.5 |
| W40 X 392 | 115.3 | 41.57 | 12.360 | 2.520 | 1.415 | W1000 X 584 | 74 400 | 1 056 | 314 | 64.0 | 36.0 |
| X 331 | 97.5 | 40.79 | 12.165 | 2.125 | 1.220 | X 494 | 62 900 | 1 036 | 309 | 54.0 | 31.0 |
| X 327 | 95.9 | 40.79 | 12.130 | 2.130 | 1.180 | X 486 | 61 900 | 1 036 | 308 | 54.1 | 30.0 |
| X 294 | 86.2 | 40.39 | 12.010 | 1.930 | 1.060 | X 438 | 55 600 | 1 026 | 305 | 49.0 | 26.9 |
| X 278 | 81.9 | 40.16 | 11.970 | 1.810 | 1.025 | X 415 | 52 800 | 1 020 | 304 | 46.0 | 26.0 |
| X 264 | 77.6 | 40.00 | 11.930 | 1.730 | 0.960 | X 393 | 50 100 | 1 016 | 303 | 43.9 | 24.4 |
| X 235 | 68.9 | 39.69 | 11.890 | 1.575 | 0.830 | X 350 | 44 600 | 1 008 | 302 | 40.0 | 21.1 |
| X 211 | 62.0 | 39.37 | 11.810 | 1.415 | 0.750 | X 314 | 40 000 | 1 000 | 300 | 35.9 | 19.1 |
| X 183 | 53.7 | 38.98 | 11.810 | 1.200 | 0.650 | X 272 | 34 600 | 990 | 300 | 31.0 | 16.5 |
| X 167 | 49.1 | 38.59 | 11.810 | 1.025 | 0.650 | X 249 | 31 700 | 980 | 300 | 26.0 | 16.5 |
| X 149 | 43.8 | 38.20 | 11.810 | 0.830 | 0.630 | X 222 | 28 200 | 970 | 300 | 21.1 | 16.0 |
| W36 X 236.4800 | 234.6 | 42.55 | 17.990 | 4.290 | 2.380 | W920 X 1191 | 152 500 | 1 081 | 457 | 109.0 | 60.5 |
| X 652 | 192.5 | 41.05 | 17.575 | 3.540 | 1.970 | X 970 | 124 100 | 1 043 | 446 | 89.9 | 50.0 |
| X 529 | 156.1 | 39.79 | 17.220 | 2.910 | 1.610 | X 787 | 100 700 | 1 011 | 437 | 73.9 | 40.9 |
| X 487 | 143.8 | 39.33 | 17.105 | 2.680 | 1.500 | X725 | 92 700 | 999 | 434 | 68.1 | 38.1 |
| X 441 | 130.2 | 38.85 | 16.965 | 2.440 | 1.360 | X 656 | 84 000 | 987 | 431 | 62.0 | 34.5 |
| X 395 | 117.4 | 38.41 | 16.830 | 2.200 | 1.220 | X 588 | 75 700 | 975 | 427 | 55.9 | 31.0 |
| X 361 | 106.5 | 37.99 | 16.730 | 2.010 | 1.120 | X 537 | 68 700 | 965 | 425 | 51.1 | 28.4 |
| X 330 | 97.4 | 37.67 | 16.630 | 1.850 | 1.020 | X 491 | 62 800 | 957 | 422 | 47.0 | 25.9 |
| X 302 | 89.3 | 37.33 | 16.655 | 1.680 | 0.945 | X 449 | 57 600 | 948 | 423 | 42.7 | 24.0 |
| X 282 | 83.4 | 37.11 | 16.595 | 1.570 | 0.885 | X 420 | 53 800 | 943 | 422 | 39.9 | 22.5 |
| X 262 | 77.4 | 36.85 | 16.550 | 1.440 | 0.840 | X 390 | 49 900 | 936 | 420 | 36.6 | 21.3 |
| X 247 | 72.9 | 36.67 | 16.510 | 1.350 | 0.800 | X 368 | 47 000 | 931 | 419 | 34.3 | 20.3 |
| X 231 | 68.5 | 36.49 | 16.470 | 1.260 | 0.760 | X 345 | 44 200 | 927 | 418 | 32.0 | 19.3 |
| W36 X 256 | 75.4 | 37.43 | 12.215 | 1.730 | 0.960 | W920 X 381 | 48 600 | 951 | 310 | 43.9 | 24.4 |
| X 232 | 68.1 | 37.12 | 12.120 | 1.570 | 0.870 | X 345 | 44 000 | 943 | 308 | 39.9 | 22.1 |

**TABLE A2.1** *Continued*

| Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot) | Area *A*, in.$^2$ | Depth *d*, in. | Flange | | Web Thickness $t_w$, in.[A] | Designation [Nominal Depth in Millimetres and Mass in Kilograms per Metre] | Area *A*, mm$^2$ | Depth *d*, mm | Flange | | Web Thickness $t_w$, mm[A] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Width $b_f$, in. | Thickness $t_f$, in.[A] | | | | | Width $b_f$, mm | Thickness, $t_f$, mm[A] | |
| X 210 | 61.8 | 36.69 | 12.180 | 1.360 | 0.830 | X 313 | 39 900 | 932 | 309 | 34.5 | 21.1 |
| X 194 | 57.0 | 36.49 | 12.115 | 1.260 | 0.765 | X 289 | 36 800 | 927 | 308 | 32.0 | 19.4 |
| X 182 | 53.6 | 36.33 | 12.075 | 1.180 | 0.725 | X 271 | 34 600 | 923 | 307 | 30.0 | 18.4 |
| X 170 | 50.0 | 36.17 | 12.030 | 1.100 | 0.680 | X 253 | 32 300 | 919 | 306 | 27.9 | 17.3 |
| X 160 | 47.0 | 36.01 | 12.000 | 1.020 | 0.650 | X 238 | 30 300 | 915 | 305 | 25.9 | 16.5 |
| X 150 | 44.2 | 35.85 | 11.975 | 0.940 | 0.625 | X 223 | 28 500 | 911 | 304 | 23.9 | 15.9 |
| X 135 | 39.7 | 35.55 | 11.950 | 0.790 | 0.600 | X 201 | 25 600 | 903 | 304 | 20.1 | 15.2 |
| W33 X 387 | 114.0 | 35.95 | 16.200 | 2.280 | 1.260 | W840 X 576 | 73 500 | 913 | 411 | 57.9 | 32.0 |
| X 354 | 104.1 | 35.55 | 16.100 | 2.090 | 1.160 | X 527 | 67 200 | 903 | 409 | 53.1 | 29.5 |
| X 318 | 93.5 | 35.16 | 15.985 | 1.890 | 1.040 | X 473 | 60 300 | 893 | 406 | 48.0 | 26.4 |
| X 291 | 85.6 | 34.84 | 15.905 | 1.730 | 0.960 | X 433 | 55 200 | 885 | 404 | 43.9 | 24.4 |
| X 263 | 77.4 | 34.53 | 15.805 | 1.570 | 0.870 | X 392 | 49 900 | 877 | 401 | 39.9 | 22.1 |
| X 241 | 70.9 | 34.18 | 15.860 | 1.400 | 0.830 | X 359 | 45 700 | 868 | 403 | 35.6 | 21.1 |
| X 221 | 65.0 | 33.93 | 15.805 | 1.275 | 0.775 | X 329 | 41 900 | 862 | 401 | 32.4 | 19.7 |
| X 201 | 59.1 | 33.68 | 15.745 | 1.150 | 0.715 | X 299 | 38 100 | 855 | 400 | 29.2 | 18.2 |
| W33 X 169 | 49.5 | 33.82 | 11.500 | 1.220 | 0.670 | W840 X 251 | 31 900 | 859 | 292 | 31.0 | 17.0 |
| X 152 | 44.7 | 33.49 | 11.565 | 1.055 | 0.635 | X 226 | 28 800 | 851 | 294 | 26.8 | 16.1 |
| X 141 | 41.6 | 33.30 | 11.535 | 0.960 | 0.605 | X 210 | 26 800 | 846 | 293 | 24.4 | 15.4 |
| X 130 | 38.3 | 33.09 | 11.510 | 0.855 | 0.580 | X 193 | 24 700 | 840 | 292 | 21.7 | 14.7 |
| X 118 | 34.7 | 32.86 | 11.480 | 0.740 | 0.550 | X 176 | 22 400 | 835 | 292 | 18.8 | 14.0 |
| W30 X 391 | 115.0 | 33.19 | 15.590 | 2.440 | 1.360 | W760 X 582 | 74 200 | 843 | 396 | 62.0 | 34.5 |
| X 357 | 104.8 | 32.80 | 15.470 | 2.240 | 1.240 | X 531 | 67 600 | 833 | 393 | 56.9 | 31.5 |
| X 326 | 95.7 | 32.40 | 15.370 | 2.050 | 1.140 | X 484 | 61 700 | 823 | 390 | 52.1 | 29.0 |
| X 292 | 85.7 | 32.01 | 15.255 | 1.850 | 1.020 | X 434 | 55 300 | 813 | 387 | 47.0 | 25.9 |
| X 261 | 76.7 | 31.61 | 15.155 | 1.650 | 0.930 | X 389 | 49 500 | 803 | 385 | 41.9 | 23.6 |
| X 235 | 69.0 | 31.30 | 15.055 | 1.500 | 0.830 | X 350 | 44 500 | 795 | 382 | 38.1 | 21.1 |
| X 211 | 62.0 | 30.94 | 15.105 | 1.315 | 0.775 | X 314 | 40 000 | 786 | 384 | 33.4 | 19.7 |
| X 191 | 56.1 | 30.68 | 15.040 | 1.185 | 0.710 | X 284 | 36 200 | 779 | 382 | 30.1 | 18.0 |
| X 173 | 50.8 | 30.44 | 14.985 | 1.065 | 0.655 | X 257 | 32 800 | 773 | 381 | 27.1 | 16.6 |
| W30 X 148 | 43.5 | 30.67 | 10.480 | 1.180 | 0.650 | W760 X 220 | 28 100 | 779 | 266 | 30.0 | 16.5 |
| X 132 | 38.9 | 30.31 | 10.545 | 1.000 | 0.615 | X 196 | 25 100 | 770 | 268 | 25.4 | 15.6 |
| X 124 | 36.5 | 30.17 | 10.515 | 0.930 | 0.585 | X 185 | 23 500 | 766 | 267 | 23.6 | 14.9 |
| X 116 | 34.2 | 30.01 | 10.495 | 0.850 | 0.565 | X 173 | 22 100 | 762 | 267 | 21.6 | 14.4 |
| X 108 | 31.7 | 29.83 | 10.475 | 0.760 | 0.545 | X 161 | 20 500 | 758 | 266 | 19.3 | 13.8 |
| X 99 | 29.1 | 29.65 | 10.450 | 0.670 | 0.520 | X 147 | 18 800 | 753 | 265 | 17.0 | 13.2 |
| X 90 | 26.4 | 29.53 | 10.400 | 0.610 | 0.470 | X 134 | 17 000 | 750 | 264 | 15.5 | 11.9 |
| W27 X 539 | 158.4 | 32.52 | 15.255 | 3.540 | 1.970 | W690 X 802 | 102 200 | 826 | 387 | 89.9 | 50.0 |
| X 368 | 108.1 | 30.39 | 14.665 | 2.480 | 1.380 | X 548 | 69 800 | 772 | 372 | 63.0 | 35.1 |
| X 336 | 98.7 | 30.0 | 14.550 | 2.280 | 1.260 | X 500 | 63 700 | 762 | 369 | 57.9 | 32.0 |
| X 307 | 90.2 | 29.61 | 14.445 | 2.090 | 1.160 | X 457 | 58 200 | 752 | 367 | 53.1 | 29.5 |
| X 281 | 82.6 | 29.29 | 14.350 | 1.930 | 1.060 | X 419 | 53 300 | 744 | 364 | 49.0 | 26.9 |
| X 258 | 75.7 | 28.98 | 14.270 | 1.770 | 0.980 | X 384 | 48 900 | 736 | 362 | 45.0 | 24.9 |
| X 235 | 69.1 | 28.66 | 14.190 | 1.610 | 0.910 | X 350 | 44 600 | 728 | 360 | 40.9 | 23.1 |
| X 217 | 63.8 | 28.43 | 14.115 | 1.500 | 0.830 | X 323 | 41 100 | 722 | 359 | 38.1 | 21.1 |
| X 194 | 57.0 | 28.11 | 14.035 | 1.340 | 0.750 | X 289 | 36 800 | 714 | 356 | 34.0 | 19.0 |
| X 178 | 52.3 | 27.81 | 14.085 | 1.190 | 0.725 | X 265 | 33 700 | 706 | 358 | 30.2 | 18.4 |
| X 161 | 47.4 | 27.59 | 14.020 | 1.080 | 0.660 | X 240 | 30 600 | 701 | 356 | 27.4 | 16.8 |
| X 146 | 42.9 | 27.38 | 13.965 | 0.975 | 0.605 | X 217 | 27 700 | 695 | 355 | 24.8 | 15.4 |
| W27 X 129 | 37.8 | 27.63 | 10.010 | 1.100 | 0.610 | W690 X 192 | 24 400 | 702 | 254 | 27.9 | 15.5 |
| X 114 | 33.5 | 27.29 | 10.070 | 0.930 | 0.570 | X 170 | 21 600 | 693 | 256 | 23.6 | 14.5 |
| X 102 | 30.0 | 27.09 | 10.015 | 0.830 | 0.515 | X 152 | 19 400 | 688 | 254 | 21.1 | 13.1 |
| X 94 | 27.7 | 26.92 | 9.990 | 0.745 | 0.490 | X 140 | 17 900 | 684 | 254 | 18.9 | 12.4 |
| X 84 | 24.8 | 26.71 | 9.960 | 0.640 | 0.460 | X 125 | 16 000 | 678 | 253 | 16.3 | 11.7 |
| W24 X 370 | 108.0 | 27.99 | 13.660 | 2.720 | 1.520 | W610 X 551 | 70 200 | 711 | 347 | 69.1 | 38.6 |
| X 335 | 98.4 | 27.52 | 13.520 | 2.480 | 1.380 | X 498 | 63 500 | 699 | 343 | 63.0 | 35.1 |
| X 306 | 89.8 | 27.13 | 13.405 | 2.280 | 1.260 | X 455 | 57 900 | 689 | 340 | 57.9 | 32.0 |
| X 279 | 82.0 | 26.73 | 13.305 | 2.090 | 1.160 | X 415 | 52 900 | 679 | 338 | 53.1 | 29.5 |
| X 250 | 73.5 | 26.34 | 13.185 | 1.890 | 1.040 | X 372 | 47 400 | 669 | 335 | 48.0 | 26.4 |
| X 229 | 67.2 | 26.02 | 13.110 | 1.730 | 0.960 | X 341 | 43 400 | 661 | 333 | 43.9 | 24.4 |
| X 207 | 60.7 | 25.71 | 13.010 | 1.570 | 0.870 | X 307 | 39 100 | 653 | 330 | 39.9 | 22.1 |
| X 192 | 56.3 | 25.47 | 12.950 | 1.460 | 0.810 | X 285 | 36 100 | 647 | 329 | 37.1 | 20.6 |
| X 176 | 51.7 | 25.24 | 12.890 | 1.340 | 0.750 | X 262 | 33 300 | 641 | 327 | 34.0 | 19.0 |

**TABLE A2.1** *Continued*

| Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot) | Area $A$, in.$^2$ | Depth $d$, in. | Flange | | Web Thickness $t_w$, in.[A] | Designation [Nominal Depth in Millimetres and Mass in Kilograms per Metre] | Area $A$, mm$^2$ | Depth $d$, mm | Flange | | Web Thickness $t_w$, mm[A] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Width $b_f$, in. | Thickness $t_f$, in.[A] | | | | | Width $b_f$, mm | Thickness, $t_f$, mm[A] | |
| X 162 | 47.7 | 25.00 | 12.955 | 1.220 | 0.705 | X 241 | 30 800 | 635 | 329 | 31.0 | 17.9 |
| X 146 | 43.0 | 24.74 | 12.900 | 1.090 | 0.650 | X 217 | 27 700 | 628 | 328 | 27.7 | 16.5 |
| X 131 | 38.5 | 24.48 | 12.855 | 0.960 | 0.605 | X 195 | 24 800 | 622 | 327 | 24.4 | 15.4 |
| X 117 | 34.4 | 24.26 | 12.800 | 0.850 | 0.550 | X 174 | 22 200 | 616 | 325 | 21.6 | 14.0 |
| X 104 | 30.6 | 24.06 | 12.750 | 0.750 | 0.500 | X 155 | 19 700 | 611 | 324 | 19.0 | 12.7 |
| W24 X 103 | 30.3 | 24.53 | 9.000 | 0.980 | 0.550 | W610 X 153 | 19 600 | 623 | 229 | 24.9 | 14.0 |
| X 94 | 27.7 | 24.31 | 9.065 | 0.875 | 0.515 | X 140 | 17 900 | 617 | 230 | 22.2 | 13.1 |
| X 84 | 24.7 | 24.10 | 9.020 | 0.770 | 0.470 | X 125 | 15 900 | 612 | 229 | 19.6 | 11.9 |
| X 76 | 22.4 | 23.92 | 8.990 | 0.680 | 0.440 | X 113 | 14 500 | 608 | 228 | 17.3 | 11.2 |
| X 68 | 20.1 | 23.73 | 8.965 | 0.585 | 0.415 | X 101 | 13 000 | 603 | 228 | 14.9 | 10.5 |
| W24 X 62 | 18.2 | 23.74 | 7.040 | 0.590 | 0.430 | W610 X 92 | 11 700 | 603 | 179 | 15.0 | 10.9 |
| X 55 | 16.2 | 23.57 | 7.005 | 0.505 | 0.395 | X 82 | 10 500 | 599 | 178 | 12.8 | 10.0 |
| W21 X 201 | 59.2 | 23.03 | 12.575 | 1.630 | 0.910 | W530 X 300 | 38 200 | 585 | 319 | 41.4 | 23.1 |
| X 182 | 53.7 | 22.72 | 12.500 | 1.480 | 0.830 | X 272 | 34 600 | 577 | 317 | 37.6 | 21.1 |
| X 166 | 48.9 | 22.48 | 12.420 | 1.360 | 0.750 | X 248 | 31 500 | 571 | 315 | 34.5 | 19.0 |
| X 147 | 43.2 | 22.06 | 12.510 | 1.150 | 0.720 | X 219 | 27 900 | 560 | 318 | 29.2 | 18.3 |
| X 132 | 38.8 | 21.83 | 12.440 | 1.035 | 0.650 | X 196 | 25 000 | 554 | 316 | 26.3 | 16.5 |
| X 122 | 35.9 | 21.68 | 12.390 | 0.960 | 0.600 | X 182 | 23 200 | 551 | 315 | 24.4 | 15.2 |
| X 111 | 32.7 | 21.51 | 12.340 | 0.875 | 0.550 | X 165 | 21 100 | 546 | 313 | 22.2 | 14.0 |
| X 101 | 29.8 | 21.36 | 12.290 | 0.800 | 0.500 | X 150 | 19 200 | 543 | 312 | 20.3 | 12.7 |
| W21 X 93 | 27.3 | 21.62 | 8.420 | 0.930 | 0.580 | W530 X 138 | 17 600 | 549 | 214 | 23.6 | 14.7 |
| X 83 | 24.3 | 21.43 | 8.355 | 0.835 | 0.515 | X 123 | 15 700 | 544 | 212 | 21.2 | 13.1 |
| X 73 | 21.5 | 21.24 | 8.295 | 0.740 | 0.455 | X 109 | 13 900 | 539 | 211 | 18.8 | 11.6 |
| X 68 | 20.0 | 21.13 | 8.270 | 0.685 | 0.430 | X 101 | 12 900 | 537 | 210 | 17.4 | 10.9 |
| X 62 | 18.3 | 20.99 | 8.240 | 0.615 | 0.400 | X 92 | 11 800 | 533 | 209 | 15.6 | 10.2 |
| X 55 | 16.2 | 20.80 | 8.220 | 0.522 | 0.375 | X 82 | 10 500 | 528 | 209 | 13.3 | 9.50 |
| X 48 | 14.1 | 20.62 | 8.140 | 0.430 | 0.350 | X 72 | 9 180 | 524 | 207 | 10.9 | 9.00 |
| W21 X 57 | 16.7 | 21.06 | 6.555 | 0.650 | 0.405 | W530 X 85 | 10 800 | 535 | 166 | 16.5 | 10.3 |
| X 50 | 14.7 | 20.83 | 6.530 | 0.535 | 0.380 | X 74 | 9 480 | 529 | 166 | 13.6 | 9.7 |
| X 44 | 13.0 | 20.66 | 6.500 | 0.450 | 0.350 | X 66 | 8 390 | 525 | 165 | 11.4 | 8.9 |
| W18 X 311 | 91.5 | 22.32 | 12.005 | 2.740 | 1.520 | W460 X 464 | 59 100 | 567 | 305 | 69.6 | 38.6 |
| X 283 | 83.2 | 21.85 | 11.890 | 2.500 | 1.400 | X 421 | 53 700 | 555 | 302 | 63.5 | 35.6 |
| X 258 | 75.9 | 21.46 | 11.770 | 2.300 | 1.280 | X 384 | 49 000 | 545 | 299 | 58.4 | 32.5 |
| X 234 | 68.8 | 21.06 | 11.650 | 2.110 | 1.160 | X 349 | 44 400 | 535 | 296 | 53.6 | 29.5 |
| X 211 | 62.1 | 20.67 | 11.555 | 1.910 | 1.060 | X 315 | 40 100 | 525 | 293 | 48.5 | 26.9 |
| X 192 | 56.4 | 20.35 | 11.455 | 1.750 | 0.960 | X 286 | 36 400 | 517 | 291 | 44.4 | 24.4 |
| X 175 | 51.3 | 20.04 | 11.375 | 1.590 | 0.890 | X 260 | 33 100 | 509 | 289 | 40.4 | 22.6 |
| X 158 | 46.3 | 19.72 | 11.300 | 1.440 | 0.810 | X 235 | 29 900 | 501 | 287 | 36.6 | 20.6 |
| X 143 | 42.1 | 19.49 | 11.220 | 1.320 | 0.730 | X 213 | 27 100 | 495 | 285 | 33.5 | 18.5 |
| X 130 | 38.2 | 19.25 | 11.160 | 1.200 | 0.670 | X 193 | 24 700 | 489 | 283 | 30.5 | 17.0 |
| X 119 | 35.1 | 18.97 | 11.265 | 1.060 | 0.655 | X 177 | 22 600 | 482 | 286 | 26.9 | 16.6 |
| X 106 | 31.1 | 18.73 | 11.200 | 0.940 | 0.590 | X 158 | 20 100 | 476 | 284 | 23.9 | 15.0 |
| X 97 | 28.5 | 18.59 | 11.145 | 0.870 | 0.535 | X 144 | 18 400 | 472 | 283 | 22.1 | 13.6 |
| X 86 | 25.3 | 18.39 | 11.090 | 0.770 | 0.480 | X 128 | 16 300 | 467 | 282 | 19.6 | 12.2 |
| X 76 | 22.3 | 18.21 | 11.035 | 0.680 | 0.425 | X 113 | 14 400 | 463 | 280 | 17.3 | 10.8 |
| W18 X 71 | 20.8 | 18.47 | 7.635 | 0.810 | 0.495 | W460 X 106 | 13 400 | 469 | 194 | 20.6 | 12.6 |
| X 65 | 19.1 | 18.35 | 7.590 | 0.750 | 0.450 | X 97 | 12 300 | 466 | 193 | 19.0 | 11.4 |
| X 60 | 17.6 | 18.24 | 7.555 | 0.695 | 0.415 | X 89 | 11 400 | 463 | 192 | 17.7 | 10.5 |
| X 55 | 16.2 | 18.11 | 7.530 | 0.630 | 0.390 | X 82 | 10 500 | 460 | 191 | 16.0 | 9.9 |
| X 50 | 14.7 | 17.99 | 7.495 | 0.570 | 0.355 | X 74 | 9 480 | 457 | 190 | 14.5 | 9.0 |
| W18 X 46 | 13.5 | 18.06 | 6.060 | 0.605 | 0.360 | W460 X 68 | 8 710 | 459 | 154 | 15.4 | 9.1 |
| X 40 | 11.8 | 17.90 | 6.015 | 0.525 | 0.315 | X 60 | 7 610 | 455 | 153 | 13.3 | 8.0 |
| X 35 | 10.3 | 17.70 | 6.000 | 0.425 | 0.300 | X 52 | 6 650 | 450 | 152 | 10.8 | 7.6 |
| W16 X 100 | 29.4 | 16.97 | 10.425 | 0.985 | 0.585 | W410 X 149 | 19 000 | 431 | 265 | 25.0 | 14.9 |
| X 89 | 26.2 | 16.75 | 10.365 | 0.875 | 0.525 | X 132 | 16 900 | 425 | 263 | 22.2 | 13.3 |
| X 77 | 22.6 | 16.52 | 10.295 | 0.760 | 0.455 | X 114 | 14 600 | 420 | 261 | 19.3 | 11.6 |
| X 67 | 19.7 | 16.33 | 10.235 | 0.665 | 0.395 | X 100 | 12 700 | 415 | 260 | 16.9 | 10.0 |
| W16 X 57 | 16.8 | 16.43 | 7.120 | 0.715 | 0.430 | W410 X 85 | 10 800 | 417 | 181 | 18.2 | 10.9 |
| X 50 | 14.7 | 16.26 | 7.070 | 0.630 | 0.380 | X 75 | 9 480 | 413 | 180 | 16.0 | 9.7 |

**TABLE A2.1** *Continued*

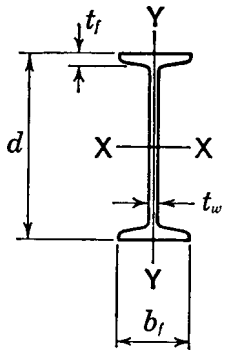
| Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot) | Area *A*, in.$^2$ | Depth *d*, in. | Flange | | Web Thickness $t_w$, in.$^A$ | Designation [Nominal Depth in Millimetres and Mass in Kilograms per Metre] | Area *A*, mm$^2$ | Depth *d*, mm | Flange | | Web Thickness $t_w$, mm$^A$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Width $b_f$, in. | Thickness $t_f$, in.$^A$ | | | | | Width $b_f$, mm | Thickness, $t_f$, mm$^A$ | |
| X 45 | 13.3 | 16.13 | 7.035 | 0.565 | 0.345 | X 67 | 8 580 | 410 | 179 | 14.4 | 8.8 |
| X 40 | 11.8 | 16.01 | 6.995 | 0.505 | 0.305 | X 60 | 7 610 | 407 | 178 | 12.8 | 7.7 |
| X 36 | 10.6 | 15.86 | 6.985 | 0.430 | 0.295 | X 53 | 6 840 | 403 | 177 | 10.9 | 7.5 |
| W16 X 31 | 9.12 | 15.88 | 5.525 | 0.440 | 0.275 | W410 X 46.1 | 5 880 | 403 | 140 | 11.2 | 7.0 |
| X 26 | 7.68 | 15.69 | 5.500 | 0.345 | 0.250 | X 38.8 | 4 950 | 399 | 140 | 8.8 | 6.4 |
| W14X 730 | 215.0 | 22.42 | 17.890 | 4.910 | 3.070 | W360 X 1086 | 139 000 | 569 | 454 | 125.0 | 78.0 |
| X 665 | 196.0 | 21.64 | 17.650 | 4.520 | 2.830 | X 990 | 126 000 | 550 | 448 | 115.0 | 71.9 |
| X 605 | 178.0 | 20.92 | 17.415 | 4.160 | 2.595 | X 900 | 115 000 | 531 | 442 | 106.0 | 65.9 |
| X 550 | 162.0 | 20.24 | 17.200 | 3.820 | 2.380 | X 818 | 105 000 | 514 | 437 | 97.0 | 60.5 |
| X 500 | 147.0 | 19.60 | 17.010 | 3.500 | 2.190 | X 744 | 94 800 | 498 | 432 | 88.9 | 55.6 |
| X 455 | 134.0 | 19.02 | 16.835 | 3.210 | 2.015 | X 677 | 86 500 | 483 | 428 | 81.5 | 51.2 |
| X 426 | 125.0 | 18.67 | 16.695 | 3.035 | 1.875 | X 634 | 80 600 | 474 | 424 | 77.1 | 47.6 |
| X 398 | 117.0 | 18.29 | 16.590 | 2.845 | 1.770 | X 592 | 75 500 | 465 | 421 | 72.3 | 45.0 |
| X 370 | 109.0 | 17.92 | 16.475 | 2.660 | 1.655 | X 551 | 70 300 | 455 | 418 | 67.6 | 42.0 |
| X 342 | 101.0 | 17.54 | 16.360 | 2.470 | 1.540 | X 509 | 65 200 | 446 | 416 | 62.7 | 39.1 |
| X 311 | 91.4 | 17.12 | 16.230 | 2.260 | 1.410 | X 463 | 59 000 | 435 | 412 | 57.4 | 35.8 |
| X 283 | 83.3 | 16.74 | 16.110 | 2.070 | 1.290 | X 421 | 53 700 | 425 | 409 | 52.6 | 32.8 |
| X 257 | 75.6 | 16.38 | 15.995 | 1.890 | 1.175 | X 382 | 48 800 | 416 | 406 | 48.0 | 29.8 |
| X 233 | 68.5 | 16.04 | 15.890 | 1.720 | 1.070 | X 347 | 44 200 | 407 | 404 | 43.7 | 27.2 |
| X 211 | 62.0 | 15.72 | 15.800 | 1.560 | 0.980 | X 314 | 40 000 | 399 | 401 | 39.6 | 24.9 |
| X 193 | 56.8 | 15.48 | 15.710 | 1.440 | 0.890 | X 287 | 36 600 | 393 | 399 | 36.6 | 22.6 |
| X 176 | 51.8 | 15.22 | 15.650 | 1.310 | 0.830 | X 262 | 33 400 | 387 | 398 | 33.3 | 21.1 |
| X 159 | 46.7 | 14.98 | 15.565 | 1.190 | 0.745 | X 237 | 30 100 | 380 | 395 | 30.2 | 18.9 |
| X 145 | 42.7 | 14.78 | 15.500 | 1.090 | 0.680 | X 216 | 27 500 | 375 | 394 | 27.7 | 17.3 |
| W14 X 132 | 38.8 | 14.66 | 14.725 | 1.030 | 0.645 | W360 X 196 | 25 000 | 372 | 374 | 26.2 | 16.4 |
| X 120 | 35.3 | 14.48 | 14.670 | 0.940 | 0.590 | X 179 | 22 800 | 368 | 373 | 23.9 | 15.0 |
| X 109 | 32.0 | 14.32 | 14.605 | 0.860 | 0.525 | X 162 | 20 600 | 364 | 371 | 21.8 | 13.3 |
| X 99 | 29.1 | 14.16 | 14.565 | 0.780 | 0.485 | X 147 | 18 800 | 360 | 370 | 19.8 | 12.3 |
| X 90 | 26.5 | 14.02 | 14.520 | 0.710 | 0.440 | X 134 | 17 100 | 356 | 369 | 18.0 | 11.2 |
| W14 X 82 | 24.1 | 14.31 | 10.130 | 0.855 | 0.510 | W360 X 122 | 15 500 | 363 | 257 | 21.7 | 13.0 |
| X 74 | 21.8 | 14.17 | 10.070 | 0.785 | 0.450 | X 110 | 14 100 | 360 | 256 | 19.9 | 11.4 |
| X 68 | 20.0 | 14.04 | 10.035 | 0.720 | 0.415 | X 101 | 12 900 | 357 | 255 | 18.3 | 10.5 |
| X 61 | 17.9 | 13.89 | 9.995 | 0.645 | 0.375 | X 91 | 11 500 | 353 | 254 | 16.4 | 9.5 |
| W14 X 53 | 15.6 | 13.92 | 8.060 | 0.660 | 0.370 | W360 X 79 | 10 100 | 354 | 205 | 16.8 | 9.4 |
| X 48 | 14.1 | 13.79 | 8.030 | 0.595 | 0.340 | X 72 | 9 100 | 350 | 204 | 15.1 | 8.6 |
| X 43 | 12.6 | 13.66 | 7.995 | 0.530 | 0.305 | X 64 | 8 130 | 347 | 203 | 13.5 | 7.7 |
| W14 X 38 | 11.2 | 14.10 | 6.770 | 0.515 | 0.310 | W360 X 58 | 7 230 | 358 | 172 | 13.1 | 7.9 |
| X 34 | 10.0 | 13.98 | 6.745 | 0.455 | 0.285 | X 51 | 6 450 | 355 | 171 | 11.6 | 7.2 |
| X 30 | 8.85 | 13.84 | 6.730 | 0.385 | 0.270 | X 44.6 | 5 710 | 352 | 171 | 9.8 | 6.9 |
| W14 X 26 | 7.69 | 13.91 | 5.025 | 0.420 | 0.255 | W360 X 39.0 | 4 960 | 353 | 128 | 10.7 | 6.5 |
| X 22 | 6.49 | 13.74 | 5.000 | 0.335 | 0.230 | X 32.9 | 4 190 | 349 | 127 | 8.5 | 5.8 |
| W12 X 336 | 98.8 | 16.82 | 13.385 | 2.955 | 1.775 | W310 X 500 | 63 700 | 427 | 340 | 75.1 | 45.1 |
| X 305 | 89.6 | 16.32 | 13.235 | 2.705 | 1.625 | X 454 | 57 800 | 415 | 336 | 68.7 | 41.3 |
| X 279 | 81.9 | 15.85 | 13.140 | 2.470 | 1.530 | X 415 | 52 800 | 403 | 334 | 62.7 | 38.9 |
| X 252 | 74.1 | 15.41 | 13.005 | 2.250 | 1.395 | X 375 | 47 800 | 391 | 330 | 57.2 | 35.4 |
| X 230 | 67.7 | 15.05 | 12.895 | 2.070 | 1.285 | X 342 | 43 700 | 382 | 328 | 52.6 | 32.6 |
| X 210 | 61.8 | 14.71 | 12.790 | 1.900 | 1.180 | X 313 | 39 900 | 374 | 325 | 48.3 | 30.0 |
| X 190 | 55.8 | 14.38 | 12.670 | 1.735 | 1.060 | X 283 | 36 000 | 365 | 322 | 44.1 | 26.9 |
| X 170 | 50.0 | 14.03 | 12.570 | 1.560 | 0.960 | X 253 | 32 300 | 356 | 319 | 39.6 | 24.4 |
| X 152 | 44.7 | 13.71 | 12.480 | 1.400 | 0.870 | X 226 | 28 800 | 348 | 317 | 35.6 | 22.1 |
| X 136 | 39.9 | 13.41 | 12.400 | 1.250 | 0.790 | X 202 | 25 700 | 341 | 315 | 31.8 | 20.1 |
| X 120 | 35.3 | 13.12 | 12.320 | 1.105 | 0.710 | X 179 | 22 800 | 333 | 313 | 28.1 | 18.0 |
| X 106 | 31.2 | 12.89 | 12.220 | 0.990 | 0.610 | X 158 | 20 100 | 327 | 310 | 25.1 | 15.5 |
| X 96 | 28.2 | 12.71 | 12.160 | 0.900 | 0.550 | X 143 | 18 200 | 323 | 309 | 22.9 | 14.0 |
| X 87 | 25.6 | 12.53 | 12.125 | 0.810 | 0.515 | X 129 | 16 500 | 318 | 308 | 20.6 | 13.1 |
| X 79 | 23.2 | 12.38 | 12.080 | 0.735 | 0.470 | X 117 | 15 000 | 314 | 307 | 18.7 | 11.9 |
| X 72 | 21.1 | 12.25 | 12.040 | 0.670 | 0.430 | X 107 | 13 600 | 311 | 306 | 17.0 | 10.9 |
| X 65 | 19.1 | 12.12 | 12.000 | 0.605 | 0.390 | X 97 | 12 300 | 308 | 305 | 15.4 | 9.9 |
| W12 X 58 | 17.0 | 12.19 | 10.010 | 0.640 | 0.360 | W310 X 86 | 11 000 | 310 | 254 | 16.3 | 9.1 |
| X 53 | 15.6 | 12.06 | 9.995 | 0.575 | 0.345 | X 79 | 10 100 | 306 | 254 | 14.6 | 8.8 |

**TABLE A2.1** *Continued*

| Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot) | Area $A$, in.$^2$ | Depth $d$, in. | Flange | | Web Thickness $t_w$, in.[A] | Designation [Nominal Depth in Millimetres and Mass in Kilograms per Metre] | Area $A$, mm$^2$ | Depth $d$, mm | Flange | | Web Thickness $t_w$, mm[A] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Width $b_f$, in. | Thickness $t_f$, in.[A] | | | | | Width $b_f$, mm | Thickness, $t_f$, mm[A] | |
| W12 X 50 | 14.7 | 12.19 | 8.080 | 0.640 | 0.370 | W310 X 74 | 9 480 | 310 | 205 | 16.3 | 9.4 |
| X 45 | 13.2 | 12.06 | 8.045 | 0.575 | 0.335 | X 67 | 8 520 | 306 | 204 | 14.6 | 8.5 |
| X 40 | 11.8 | 11.94 | 8.005 | 0.515 | 0.295 | X 60 | 7 610 | 303 | 203 | 13.1 | 7.5 |
| W12 X 35 | 10.3 | 12.50 | 6.560 | 0.520 | 0.300 | W310 X 52 | 6 650 | 317 | 167 | 13.2 | 7.6 |
| X 30 | 8.79 | 12.34 | 6.520 | 0.440 | 0.260 | X 44.5 | 5 670 | 313 | 166 | 11.2 | 6.6 |
| X 26 | 7.65 | 12.22 | 6.490 | 0.380 | 0.230 | X 38.7 | 4 940 | 310 | 165 | 9.7 | 5.8 |
| W12 X 22 | 6.48 | 12.31 | 4.030 | 0.425 | 0.260 | W310 X 32.7 | 4 180 | 313 | 102 | 10.8 | 6.6 |
| X 19 | 5.57 | 12.16 | 4.005 | 0.350 | 0.235 | X 28.3 | 3 590 | 309 | 102 | 8.9 | 6.0 |
| X 16 | 4.71 | 11.99 | 3.990 | 0.265 | 0.220 | X 23.8 | 3 040 | 305 | 101 | 6.7 | 5.6 |
| X 14 | 4.16 | 11.91 | 3.970 | 0.225 | 0.200 | X 21.0 | 2 680 | 303 | 101 | 5.7 | 5.1 |
| W10 X 112 | 32.9 | 11.36 | 10.415 | 1.250 | 0.755 | W250 X 167 | 21 200 | 289 | 265 | 31.8 | 19.2 |
| X 100 | 29.4 | 11.10 | 10.340 | 1.120 | 0.680 | X 149 | 19 000 | 282 | 263 | 28.4 | 17.3 |
| X 88 | 25.9 | 10.84 | 10.265 | 0.990 | 0.605 | X 131 | 16 700 | 275 | 261 | 25.1 | 15.4 |
| X 77 | 22.6 | 10.60 | 10.190 | 0.870 | 0.530 | X 115 | 14 600 | 269 | 259 | 22.1 | 13.5 |
| X 68 | 20.0 | 10.40 | 10.130 | 0.770 | 0.470 | X 101 | 12 900 | 264 | 257 | 19.6 | 11.9 |
| X 60 | 17.6 | 10.22 | 10.080 | 0.680 | 0.420 | X 89 | 11 400 | 260 | 256 | 17.3 | 10.7 |
| X 54 | 15.8 | 10.09 | 10.030 | 0.615 | 0.370 | X 80 | 10 200 | 256 | 255 | 15.6 | 9.4 |
| X 49 | 14.4 | 9.98 | 10.000 | 0.560 | 0.340 | X 73 | 9 290 | 253 | 254 | 14.2 | 8.6 |
| W10 X 45 | 13.3 | 10.10 | 8.020 | 0.620 | 0.350 | W250 X 67 | 8 580 | 257 | 204 | 15.7 | 8.9 |
| X 39 | 11.5 | 9.92 | 7.985 | 0.530 | 0.315 | X 58 | 7 420 | 252 | 203 | 13.5 | 8.0 |
| X 33 | 9.71 | 9.73 | 7.960 | 0.435 | 0.290 | X 49.1 | 6 260 | 247 | 202 | 11.0 | 7.4 |
| W10 X 30 | 8.84 | 10.47 | 5.810 | 0.510 | 0.300 | W250 X 44.8 | 5 700 | 266 | 148 | 13.0 | 7.6 |
| X 26 | 7.61 | 10.33 | 5.770 | 0.440 | 0.260 | X 38.5 | 4 910 | 262 | 147 | 11.2 | 6.6 |
| X 22 | 6.49 | 10.17 | 5.750 | 0.360 | 0.240 | X 32.7 | 4 190 | 258 | 146 | 9.1 | 6.1 |
| W10 X 19 | 5.62 | 10.24 | 4.020 | 0.395 | 0.250 | W250 X 28.4 | 3 630 | 260 | 102 | 10.0 | 6.4 |
| X 17 | 4.99 | 10.11 | 4.010 | 0.330 | 0.240 | X 25.3 | 3 220 | 257 | 102 | 8.4 | 6.1 |
| X 15 | 4.41 | 9.99 | 4.000 | 0.270 | 0.230 | X 22.3 | 2 850 | 254 | 102 | 6.9 | 5.8 |
| X 12 | 3.54 | 9.87 | 3.960 | 0.210 | 0.190 | X 17.9 | 2 280 | 251 | 101 | 5.3 | 4.8 |
| W8 X 67 | 19.7 | 9.00 | 8.280 | 0.935 | 0.570 | W200 X 100 | 12 700 | 229 | 210 | 23.7 | 14.5 |
| X 58 | 17.1 | 8.75 | 8.220 | 0.810 | 0.510 | X 86 | 11 000 | 222 | 209 | 20.6 | 13.0 |
| X 48 | 14.1 | 8.50 | 8.110 | 0.685 | 0.400 | X 71 | 9 100 | 216 | 206 | 17.4 | 10.2 |
| X 40 | 11.7 | 8.25 | 8.070 | 0.560 | 0.360 | X 59 | 7 550 | 210 | 205 | 14.2 | 9.1 |
| X 35 | 10.3 | 8.12 | 8.020 | 0.495 | 0.310 | X 52 | 6 650 | 206 | 204 | 12.6 | 7.9 |
| X 31 | 9.13 | 8.00 | 7.995 | 0.435 | 0.285 | X 46.1 | 5 890 | 203 | 203 | 11.0 | 7.2 |
| W8 X 28 | 8.25 | 8.06 | 6.535 | 0.465 | 0.285 | W200 X 41.7 | 5 320 | 205 | 166 | 11.8 | 7.2 |
| X 24 | 7.08 | 7.93 | 6.495 | 0.400 | 0.245 | X 35.9 | 4 570 | 201 | 165 | 10.2 | 6.2 |
| W8 X 21 | 6.16 | 8.28 | 5.270 | 0.400 | 0.250 | W200 X 31.3 | 3 970 | 210 | 134 | 10.2 | 6.4 |
| X 18 | 5.26 | 8.14 | 5.250 | 0.330 | 0.230 | X 26.6 | 3 390 | 207 | 133 | 8.4 | 5.8 |
| W8 X 15 | 4.44 | 8.11 | 4.015 | 0.315 | 0.245 | W200 X 22.5 | 2 860 | 206 | 102 | 8.0 | 6.2 |
| X 13 | 3.84 | 7.99 | 4.000 | 0.255 | 0.230 | X 19.3 | 2 480 | 203 | 102 | 6.5 | 5.8 |
| X 10 | 2.96 | 7.89 | 3.940 | 0.205 | 0.170 | X 15.0 | 1 910 | 200 | 100 | 5.2 | 4.3 |
| W6 X 25 | 7.34 | 6.38 | 6.080 | 0.455 | 0.320 | W150 X 37.1 | 4 740 | 162 | 154 | 11.6 | 8.1 |
| X 20 | 5.87 | 6.20 | 6.020 | 0.365 | 0.260 | X 29.8 | 3 790 | 157 | 153 | 9.3 | 6.6 |
| X 15 | 4.43 | 5.99 | 5.990 | 0.260 | 0.230 | X 22.5 | 2 860 | 152 | 152 | 6.6 | 5.8 |
| W6 X 16 | 4.74 | 6.28 | 4.030 | 0.405 | 0.260 | W150 X 24.0 | 3 060 | 160 | 102 | 10.3 | 6.6 |
| X 12 | 3.55 | 6.03 | 4.000 | 0.280 | 0.230 | X 18.0 | 2 290 | 153 | 102 | 7.1 | 5.8 |
| X 9 | 2.68 | 5.90 | 3.940 | 0.215 | 0.170 | X 13.5 | 1 730 | 150 | 100 | 5.5 | 4.3 |
| X 8.5 | 2.52 | 5.83 | 3.940 | 0.195 | 0.170 | X 13.0 | 1 630 | 148 | 100 | 4.9 | 4.3 |
| W5 X 19 | 5.54 | 5.15 | 5.030 | 0.430 | 0.270 | W130 X 28.1 | 3 590 | 131 | 128 | 10.9 | 6.9 |
| X 16 | 4.68 | 5.01 | 5.000 | 0.360 | 0.240 | X 23.8 | 3 040 | 127 | 127 | 9.1 | 6.1 |
| W4 X 13 | 3.83 | 4.16 | 4.060 | 0.345 | 0.280 | W100 X 19.3 | 2 470 | 106 | 103 | 8.8 | 7.1 |

[A]Actual flange and web thicknesses vary due to mill rolling practices; however, permitted variations for such dimensions are not addressed.

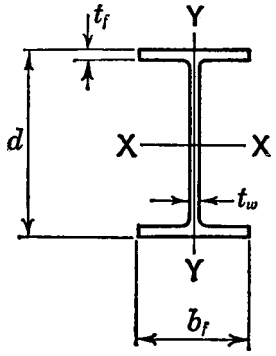
**TABLE A2.2 “S” Shapes**




| Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot) | Area *A*, in.$^2$ | Depth *d*, in. | Flange | | Web Thickness $t_w$, in.[A] | Designation [Nominal Depth in Millimetres and Mass in Kilograms per Metre] | Area *a*, mm$^2$ | Depth *d*, mm | Flange | | Web Thickness $t_w$, mm[A] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Width $b_f$, in. | Thickness $t_f$, in.[A] | | | | | Width $b_f$, mm | Thickness, $t_f$, mm[A] | |
| S 24 X 121 | 35.6 | 24.50 | 8.050 | 1.090 | 0.800 | S 610 X 180 | 23 000 | 622 | 204 | 27.7 | 20.3 |
| X 106 | 31.2 | 24.50 | 7.870 | 1.090 | 0.620 | X 158 | 20 100 | 622 | 200 | 27.7 | 15.7 |
| S 24 X 100 | 29.3 | 24.00 | 7.245 | 0.870 | 0.745 | S 610 X 149 | 18 900 | 610 | 184 | 22.1 | 18.9 |
| X 90 | 26.5 | 24.00 | 7.125 | 0.870 | 0.625 | X 134 | 17 100 | 610 | 181 | 22.1 | 15.9 |
| X 80 | 23.5 | 24.00 | 7.000 | 0.870 | 0.500 | X 119 | 15 200 | 610 | 178 | 22.1 | 12.7 |
| S 20 X 96 | 28.2 | 20.30 | 7.200 | 0.920 | 0.800 | S 510 X 143 | 18 200 | 516 | 183 | 23.4 | 20.3 |
| X 86 | 25.3 | 20.30 | 7.060 | 0.920 | 0.660 | X 128 | 16 300 | 516 | 179 | 23.4 | 16.8 |
| S 20 X 75 | 22.0 | 20.00 | 6.385 | 0.795 | 0.635 | S 510 X 112 | 14 200 | 508 | 162 | 20.2 | 16.1 |
| X 66 | 19.4 | 20.00 | 6.255 | 0.795 | 0.505 | X 98 | 12 500 | 508 | 159 | 20.2 | 12.8 |
| S 18 X 70 | 20.6 | 18.00 | 6.251 | 0.691 | 0.711 | S 460 X 104 | 13 300 | 457 | 159 | 17.6 | 18.1 |
| X 54.7 | 16.1 | 18.00 | 6.001 | 0.691 | 0.461 | X 81.4 | 10 400 | 457 | 152 | 17.6 | 11.7 |
| S 15 X 50 | 14.7 | 15.00 | 5.640 | 0.622 | 0.550 | S 380 X 74 | 9 480 | 381 | 143 | 15.8 | 14.0 |
| X 42.9 | 12.6 | 15.00 | 5.501 | 0.622 | 0.411 | X 64 | 8 130 | 381 | 140 | 15.8 | 10.4 |
| S 12 X 50 | 14.7 | 12.00 | 5.477 | 0.659 | 0.687 | S 310 X 74 | 9 480 | 305 | 139 | 16.7 | 17.4 |
| X 40.8 | 12.0 | 12.00 | 5.252 | 0.659 | 0.462 | X 60.7 | 7 740 | 305 | 133 | 16.7 | 11.7 |
| S 12 X 35 | 10.3 | 12.00 | 5.078 | 0.544 | 0.428 | S 310 X 52 | 6 650 | 305 | 129 | 13.8 | 10.9 |
| X 31.8 | 9.35 | 12.00 | 5.000 | 0.544 | 0.350 | X 47.3 | 6 030 | 305 | 127 | 13.8 | 8.9 |
| S 10 X 35 | 10.3 | 10.00 | 4.944 | 0.491 | 0.594 | S 250 X 52 | 6 650 | 254 | 126 | 12.5 | 15.1 |
| X 25.4 | 7.46 | 10.00 | 4.661 | 0.491 | 0.311 | X 37.8 | 4 810 | 254 | 118 | 12.5 | 7.9 |
| S 8 X 23 | 6.77 | 8.00 | 4.171 | 0.425 | 0.441 | S 200 X 34 | 4 370 | 203 | 106 | 10.8 | 11.2 |
| X 18.4 | 5.41 | 8.00 | 4.001 | 0.425 | 0.271 | X 27.4 | 3 480 | 203 | 102 | 10.8 | 6.9 |
| S 6 X 17.2 | 5.07 | 6.00 | 3.565 | 0.359 | 0.465 | S 150 X 25.7 | 3 270 | 152 | 91 | 9.1 | 11.8 |
| X 12.5 | 3.67 | 6.00 | 3.332 | 0.359 | 0.232 | X 18.6 | 2 360 | 152 | 85 | 9.1 | 5.9 |
| S 5 X 10 | 2.94 | 5.00 | 3.004 | 0.326 | 0.214 | S 130 X 15 | 1 880 | 127 | 76 | 8.3 | 5.4 |
| S 4 X | 2.79 | 4.00 | 2.796 | 0.293 | 0.326 | S 100 X | 1 800 | 102 | 71 | 7.4 | 8.3 |
| 9.5 X 7.7 | 2.26 | 4.00 | 2.663 | 0.293 | 0.193 | 14.1 X 11.5 | 1 450 | 102 | 68 | 7.4 | 4.9 |
| S 3 X | 2.21 | 3.00 | 2.509 | 0.260 | 0.349 | S 75 X | 1 430 | 76 | 64 | 6.6 | 8.9 |
| 7.5 X 5.7 | 1.67 | 3.00 | 2.330 | 0.260 | 0.170 | 11.2 X 8.5 | 1 080 | 76 | 59 | 6.6 | 4.3 |

[A]Actual flange and web thicknesses vary due to mill rolling practices; however, permitted variations for such dimensions are not addressed.

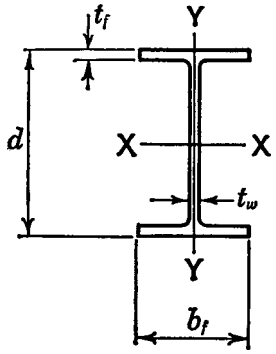
**TABLE A2.3 "M" Shapes**




| Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot) | Area *A*, in.$^2$ | Depth *d*, in. | Flange | | Web Thickness $t_w$, in.[A] | | Designation [Nominal Depth in Millimetres and Mass in Kilograms per Metre] | Area *A*, mm$^2$ | Depth *d*, mm | Flange | | Web Thickness $t_w$, mm[A] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Width $b_f$, in. | Thickness $t_w$, in.[A] | | | | | | Width $b_f$, mm | Thickness, $t_f$, mm[A] | |
| M 12.5X12.4 | 3.66 | 12.534 | 3.750 | 0.228 | 0.155 | | M318 X18.5 | 2 361 | 318 | 95 | 5.8 | 3.9 |
| X11.6 | 3.43 | 12.500 | 3.500 | 0.211 | 0.155 | | M318X17.3 | 2 213 | 317 | 89 | 5.4 | 3.9 |
| M 12 X11.8 | 3.47 | 12.00 | 3.065 | 0.225 | 0.177 | | M 310 X17.6 | 2 240 | 305 | 78 | 5.7 | 4.5 |
| X10.8 | 3.18 | 11.97 | 3.065 | 0.210 | 0.160 | | M 310 X16.1 | 2 050 | 304 | 78 | 5.3 | 4.1 |
| X10.0 | 2.94 | 11.97 | 3.250 | 0.180 | 0.149 | | M 310 X14.9 | 1 900 | 304 | 83 | 4.6 | 3.8 |
| M 10 X9.0 | 2.65 | 10.00 | 2.690 | 0.206 | 0.157 | | M 250 X13.4 | 1 710 | 254 | 68 | 4.6 | 3.6 |
| X8.0 | 2.35 | 9.95 | 2.690 | 0.182 | 0.141 | | M 250 X11.9 | 1 520 | 253 | 68 | 5.2 | 4.0 |
| M 10 X7.5 | 2.21 | 9.99 | 2.688 | 0.173 | 0.130 | | M 250 X11.2 | 1 430 | 253 | 68 | 4.4 | 3.3 |
| M 8 X6.5 | 1.92 | 8.00 | 2.281 | 0.189 | 0.135 | | M 200 X9.7 | 1 240 | 203 | 57 | 4.8 | 3.4 |
| X6.2 | 1.81 | 8.00 | 2.281 | 0.177 | 0.129 | | M 200 X9.2 | 1 170 | 203 | 58 | 4.5 | 3.3 |
| M 6 X4.4 | 1.29 | 6.00 | 1.844 | 0.171 | 0.114 | | M 150 X6.6 | 832 | 152 | 47 | 4.3 | 2.9 |
| X3.7 | 1.09 | 5.92 | 2.000 | 0.129 | 0.098 | | M 150 X5.5 | 703 | 150 | 51 | 3.3 | 2.5 |
| M 5 X18.9 | 5.55 | 5.00 | 5.003 | 0.416 | 0.316 | | M 130 X28.1 | 3 580 | 127 | 127 | 10.6 | 8.0 |
| M 4 X6.0 | 1.78 | 3.80 | 3.80 | 0.160 | 0.130 | | M 100 X8.9 | 1 150 | 97 | 97 | 4.1 | 3.3 |
| X 4.08 | 1.20 | 4.00 | 2.250 | 0.170 | 0.115 | | M 100 X 6.1 | 775 | 102 | 57 | 4.3 | 2.9 |
| X 3.45 | 1.029 | 4.00 | 2.250 | 0.130 | 0.092 | | M 100 X 5.1 | 665 | 102 | 57 | 3.3 | 2.8 |
| X 3.2 | 0.94 | 4.00 | 2.250 | 0.130 | 0.092 | | M 100 X 4.8 | 610 | 102 | 57 | 3.3 | 2.3 |
| M 3X 2.9 | 0.853 | 3.00 | 2.250 | 0.130 | 0.090 | | M 75 X 4.3 | 550 | 76 | 57 | 3.3 | 2.3 |

[A]Actual flange and web thicknesses vary due to mill rolling practices; however, permitted variations for such dimensions are not addressed.

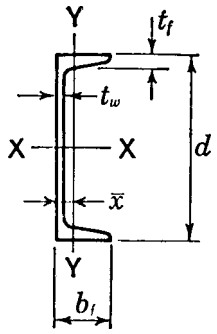
**TABLE A2.4 "HP" Shapes**




| Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot) | Area *A*, in.$^2$ | Depth *d*, in. | Flange | | Web Thickness *tw*, in.[A] | | Designation [Nominal Depth in Millimetres and Mass in Kilograms per Metre] | Area *A*, mm$^2$ | Depth *d*, mm | Flange | | Web Thickness $t_w$, mm[A] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Width $b_f$, in. | Thickness $t_f$, in.[A] | | | | | | Width $b_f$, mm | Thickness, $t_f$, mm[A] | |
| HP14 X 117 | 34.4 | 14.21 | 14.885 | 0.805 | 0.805 | | HP360 X 174 | 22 200 | 361 | 378 | 20.4 | 20.4 |
| X 102 | 30.0 | 14.01 | 14.785 | 0.705 | 0.705 | | X 152 | 19 400 | 356 | 376 | 17.9 | 17.9 |
| X 89 | 26.1 | 13.83 | 14.695 | 0.615 | 0.615 | | X 132 | 16 800 | 351 | 373 | 15.6 | 15.6 |
| X 73 | 21.4 | 13.61 | 14.585 | 0.505 | 0.505 | | X 108 | 13 800 | 346 | 370 | 12.8 | 12.8 |
| HP12 X 84 | 24.6 | 12.28 | 12.295 | 0.685 | 0.685 | | HP310 X 125 | 15 900 | 312 | 312 | 17.4 | 17.4 |
| X 74 | 21.8 | 12.13 | 12.215 | 0.610 | 0.605 | | X 110 | 14 100 | 308 | 310 | 15.5 | 15.4 |
| X 63 | 18.4 | 11.94 | 12.125 | 0.515 | 0.515 | | X 93 | 11 900 | 303 | 308 | 13.1 | 13.1 |
| X 53 | 15.5 | 11.78 | 12.045 | 0.435 | 0.435 | | X 79 | 10 000 | 299 | 306 | 11.0 | 11.0 |
| HP10 X 57 | 16.8 | 9.99 | 10.225 | 0.565 | 0.565 | | HP250X 85 | 10 800 | 254 | 260 | 14.4 | 14.4 |
| X 42 | 12.4 | 9.70 | 10.075 | 0.420 | 0.415 | | X 62 | 8 000 | 246 | 256 | 10.7 | 10.5 |
| HP8 X 36 | 10.6 | 8.02 | 8.155 | 0.445 | 0.445 | | HP200 X 53 | 6 840 | 204 | 207 | 11.3 | 11.3 |

[A]Actual flange and web thicknesses vary due to mill rolling practices; however, permitted variations for such dimensions are not addressed.

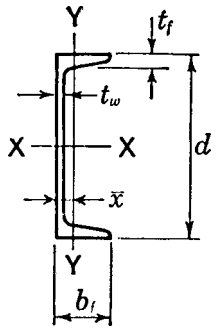
**TABLE A2.5 "C" Shapes**




| Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot) | Area $A$, in.$^2$ | Depth $d$, in. | Flange | | Web Thickness $tw$, in.[A] | | Designation [Nominal Depth in Millimetres in Mass in Kilograms per Metre] | Area $A$, mm$^2$ | Depth $d$, mm | Flange | | Web Thickness $t_w$, mm[A] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Width $b_f$, in. | Thickness $t_f$, in.[A] | | | | | | Width $b_f$, mm | Thickness $t_f$, mm[A] | |
| C 15 X 50 | 14.7 | 15.00 | 3.716 | 0.650 | 0.716 | | C 380 X 74 | 9 480 | 381 | 94 | 16.5 | 18.2 |
| X 40 | 11.8 | 15.00 | 3.520 | 0.650 | 0.520 | | X 60 | 7 610 | 381 | 89 | 16.5 | 13.2 |
| X 33.9 | 9.96 | 15.00 | 3.400 | 0.650 | 0.400 | | X 50.4 | 6 430 | 381 | 86 | 16.5 | 10.2 |
| C 12 X 30 | 8.82 | 12.00 | 3.170 | 0.501 | 0.510 | | C 310 X 45 | 5 690 | 305 | 80 | 12.7 | 13.0 |
| X 25 | 7.35 | 12.00 | 3.047 | 0.501 | 0.387 | | X 37 | 4 740 | 305 | 77 | 12.7 | 9.8 |
| X 20.7 | 6.09 | 12.00 | 2.942 | 0.501 | 0.282 | | X 30.8 | 3 930 | 305 | 74 | 12.7 | 7.2 |
| C 10 X 30 | 8.82 | 10.00 | 3.033 | 0.436 | 0.673 | | C 250 X 45 | 5 690 | 254 | 76 | 11.1 | 17.1 |
| X 25 | 7.35 | 10.00 | 2.886 | 0.436 | 0.526 | | X 37 | 4 740 | 254 | 73 | 11.1 | 13.4 |
| X 20 | 5.88 | 10.00 | 2.739 | 0.436 | 0.379 | | X 30 | 3 790 | 254 | 69 | 11.1 | 9.6 |
| X 15.3 | 4.49 | 10.00 | 2.600 | 0.436 | 0.240 | | X 22.8 | 2 900 | 254 | 65 | 11.1 | 6.1 |
| C 9 X 20 | 5.88 | 9.00 | 2.648 | 0.413 | 0.448 | | C 230 X 30 | 3 790 | 229 | 67 | 10.5 | 11.4 |
| X 15 | 4.41 | 9.00 | 2.485 | 0.413 | 0.285 | | X 22 | 2 850 | 229 | 63 | 10.5 | 7.2 |
| X 13.4 | 3.94 | 9.00 | 2.433 | 0.413 | 0.233 | | X 19.9 | 2 540 | 229 | 61 | 10.5 | 5.9 |
| C 8 X 18.5 | 5.51 | 8.00 | 2.527 | 0.390 | 0.487 | | C 200 X 27.9 | 3 550 | 203 | 64 | 9.9 | 12.4 |
| X 13.7 | 4.04 | 8.00 | 2.343 | 0.390 | 0.303 | | X 20.5 | 2 610 | 203 | 59 | 9.9 | 7.7 |
| X 11.5 | 3.38 | 8.00 | 2.260 | 0.390 | 0.220 | | X 17.1 | 2 180 | 203 | 57 | 9.9 | 5.6 |
| C 7 X 14.7 | 4.33 | 7.00 | 2.299 | 0.366 | 0.419 | | C 180 X 22 | 2 790 | 178 | 58 | 9.3 | 10.6 |
| X 12.2 | 3.60 | 7.00 | 2.194 | 0.366 | 0.314 | | X 18.2 | 2 320 | 178 | 55 | 9.3 | 8.0 |
| X 9.8 | 2.87 | 7.00 | 2.090 | 0.366 | 0.210 | | X 14.6 | 1 850 | 178 | 53 | 9.3 | 5.3 |
| C 6 X 13 | 3.83 | 6.00 | 2.157 | 0.343 | 0.437 | | C 150 X 19.3 | 2 470 | 152 | 54 | 8.7 | 11.1 |
| X 10.5 | 3.09 | 6.00 | 2.034 | 0.343 | 0.314 | | X 15.6 | 1 990 | 152 | 51 | 8.7 | 8.0 |
| X 8.2 | 2.40 | 6.00 | 1.920 | 0.343 | 0.200 | | X 12.2 | 1 550 | 152 | 48 | 8.7 | 5.1 |
| C 5 X 9 | 2.64 | 5.00 | 1.885 | 0.320 | 0.325 | | C 130 X 13 | 1 700 | 127 | 47 | 8.1 | 8.3 |
| X 6.7 | 1.97 | 5.00 | 1.750 | 0.320 | 0.190 | | X 10.4 | 1 270 | 127 | 44 | 8.1 | 4.8 |
| C 4 X 7.2 | 2.13 | 4.00 | 1.721 | 0.296 | 0.321 | | C 100 X 10.8 | 1 370 | 102 | 43 | 7.5 | 8.2 |
| X 5.4 | 1.59 | 4.00 | 1.584 | 0.296 | 0.184 | | X 8 | 1 030 | 102 | 40 | 7.5 | 4.7 |
| X 4.5 | 1.32 | 4.00 | 1.584 | 0.296 | 0.125 | | X 6.7 | 852 | 102 | 40 | 7.5 | 3.2 |
| C 3 X 6 | 1.76 | 3.00 | 1.596 | 0.273 | 0.356 | | C 75 X 8.9 | 1 130 | 76 | 40 | 6.9 | 9.0 |
| X 5 | 1.47 | 3.00 | 1.498 | 0.273 | 0.258 | | X 7.4 | 948 | 76 | 37 | 6.9 | 6.6 |
| X 4.1 | 1.21 | 3.00 | 1.410 | 0.273 | 0.170 | | X 6.1 | 781 | 76 | 35 | 6.9 | 4.3 |
| X 3.5 | 1.03 | 3.00 | 1.372 | 0.273 | 0.132 | | X 5.2 | 665 | 76 | 35 | 6.9 | 3.4 |

[A]Actual flange and web thicknesses vary due to mill rolling practices; however, permitted variations for such dimensions are not addressed.

**TABLE A2.6 "MC" Shapes**

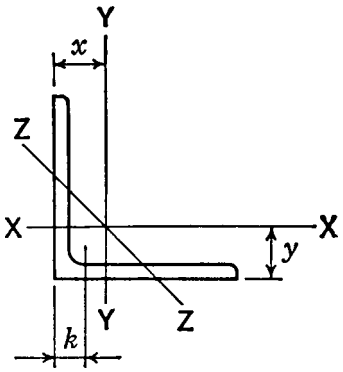



| Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot) | Area *A*, in.$^2$ | Depth *d*, in. | Flange | | Web Thickness *tw*, in.[A] | Designation [Nominal Depth in Millimetres and Mass in Kilograms per Metre] | Area *A*, mm$^2$ | Depth *d*, mm | Flange | | Web Thickness $t_w$, mm[A] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Width $b_f$, in. | Thickness $t_f$, in.[A] | | | | | Width $b_f$, mm | Thickness $t_f$, mm | |
| MC 18 X 58 | 17.1 | 18.00 | 4.200 | 0.625 | 0.700 | MC 460 X 86 | 11 000 | 457 | 107 | 15.9 | 17.8 |
| X 51.9 | 15.3 | 18.00 | 4.100 | 0.625 | 0.600 | X 77.2 | 9 870 | 457 | 104 | 15.9 | 15.2 |
| X 45.8 | 13.5 | 18.00 | 4.000 | 0.625 | 0.500 | X 68.2 | 8 710 | 457 | 102 | 15.9 | 12.7 |
| X 42.7 | 12.6 | 18.00 | 3.950 | 0.625 | 0.450 | X 63.5 | 8 130 | 457 | 100 | 15.9 | 11.4 |
| MC 13 X 50 | 14.7 | 13.00 | 4.412 | 0.610 | 0.787 | MC 330 X 74 | 9 480 | 330 | 112 | 15.5 | 20.0 |
| X 40 | 11.8 | 13.00 | 4.185 | 0.610 | 0.560 | X 60 | 7 610 | 330 | 106 | 15.5 | 14.2 |
| X 35 | 10.3 | 13.00 | 4.072 | 0.610 | 0.447 | X 52 | 6 640 | 330 | 103 | 15.5 | 11.4 |
| X 31.8 | 9.35 | 13.00 | 4.000 | 0.610 | 0.375 | X 47.3 | 6 030 | 330 | 102 | 15.5 | 9.5 |
| MC 12 X 50 | 14.7 | 12.00 | 4.135 | 0.700 | 0.835 | MC 310 X 74 | 9 480 | 305 | 105 | 17.8 | 21.2 |
| X 45 | 13.2 | 12.00 | 4.010 | 0.700 | 0.710 | X 67 | 8 502 | 305 | 102 | 17.8 | 18.0 |
| X 40 | 11.8 | 12.00 | 3.890 | 0.700 | 0.590 | X 60 | 7 610 | 305 | 98 | 17.8 | 15.0 |
| X 35 | 10.3 | 12.00 | 3.765 | 0.700 | 0.465 | X 52 | 6 620 | 305 | 96 | 17.8 | 11.8 |
| X 31 | 9.12 | 12.00 | 3.670 | 0.700 | 0.370 | X 46 | 5 890 | 305 | 93 | 17.8 | 9.4 |
| MC 12 X 10.6 | 3.10 | 12.00 | 1.500 | 0.309 | 0.190 | MC 310 X 15.8 | 2 000 | 305 | 38 | 7.8 | 4.8 |
| MC 10 X 41.1 | 12.1 | 10.00 | 4.321 | 0.575 | 0.796 | MC 250 X 61.2 | 7 810 | 254 | 110 | 14.6 | 20.2 |
| X 33.6 | 9.87 | 10.00 | 4.100 | 0.575 | 0.575 | X 50 | 6 370 | 254 | 104 | 14.6 | 14.6 |
| X 28.5 | 8.37 | 10.00 | 3.950 | 0.575 | 0.425 | X 42.4 | 5 400 | 254 | 100 | 14.6 | 10.8 |
| MC 10 X 25 | 7.35 | 10.00 | 3.405 | 0.575 | 0.380 | MC 250 X 37 | 4 740 | 254 | 86 | 14.6 | 9.7 |
| X 22 | 6.45 | 10.00 | 3.315 | 0.575 | 0.290 | X 33 | 4 160 | 254 | 84 | 14.6 | 7.4 |
| MC 10 X 8.4 | 2.46 | 10.00 | 1.500 | 0.280 | 0.170 | MC 250 X 12.5 | 1 590 | 254 | 38 | 7.1 | 4.3 |
| X 6.5 | 1.91 | 10.00 | 1.17 | 0.202 | 0.152 | X 9.7 | 1 240 | 254 | 28 | 5.1 | 3.9 |
| MC 9 X 25.4 | 7.47 | 9.00 | 3.500 | 0.550 | 0.450 | MC 230 X 37.8 | 4 820 | 229 | 88 | 14.0 | 11.4 |
| X 23.9 | 7.02 | 9.00 | 3.450 | 0.550 | 0.400 | X 35.6 | 4 530 | 229 | 87 | 14.0 | 10.2 |
| MC 8 X 22.8 | 6.70 | 8.00 | 3.502 | 0.525 | 0.427 | MC 200 X 33.9 | 4 320 | 203 | 88 | 13.3 | 10.8 |
| X 21.4 | 6.28 | 8.00 | 3.450 | 0.525 | 0.375 | X 31.8 | 4 050 | 203 | 87 | 13.3 | 9.5 |
| MC 8 X 20 | 5.88 | 8.00 | 3.025 | 0.500 | 0.400 | MC 200 X 29.8 | 3 790 | 203 | 76 | 12.7 | 10.2 |
| X 18.7 | 5.50 | 8.00 | 2.978 | 0.500 | 0.353 | X 27.8 | 3 550 | 203 | 75 | 12.7 | 9.0 |
| MC 8 X 8.5 | 2.50 | 8.00 | 1.874 | 0.311 | 0.179 | MC 200 X 12.6 | 1 610 | 203 | 47 | 7.9 | 4.5 |
| MC 7 X 22.7 | 6.67 | 7.00 | 3.603 | 0.500 | 0.503 | MC 180 X 33.8 | 4 300 | 178 | 91 | 12.7 | 12.8 |
| X 19.1 | 5.61 | 7.00 | 3.452 | 0.500 | 0.352 | X 28.4 | 3 620 | 178 | 87 | 12.7 | 8.9 |
| MC 6 X 18 | 5.29 | 6.00 | 3.504 | 0.475 | 0.379 | MC 150 X 26.8 | 3 410 | 152 | 88 | 12.1 | 9.6 |
| X 15.3 | 4.50 | 6.00 | 3.500 | 0.385 | 0.340 | X 22.8 | 2 900 | 152 | 88 | 9.8 | 8.6 |
| MC 6 X 16.3 | 4.79 | 6.00 | 3.000 | 0.475 | 0.375 | MC 150 X 24.3 | 3 090 | 152 | 76 | 12.1 | 9.5 |
| X 15.1 | 4.44 | 6.00 | 2.941 | 0.475 | 0.316 | X 22.5 | 2 860 | 152 | 74 | 12.1 | 8.0 |
| MC 6 X 12 | 3.53 | 6.00 | 2.497 | 0.375 | 0.310 | MC 150 X 17.9 | 2 280 | 152 | 63 | 9.5 | 7.9 |

**TABLE A2.6** *Continued*

| Designation (Nominal Depth in Inches and Weight in Pounds per Linear Foot) | Area *A*, in.$^2$ | Depth *d*, in. | Flange | | Web Thickness *tw*, in.[A] | | Designation [Nominal Depth in Millimetres and Mass in Kilograms per Metre] | Area *A*, mm$^2$ | Depth *d*, mm | Flange | | Web Thickness $t_w$, mm[A] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Width $b_f$, in. | Thickness $t_f$, in.[A] | | | | | | Width $b_f$, mm | Thickness $t_f$, mm | |
| MC 6 X 7.0<br>X6.5 | 2.07<br>1.93 | 6.00<br>6.00 | 1.875<br>1.850 | 0.291<br>0.291 | 0.179<br>0.155 | | MC 150 X 10.4<br>X 9.7 | 1 341<br>1 250 | 152<br>152 | 48<br>47 | 7.4<br>7.4 | 4.5<br>3.9 |
| MC 4 X 13.8 | 4.02 | 4.00 | 2.500 | 0.500 | 0.500 | | MC 100 X20.5 | 2 594 | 102 | 64 | 13 | 13 |
| MC 3 x 7.1 | 2.09 | 3.00 | 1.938 | 0.351 | 0.312 | | MC 75 X 10.6 | 1 348 | 76 | 49 | 8.9 | 7.9 |

**TABLE A2.7 "L" Shapes (Equal Legs)**

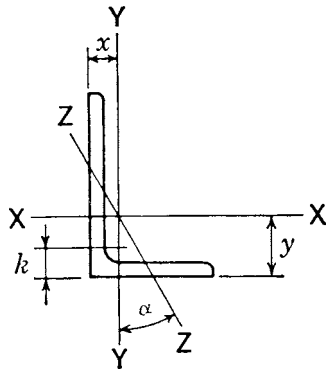



| Size and Thickness, in. | Weight per Foot, lb | Area, in.$^2$ | Size and Thickness, mm | Mass per Metre, kg | Area, mm$^2$ |
|---|---|---|---|---|---|
| L8 × 8 × 1⅛ | 56.9 | 16.7 | L203 × 203 × 28.6 | 84.7 | 10 800 |
| L8 × 8 × 1 | 51.0 | 15.0 | L203 × 203 × 25.4 | 75.9 | 9 680 |
| L8 × 8 × ⅞ | 45.0 | 13.2 | L203 × 203 × 22.2 | 67.0 | 8 500 |
| L8 × 8 × ¾ | 38.9 | 11.4 | L203 × 203 × 19.0 | 57.9 | 7 360 |
| L8 × 8 × ⅝ | 32.7 | 9.61 | L203 × 203 × 15.9 | 48.7 | 6 200 |
| L8 × 8 × 9/16 | 29.6 | 8.68 | L203 × 203 × 14.3 | 44.0 | 5 600 |
| L8 × 8 × ½ | 26.4 | 7.75 | L203 × 203 × 12.7 | 39.3 | 5 000 |
| L6 × 6 × 1 | 37.4 | 11.0 | L152 × 152 × 25.4 | 55.7 | 7 100 |
| L6 × 6 × ⅞ | 33.1 | 9.73 | L152 × 152 × 22.2 | 49.3 | 6 280 |
| L6 × 6 × ¾ | 28.7 | 8.44 | L152 × 152 × 19.0 | 42.7 | 5 450 |
| L6 × 6 × ⅝ | 24.2 | 7.11 | L152 × 152 × 15.9 | 36.0 | 4 590 |
| L6 × 6 × 9/16 | 21.9 | 6.43 | L152 × 152 × 14.3 | 32.6 | 4 150 |
| L6 × 6 × ½ | 19.6 | 5.75 | L152 × 152 × 12.7 | 29.2 | 3 710 |
| L6 × 6 × 7/16 | 17.2 | 5.06 | L152 × 152 × 11.1 | 25.6 | 3 270 |
| L6 × 6 × ⅜ | 14.9 | 4.36 | L152 × 152 × 9.5 | 22.2 | 2 810 |
| L6 × 6 × 5/16 | 12.4 | 3.65 | L152 × 152 × 7.9 | 18.5 | 2 360 |
| L5 × 5 × ⅞ | 27.2 | 7.98 | L127 × 127 × 22.2 | 40.5 | 5 150 |
| L5 × 5 × ¾ | 23.6 | 6.94 | L127 × 127 × 19.0 | 35.1 | 4 480 |
| L5 × 5 × ⅝ | 20.0 | 5.86 | L127 × 127 × 15.9 | 29.8 | 3 780 |
| L5 × 5 × ½ | 16.2 | 4.75 | L127 × 127 × 12.7 | 24.1 | 3 070 |
| L5 × 5 × 7/16 | 14.3 | 4.18 | L127 × 127 × 11.1 | 21.3 | 2 700 |
| L5 × 5 × ⅜ | 12.3 | 3.61 | L127 × 127 × 9.5 | 18.3 | 2 330 |
| L5 × 5 × 5/16 | 10.3 | 3.03 | L127 × 127 × 7.9 | 15.3 | 1 960 |
| L4 × 4 × ¾ | 18.5 | 5.44 | L102 × 102 × 19.0 | 27.5 | 3 510 |
| L4 × 4 × ⅝ | 15.7 | 4.61 | L102 × 102 × 15.9 | 23.4 | 2 970 |
| L4 × 4 × ½ | 12.8 | 3.75 | L102 × 102 × 12.7 | 19.0 | 2 420 |
| L4 × 4 × 7/16 | 11.3 | 3.31 | L102 × 102 × 11.1 | 16.8 | 2 140 |
| L4 × 4 × ⅜ | 9.80 | 2.86 | L102 × 102 × 9.5 | 14.6 | 1 850 |
| L4 × 4 × 5/16 | 8.20 | 2.40 | L102 × 102 × 7.9 | 12.2 | 1 550 |
| L4 × 4 × ¼ | 6.60 | 1.94 | L102 × 102 × 6.4 | 9.8 | 1 250 |
| L3½ × 3½ × ½ | 11.1 | 3.25 | L89 × 89 × 12.7 | 16.5 | 2 100 |
| L3½ × 3½ × 7/16 | 9.80 | 2.87 | L89 × 89 × 11.1 | 14.6 | 1 850 |
| L3½ × 3½ × ⅜ | 8.50 | 2.48 | L89 × 89 × 9.5 | 12.6 | 1 600 |
| L3½ × 3½ × 5/16 | 7.20 | 2.09 | L89 × 89 × 7.9 | 10.7 | 1 350 |
| L3½ × 3½ × ¼ | 5.80 | 1.69 | L89 × 89 × 6.4 | 8.6 | 1 090 |
| L3 × 3 × ½ | 9.40 | 2.75 | L76 × 76 × 12.7 | 14.0 | 1 770 |
| L3 × 3 × 7/16 | 8.30 | 2.43 | L76 × 76 × 11.1 | 12.4 | 1 570 |
| L3 × 3 × ⅜ | 7.20 | 2.11 | L76 × 76 × 9.5 | 10.7 | 1 360 |
| L3 × 3 × 5/16 | 6.10 | 1.78 | L76 × 76 × 7.9 | 9.1 | 1 150 |
| L3 × 3 × ¼ | 4.90 | 1.44 | L76 × 76 × 6.4 | 7.3 | 929 |
| L3 × 3 × 3/16 | 3.71 | 1.09 | L76 × 76 × 4.8 | 5.5 | 703 |
| L2½ × 2½ × ½ | 7.70 | 2.25 | L64 × 64 × 12.7 | 11.4 | 1 450 |
| L2½ × 2½ × ⅜ | 5.90 | 1.73 | L64 × 64 × 9.5 | 8.7 | 1 120 |
| L2½ × 2½ × 5/16 | 5.00 | 1.46 | L64 × 64 × 7.9 | 7.4 | 942 |
| L2½ × 2½ × ¼ | 4.10 | 1.19 | L64 × 64 × 6.4 | 6.1 | 768 |
| L2½ × 2½ × 3/16 | 3.07 | 0.90 | L64 × 64 × 4.8 | 4.6 | 581 |

**TABLE A2.7** *Continued*

| Size and Thickness, in. | Weight per Foot, lb | Area, in.$^2$ | Size and Thickness, mm | Mass per Metre, kg | Area, mm$^2$ |
|---|---|---|---|---|---|
| L2 × 2 × 3/8 | 4.70 | 1.36 | L51 × 51 × 9.5 | 7.0 | 877 |
| L2 × 2 × 5/16 | 3.92 | 1.15 | L51 × 51 × 7.9 | 5.8 | 742 |
| L2 × 2 × 1/4 | 3.19 | 0.938 | L51 × 51 × 6.4 | 4.7 | 605 |
| L2 × 2 × 3/16 | 2.44 | 0.715 | L51 × 51 × 4.8 | 3.6 | 461 |
| L2 × 2 × 1/8 | 1.65 | 0.484 | L51 × 51 × 3.2 | 2.4 | 312 |
| L1 3/4 × 1 3/4 × 1/4 | 2.77 | 0.813 | L44 × 44 × 6.4 | 4.1 | 525 |
| L1 3/4 × 1 3/4 × 3/16 | 2.12 | 0.621 | L44 × 44 × 4.8 | 3.1 | 401 |
| L1 3/4 × 1 3/4 × 1/8 | 1.44 | 0.422 | L44 × 44 × 3.2 | 2.1 | 272 |
| L1 1/2 × 1 1/2 × 1/4 | 2.34 | 0.688 | L38 × 38 × 6.4 | 3.4 | 444 |
| L1 1/2 × 1 1/2 × 3/16 | 1.80 | 0.527 | L38 × 38 × 4.8 | 2.7 | 340 |
| L1 1/2 × 1 1/2 × 5/32 | 1.52 | 0.444 | L38 × 38 × 4.0 | 2.2 | 286 |
| L1 1/2 × 1 1/2 × 1/8 | 1.23 | 0.359 | L38 × 38 × 3.2 | 1.8 | 232 |
| L1 1/4 × 1 1/4 × 1/4 | 1.92 | 0.563 | L32 × 32 × 6.4 | 2.8 | 363 |
| L1 1/4 × 1 1/4 × 3/16 | 1.48 | 0.434 | L32 × 32 × 4.8 | 2.2 | 280 |
| L1 1/4 × 1 1/4 × 1/8 | 1.01 | 0.297 | L32 × 32 × 3.2 | 1.5 | 192 |
| L1 × 1 × 1/4 | 1.49 | 0.438 | L25 × 25 × 6.4 | 2.2 | 283 |
| L1 × 1 × 3/16 | 1.16 | 0.340 | L25 × 25 × 4.8 | 1.8 | 219 |
| L1 × 1 × 1/8 | 0.80 | 0.234 | L25 × 25 × 3.2 | 1.2 | 151 |
| L3/4 × 3/4 × 1/8 | 0.59 | 0.172 | L19 × 19 × 3.2 | 0.9 | 111 |

**TABLE A2.8 “L” Shapes (Unequal Legs)**




| Size and Thickness, in. | Weight per Foot, lb | Area, in.$^2$ | Size and Thickness, mm | Mass per Metre, kg | Area, mm$^2$ |
|---|---|---|---|---|---|
| L8 × 6 × 1 | 44.2 | 13.0 | L203 × 152 × 25.4 | 65.5 | 8 390 |
| L8 × 6 × ⅞ | 39.1 | 11.5 | L203 × 152 × 22.2 | 57.9 | 7 420 |
| L8 × 6 × ¾ | 33.8 | 9.94 | L203 × 152 × 19.0 | 50.1 | 6 410 |
| L8 × 6 × ⅝ | 28.5 | 8.36 | L203 × 152 × 15.9 | 42.2 | 5 390 |
| L8 × 6 × 9⁄16 | 25.7 | 7.56 | L203 × 152 × 14.3 | 38.1 | 4 880 |
| L8 × 6 × ½ | 23.0 | 6.75 | L203 × 152 × 12.7 | 34.1 | 4 350 |
| L8 × 6 × 7⁄16 | 20.2 | 5.93 | L203 × 152 × 11.1 | 29.9 | 3 830 |
| L8 × 4 × 1 | 37.4 | 11.0 | L203 × 102 × 25.4 | 55.4 | 7 100 |
| L8 × 4 × ⅞ | 33.1 | 9.73 | L203 × 102 × 22.2 | 49.3 | 6 280 |
| L8 × 4 × ¾ | 28.7 | 8.44 | L203 × 102 × 19.0 | 42.5 | 5 450 |
| L8 × 4 × ⅝ | 24.2 | 7.11 | L203 × 102 × 15.9 | 36.0 | 4 590 |
| L8 × 4 × 9⁄16 | 21.9 | 6.43 | L203 × 102 × 14.3 | 32.4 | 4 150 |
| L8 × 4 × ½ | 19.6 | 5.75 | L203 × 102 × 12.7 | 29.0 | 3 710 |
| L8 × 4 × 7⁄16 | 17.2 | 5.06 | L203 × 102 × 11.1 | 25.6 | 3 260 |
| L7 × 4 × ¾ | 26.2 | 7.69 | L178 × 102 × 19.0 | 38.8 | 4 960 |
| L7 × 4 × ⅝ | 22.1 | 6.48 | L178 × 102 × 15.9 | 32.7 | 4 180 |
| L7 × 4 × ½ | 17.9 | 5.25 | L178 × 102 × 12.7 | 26.5 | 3 390 |
| L7 × 4 × 7⁄16 | 15.7 | 4.62 | L178 × 102 × 11.1 | 23.4 | 2 980 |
| L7 × 4 × ⅜ | 13.6 | 3.98 | L178 × 102 × 9.5 | 20.2 | 2 570 |
| L6 × 4 × ⅞ | 27.2 | 7.98 | L152 × 102 × 22.2 | 40.3 | 5 150 |
| L6× 4 × ¾ | 23.6 | 6.94 | L152 × 102 × 19.0 | 35.0 | 4 480 |
| L6 × 4 × ⅝ | 20.0 | 5.86 | L152 × 102 × 15.9 | 29.6 | 3 780 |
| L6 × 4 × 9⁄16 | 18.1 | 5.31 | L152 × 102 ×14.3 | 26.8 | 3 430 |
| L6 × 4 × ½ | 16.2 | 4.75 | L152 × 102 × 12.7 | 24.0 | 3 060 |
| L6 × 4 × 7⁄16 | 14.3 | 4.18 | L152 × 102 × 11.1 | 21.2 | 2 700 |
| L6 × 4 × ⅜ | 12.3 | 3.61 | L152 × 102 × 9.5 | 18.2 | 2 330 |
| L6 × 4 × 5⁄16 | 10.3 | 3.03 | L152 × 102 × 7.9 | 15.3 | 1 950 |
| L6 × 3½ × ½ | 15.3 | 4.50 | L152 × 89 × 12.7 | 22.7 | 2 900 |
| L6 × 3 ½ × ⅜ | 11.7 | 3.42 | L152 × 89 × 9.5 | 17.3 | 2 210 |
| L6 × 3½ × 5⁄16 | 9.80 | 2.87 | L152 × 89 × 7.9 | 14.5 | 1 850 |
| L5 × 3½ × ¾ | 19.8 | 5.81 | L127 × 89 × 19.0 | 29.3 | 3 750 |
| L5 × 3½ × ⅝ | 16.8 | 4.92 | L127 × 89 × 15.9 | 24.9 | 3 170 |
| L5 × 3½ × ½ | 13.6 | 4.00 | L127 × 89 × 12.7 | 20.2 | 2 580 |
| L5 × 3½ × ⅜ | 10.4 | 3.05 | L127 × 89 × 9.5 | 15.4 | 1 970 |
| L5 × 3½ × 5⁄16 | 8.70 | 2.56 | L127 × 89 × 7.9 | 12.9 | 1 650 |
| L5 × 3½ × ¼ | 7.00 | 2.06 | L127 × 89 × 6.4 | 10.4 | 1 330 |
| L5 × 3 × ½ | 12.8 | 3.75 | L127 × 76 × 12.7 | 19.0 | 2 420 |
| L5 × 3 × 7⁄16 | 11.3 | 3.31 | L127 × 76 × 11.1 | 16.7 | 2 140 |
| L5 × 3 × ⅜ | 9.80 | 2.86 | L127 × 76 × 9.5 | 14.5 | 1 850 |
| L5 × 3 × 5⁄16 | 8.20 | 2.40 | L127 × 76 × 7.9 | 12.1 | 1 550 |
| L5 × 3 × ¼ | 6.60 | 1.94 | L127 × 76 × 6.4 | 9.8 | 1 250 |
| L4 × 3½ × ½ | 11.9 | 3.50 | L102 × 89 × 12.7 | 17.6 | 2 260 |
| L4 × 3½ × ⅜ | 9.10 | 2.67 | L102 × 89 × 9.5 | 13.5 | 1 720 |
| L4 × 3½ × 5⁄16 | 7.70 | 2.25 | L102 × 89 × 7.9 | 11.4 | 1 450 |
| L4 × 3½ × ¼ | 6.20 | 1.81 | L102 × 89 × 6.4 | 9.2 | 1 170 |

**TABLE A2.8** *Continued*

| Size and Thickness, in. | Weight per Foot, lb | Area, in.$^2$ | Size and Thickness, mm | Mass per Metre, kg | Area, mm$^2$ |
|---|---|---|---|---|---|
| L4 × 3 × 5/8 | 13.6 | 3.98 | L102 × 76 × 15.9 | 20.2 | 2 570 |
| L4 × 3 × 1/2 | 11.1 | 3.25 | L102 × 76 × 12.7 | 16.4 | 2 100 |
| L4 × 3 × 3/8 | 8.50 | 2.48 | L102 × 76 × 9.5 | 12.6 | 1 600 |
| L4 × 3 × 5/16 | 7.20 | 2.09 | L102 × 76 × 7.9 | 10.7 | 1 350 |
| L4 × 3 × 1/4 | 5.80 | 1.69 | L102 × 76 × 6.4 | 8.6 | 1 090 |
| L3½ × 3 × 1/2 | 10.2 | 3.00 | L89 × 76 × 12.7 | 15.1 | 1 940 |
| L3½ × 3 × 7/16 | 9.10 | 2.65 | L89 × 76 × 11.1 | 13.5 | 1 710 |
| L3½ × 3 × 3/8 | 7.90 | 2.30 | L89 × 76 × 9.5 | 11.7 | 1 480 |
| L3½ × 3 × 5/16 | 6.60 | 1.93 | L89 × 76 × 7.9 | 9.8 | 1 250 |
| L3½ × 3 × 1/4 | 5.40 | 1.56 | L89 × 76 × 6.4 | 8.0 | 1 010 |
| L3½ × 2½ × 1/2 | 9.40 | 2.75 | L89 × 64 × 12.7 | 13.9 | 1 770 |
| L3½ × 2½ × 3/8 | 7.20 | 2.11 | L89 × 64 × 9.5 | 10.7 | 1 360 |
| L3½ × 2½ × 5/16 | 6.10 | 1.78 | L89 × 64 × 7.9 | 9.0 | 1 150 |
| L3½ × 2½ × 1/4 | 4.90 | 1.44 | L89 × 64 × 6.4 | 7.3 | 929 |
| L3 × 2½ × 1/2 | 8.50 | 2.50 | L76 × 64 × 12.7 | 12.6 | 1 610 |
| L3 × 2½ × 7/16 | 7.60 | 2.21 | L76 × 64 × 11.1 | 11.3 | 1 430 |
| L3 × 2½ × 3/8 | 6.60 | 1.92 | L76 × 64 × 9.5 | 9.8 | 1 240 |
| L3 × 2½ × 5/16 | 5.60 | 1.62 | L76 × 64 × 7.9 | 8.3 | 1 050 |
| L3 × 2½ × 1/4 | 4.50 | 1.31 | L76 × 64 × 6.4 | 6.7 | 845 |
| L3 × 2½ × 3/16 | 3.39 | 0.996 | L76 × 64 × 4.8 | 5.1 | 643 |
| L3 × 2 × 1/2 | 7.70 | 2.25 | L76 × 51 × 12.7 | 11.5 | 1 450 |
| L3 × 2 × 3/8 | 5.90 | 1.73 | L76 × 51 × 9.5 | 8.8 | 1 120 |
| L3 × 2 × 5/16 | 5.00 | 1.46 | L76 × 51 × 7.9 | 7.4 | 942 |
| L3 × 2 × 1/4 | 4.10 | 1.19 | L76 × 51 × 6.4 | 6.1 | 768 |
| L3 × 2 × 3/16 | 3.07 | 0.902 | L76 × 51 × 4.8 | 4.6 | 582 |
| L2½ × 2 × 3/8 | 5.30 | 1.55 | L64 × 51 × 9.5 | 7.9 | 1 000 |
| L2½ × 2 × 5/16 | 4.50 | 1.31 | L64 × 51 × 7.9 | 6.7 | 845 |
| L2½ × 2 × 1/4 | 3.62 | 1.06 | L64 × 51 × 6.4 | 5.4 | 684 |
| L2½ × 2 × 3/16 | 2.75 | 0.809 | L64 × 51 × 4.8 | 4.2 | 522 |
| L2½ × 1½ × 1/4 | 3.19 | 0.938 | L64 × 38 × 6.4 | 4.8 | 605 |
| L2½ × 1½ × 3/16 | 2.44 | 0.715 | L64 × 38 × 4.8 | 3.6 | 461 |
| L2 × 1½ × 1/4 | 2.77 | 0.813 | L51 × 38 × 6.4 | 4.2 | 525 |
| L2 × 1½ × 3/16 | 2.12 | 0.621 | L51 × 38 × 4.8 | 3.1 | 401 |
| L2 × 1½ × 1/8 | 1.44 | 0.422 | L51 × 38 × 3.2 | 2.1 | 272 |

## APPENDIXES

**(Nonmandatory Information)**

### X1. COIL AS A SOURCE OF STRUCTURAL PRODUCTS

X1.1 Continuous wide hot strip rolling mills are normally equipped with coilers. Regardless of the different types of systems employed during or following the rolling operations, it is common for the steel to be reeled into the coiler at temperatures in the stress-relieving range. In general, such temperatures are higher as the steel thickness increases. The coils subsequently cool to ambient temperature with outer and inner laps cooling more rapidly than central laps. The difference in cooling rate can result in measurable differences in the mechanical properties throughout a coil. Data confirm reduced yield and tensile strength with increased percent elongation for the steel with slower cooling rates from the coiling temperature to ambient. Such differences are in addition to the effects on mechanical properties caused by differences in heat analysis and chemical segregation.

## X2. VARIATION OF TENSILE PROPERTIES IN PLATES AND SHAPES

X2.1 The tension testing requirements of Specification A 6/A 6M are intended only to characterize the tensile properties of a heat of steel for determination of conformance to the requirements of the applicable product specification. Such testing procedures are not intended to define the upper or lower limits of tensile properties at all possible test locations within a heat of steel. It is well known and documented that tensile properties will vary within a heat or individual piece of steel as a function of chemical composition, processing, testing procedure and other factors. It is, therefore, incumbent on designers and engineers to use sound engineering judgement when using tension test results shown on mill test reports. The testing procedures of Specification A 6/A 6M have been found to provide structural products adequate for normal structural design criteria.

X2.2 A survey of the variation to be expected in tensile properties obtained from plates and structural shapes was conducted by the American Iron and Steel Institute (AISI).[7] The results of this survey are contained in a *Contributions to the Metallurgy of Steel*entitled "The Variation of Product Analysis and Tensile Properties—Carbon Steel Plates and Wide Flange Shapes" (SU/18, SU/19 and SU/20), published in September 1974. The data are presented in tables of probability that tensile properties at other than the official location may differ from those of the reported test location. Another survey sponsored by the AISI entitled "Statistical Analysis of Structural Plate Mechanical Properties" was published in January 2003. That survey analyzed the results of variability testing on more modern as-rolled steels that were generally of higher minimum yield strength steels and also compared those results statistically to the previous surveys.[8]

X2.3 Specification A 6/A 6M contains no requirements applicable to product tension tests; conformance to the applicable product specification is determined on the basis of tests performed at the place of manufacture or processing prior to shipment, unless otherwise specified.

X2.4 A Task Group of ASTM Subcommittee A01.02 has determined, based on review of the earlier AISI data,[7] that the variation in tensile properties of plates and structural shapes can be expressed as a function of specified requirements: one standard deviation equals approximately 4 % of required tensile strength, 8 % of required yield strength, and 3 percentage points of required elongation. The January 2003 survey resulted in similar findings.

X2.5 Acceptance criteria for product testing based upon these values, either below the minimum or above the maximum allowed by the applicable product specification, are generally acceptable to manufacturers. Such tolerances could be considered by users of structural products as a reasonable basis for acceptance of structural products that, due to their inherent variability, deviate from the applicable product specification requirements when subjected to product tension testing.

[7] Originally published by the American Iron and Steel Institute, 1133 15th St., N.W., Washington, DC 20005. Available from ASTM Headquarters as PCN: 29-000390-02.

[8] Available from AISI directly at http://www.steel.org/infrastructure/bridges/index.html.

## X3. WELDABILITY OF STEEL

X3.1 *Weldability* is a term that usually refers to the relative ease with which a metal can be welded using conventional practice. Difficulties arise in steel when the cooling rates associated with weld thermal cycles produce microstructures (for example, martensite) that are susceptible to brittle fracture or, more commonly, hydrogen-induced (or cold) cracking.[9] (Solidification or hot cracking is a relatively rare phenomenon that will not be addressed here. See Randall[10] for further information.)

X3.2 The relative sensitivity of steels to forming cold cracking microstructures is called hardenability and can be measured in a number of ways. Perhaps the most popular method of assessing this is by the carbon equivalent (CE) formula, which attempts to equate the relative hardening contributions of a steel's constituent elements (for example, manganese, vanadium) to an equivalent amount of carbon, which is the most significant hardening agent. The most popular formula is the IIW (International Institute of Welding) equation presented in S31.2, which has been found suitable for predicting hardenability in a wide range of commonly used carbon-manganese and low alloy steels.[11]

X3.3 It should be noted, however, that for the current generation of low carbon (<0.10 %) low alloy steels that derive strength from a combination of microalloys and thermal processing methods the use of other formulae may more accurately assess hardenability and cold cracking sensitivity.[12]

X3.4 For a vast number of common structural applications

[9] Graville, B. A., *The Principles of Cold Cracking Control in Welds*, Dominion Bridge Company, 1975.

[10] Randall, M. D., "Welding Procedure Factors Affecting Weldability for Service," *Weldability of Steels*, by Stout and Doty, Welding Research Council.

[11] Bailey, N., "The Development and Use of Carbon Equivalent in Britain," *Hardenability of Steels*, Abington Publishing, 1990.

[12] International Institute of Welding, "Guide to the Metallurgy of Welding and Weldability of Low Carbon Microalloyed Hot Rolled Steels," Document IIS/IIW-843-87.

it is unnecessary to specify the use of CE limits. However, in order to obtain a higher level of confidence in avoiding cold cracking, the chemistry controls in S31 are available. A purchaser who specifies the use of S31 should be aware that there are several factors involved in the judicious selection of a maximum CE value, such as the following:

X3.4.1 Actual production joint restraint/base metal thickness(es),

X3.4.2 Filler metal and base metal strength compatibility,

X3.4.3 Deposited weld metal diffusible hydrogen content,

X3.4.4 Preheat and interpass temperatures,

X3.4.5 Filler metal and base metal cleanliness, and

X3.4.6 Heat input.

X3.5 Though it is widely believed that low CE steels are immune to weld cracking problems, failure to consider these factors and others have resulted in weld or base metal HAZ (heat affected zone) cracks in such steels.[10]

X3.6 It is important to note that carbon equivalence is only a qualitative assessment of potential welding problems, and should never be solely relied on to ensure weld integrity. The proper use of welding specifications, coupled with the knowledge of actual construction conditions, must also be used.

## X4. RADIUS FOR COLD BENDING

X4.1 Suggested minimum inside bend radii for cold forming are referenced to Group Designations A to F inclusive as defined in Table X4.1. The suggested radii listed in Table X4.2 should be used as minimums in typical shop fabrication. Material that does not form satisfactorily when fabricated in accordance with Table X4.2 may be subject to rejection pending negotiation with the steel supplier. When tighter bends are required, the manufacturer should be consulted.

**TABLE X4.1 Group Designations for Cold Bending**

| Specification | Grade | Group Designation[A] |
|---|---|---|
| A 36/A 36M | [B] | B |
| A 131/A 131M | A, B, D, CS and E | B |
| | A, B, D, CS and E (all cold flanging) | B |
| | AH32, DH32, EH32 and FH 32 | C |
| | AH36, DH36, EH36 andFH36 | C |
| | AH40, DH40, EH40 and FH40 | C |
| A 242/A 242M | [B] | C |
| A 283/A 283M | A or B | A |
| | C or D | B |
| A 514/A 514M | any | F |
| A 529/A 529M | 50 [345] or 55 [380] | C |
| A 572/A 572M | 42 [290] | B |
| | 50 [345] | C |
| | 55 [380] | D |
| | 60 [415] or 65 [450] | E |
| A 573/A 573M | 58 [400] or 65 [450] | B |
| | 70 [485] | C |
| A 588/A 588M | any | C |
| A 633/A 633M | any | B |
| A 656/A 656M | 50 [345] | B |
| | 60 [415] | D |
| | 70 [485] | E |
| | 80 [550] | F |
| A 678/A 678M | A or B | C |
| | C or D | D |
| A 709/A 709M | 36 [250] | B |
| | 50 [345], 50W [345W] or HPS 50W [HPS 345W] | C |
| | HPS70W [HPS485W] | D |
| | 100 [690] or 100W [690W] | F |
| A 710/A 710M | A | F |
| A 808/A 808M | [B] | C |
| A 852/A 852M | [B] | D |
| A 871/A 871M | 60 [415] or 65 [450] | E |
| A 945/A 945M | 50 [345] or 65 [450] | B |

[A]Steels having a ratio of specified minimum tensile strength to specified minimum yield strength of 1.15 or less are in Group F; other steels are in Groups A to E inclusive, which are grouped on the basis of their having similar specified values for minimum elongation in 2 in. [50 mm].

[B]Grade designations are not applicable for this specification.

**TABLE X4.2 Suggested Minimum Inside Radii for Cold Bending[A]**

| Group Designation[B] | Thickness (t), in. [mm] | | | |
|---|---|---|---|---|
| | Up to ¾ in. [20 mm] | Over ¾ in. [20 mm] To 1 [25 mm, incl.] | Over 1 in. [25 mm] To 2 in. [50 mm], incl. | Over 2 in. [50 mm] |
| A | 1.5t | 1.5t | 1.5t | 1.5t |
| B | 1.5t | 1.5t | 1.5t | 2.0t |
| C | 1.5t | 1.5t | 2.0t | 2.5t |
| D | 1.5t | 1.5t | 2.5t | 3.0t |
| E | 1.5t | 1.5t | 3.0t | 3.5t |
| F | 1.75t | 2.25t | 4.5t | 5.5t |

[A]Values are for bend lines perpendicular to the direction of final rolling. These radii apply when the precautions listed in X4.2 are followed. If bend lines are parallel to the direction of final rolling, multiply values by 1.5.

[B]Steel specifications included in the group designations may not include the entire thickness range shown in this table.

X4.2 The bend radius and the radius of the male die should be as liberal as the finished part will permit. The width across the shoulders of the female die should be at least eight times the plate thickness. Higher strength steels require larger die openings. The surface of the dies in the area of radius should be smooth.

X4.2.1 Since cracks in cold bending commonly originate from the outside edges, shear burrs and gas cut edges should be removed by grinding. Sharp corners on edges and on punched or gas cut holes should be removed by chamfering or grinding to a radius.

X4.2.2 If possible, parts should be formed such that the bend line is perpendicular to the direction of final rolling. If it is necessary to bend with the bend line parallel to the direction of final rolling, a more generous radius is suggested (1½ times applicable value given in Table X4.2 for bend lines perpendicular to the direction of rolling).

X4.3 *References:*

X4.3.1 Holt, G. E., et al, “Minimum Cold Bend Radii Project—Final Report,” Concurrent Technologies Corporation, January 27, 1997.

X4.3.2 Brockenbrough, R. L., “Fabrication Guidelines for Cold Bending,” R. L. Brockenbrough & Associates, June 28, 1998.

X4.3.3 Both of these references are available from American Iron and Steel Institute, 1101 17th Street NW, Washington, DC 20036-4700.

## SUMMARY OF CHANGES

Committee A01 has identified the location of the following changes to this standard since the last issue (A 6/A 6M-05) that may impact the use of this standard (approved Sept. 1, 2005).

*(1)* Terminology A 941 was added to section 2.1 as a referenced document.
*(2)* Terminology A 941 was added to on Terminology.
*(3)* Section 14.1.1 was revised.

Committee A01 has identified the location of the following changes to this standard since the last issue (A 6/A 6M-04b) that may impact the use of this standard (approved April 1, 2005).

*(1)* The titles for Tables 13, 14, 15, A1.13, A1.14, and A1.15 were revised.
*(2)* In Table A2.1, the distance between inside parallel faces of the flange were increased from 33.39 in. to 33.97 in., which results in the following: an increase in the nominal weight of thebeam by 2 lbs/ft (3 kg/m); an increase in the depth of the beam by 0.58 in. (15 mm); and cross-sectional areas will increase from the current values.
*(3)* Shape W 36 X 487 was added to Table A2.1

Committee A01 has identified the location of the following changes to this standard since the last issue (A 6/A 6M-04a) that may impact the use of this standard (approved Sept. 1, 2004).

*(1)* Table A was revised.
*(2)* Note 10 was revised.
*(3)* 11.6.1 was revised.

Committee A01 has identified the location of the following changes to this standard since the last issue (A 6/A 6M-04) that may impact the use of this standard (approved March 1, 2004).

*(1)* Footnote B in Table 3 was revised.
*(2)* 11.4.2.1 was revised.
*(3)* 11.4.4 was added.
*(4)* The titles of Table B and Table C were revised.
*(5)* 11.6.4, including Note 5, was deleted.
*(6)* X2.2 and X2.4 were revised.

Committee A01 has identified the location of the following changes to this standard since the last issue (A 6/A 6M-03c) that may impact the use of this standard (approved Feb. 1, 2004).

*(1)* Supplementary Requirement S30 was added.

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**Designation: A 20/A20M – 01**

# Standard Specification for General Requirements for Steel Plates for Pressure Vessels[1]

This standard is issued under the fixed designation A 20/A20M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

## 1. Scope

1.1 This specification[2] covers a group of common requirements which, unless otherwise specified in the individual material specification, shall apply to rolled steel plates for pressure vessels under each of the following specifications issued by ASTM:

| Title of Specification | ASTM Designation[3] |
|---|---|
| Pressure Vessel Plates, Alloy Steel, Chromium-Manganese Silicon | A 202/A 202M |
| Pressure Vessel Plates, Alloy Steel, Nickel | A 203/A 203M |
| Pressure Vessel Plates, Alloy Steel, Molybdenum | A 204/A 204M |
| Pressure Vessel Plates, Alloy Steel, Manganese-Vanadium | A 225/A 225M |
| Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength | A 285/A 285M |
| Pressure Vessel Plates, Carbon Steel, Manganese-Silicon | A 299/A 299M |
| Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel | A 302/A 302M |
| Pressure Vessel Plates, Alloy Steel, 9 Percent Nickel Double-Normalized and Tempered | A 353/A 353M |
| Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum | A 387/A 387M |
| Pressure Vessel Plates, Carbon Steel, High Strength Manganese | A 455/A 455M |
| Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service | A 515/A 515M |
| Pressure Vessel Plates, Carbon Steel, Moderate- and Lower-Temperature Service | A 516/A 516M |
| Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered | A 517/A 517M |
| Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Manganese-Molybdenum and Manganese-Molybdenum-Nickel | A 533/A 533M |
| Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel | A 537/A 537M |
| Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Chromium-Molybdenum | A 542/A 542M |
| Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Nickel-Chromium-Molybdenum | A 543/A 543M |
| Pressure Vessel Plates, Alloy Steel, Quenched and Tempered 8 and 9 Percent Nickel | A 553/A 553M |
| Pressure Vessel Plates, Carbon Steel, Manganese-Titanium for Glass or Diffused Metallic Coatings | A 562/A 562M |
| Pressure Vessel Plates, Carbon Steel, High Strength, for Moderate and Lower Temperature Service | A 612/A 612M |
| Pressure Vessel Plates, Five Percent Nickel Alloy Steel, Specially Heat Treated | A 645/A 645M |
| Pressure Vessel Plates, Carbon-Manganese, for Moderate and Lower Temperature Service | A 662/A 662M |
| Pressure Vessel Plates, Carbon Steel, Quenched and Tempered, for Welded Layered Pressure Vessels | A 724/A 724M |
| Pressure Vessel Plates, Alloy Steel and High-Strength Low-Alloy Steel, Quenched and Tempered | A 734/A 734M |
| Pressure Vessel Plates, Low-Carbon Manganese-Molybdenum-Columbium Alloy Steel, for Moderate and Lower Temperature Service | A 735/A 735M |
| Pressure Vessel Plates, Low-Carbon Age-Hardening Nickel-Copper-Chromium-Molybdenum-Columbium Alloy Steel | A 736/A 736M |
| Pressure Vessel Plates, High-Strength Low-Alloy Steel | A 737/A 737M |
| Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel, for Moderate and Lower Temperature Service | A 738/A 738M |
| Pressure-Vessel Plates, Quenched and Tempered, Manganese-Chromium-Molybdenum-Silicon-Zirconium Alloy Steel | A 782/A 782M |
| Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum-Vanadium | A 832/A 832M |
| Pressure Vessel Plates, Produced by the Thermo-Mechanical Control Process (TMCP) | A 841/A 841M |
| Pressure Vessel Plates, 9 % Nickel Alloy, Produced by the Direct-Quenching Process | A 844/A 844M |

1.1.1 This specification also covers a group of supplementary requirements which are applicable to several of the above specifications as indicated therein. These are provided for use when additional testing or inspection is desired and apply only when specified individually by the purchaser in the order.

1.2 Appendix X1 describes the production and some of the characteristics of coiled product from which pressure vessel plates may be produced.

1.3 Appendix X2 provides information on the variability of tensile properties in plates for pressure vessels.

1.4 Appendix X3 provides information on the variability of Charpy-V-Notch impact test properties in plates for pressure vessels.

1.5 Appendix X4 provides information on cold bending of plates including suggested minimum inside radii for cold bending.

1.6 These materials are intended to be suitable for fusion welding. When the steel is to be welded, it is presupposed that a welding procedure suitable for the grade of steel and intended use or service will be utilized.

1.7 In case of any conflict in requirements, the requirements of the individual material specification shall prevail over those

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.11 on Steel Plates for Boilers and Pressure Vessels.

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[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-20/SA-20M in Section II of that Code.

[3] These designations refer to the latest issue of the respective specification which appears in the *Annual Book of ASTM Standards*, Vol 01.04.

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of this general specification.

1.8 The purchaser may specify additional requirements which do not negate any of the provisions of this general specification or of the individual material specifications. Such additional requirements, the acceptance of which are subject to negotiation with the supplier, must be included in the order information (see 4.1.8).

1.9 For purposes of determining conformance with this specification and the various material specifications referenced in 1.1, values shall be rounded to the nearest unit in the right-hand place of figures used in expressing the limiting values in accordance with the rounding method of Practice E 29.

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

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

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 202/A202M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Manganese-Silicon[4]

A 203/A203M Specification for Pressure Vessel Plates, Alloy Steel, Nickel[4]

A 204/A204M Specification for Pressure Vessel Plates, Alloy Steel, Molybdenum[4]

A 225/A225M Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Vanadium-Nickel[4]

A 285/A285M Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength[4]

A 299/A299M Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Silicon[4]

A 302/A302M Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel[4]

A 353/A353M Specification for Pressure Vessel Plates, Alloy Steel, 9 Percent Nickel, Double-Normalized and Tempered[4]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[5]

A 387/A387M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum[4]

A 435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates[4]

A 455/A455M Specification for Pressure Vessel Plates, Carbon Steel, High Strength Manganese[4]

A 515/A515M Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service[4]

A 516/A516M Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service[4]

A 517/A517M Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered[4]

A 533/A533M Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Manganese-Molybdenum and Manganese-Molybdenum-Nickel[4]

A 537/A537M Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel[4]

A 542/A542M Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, Chromium-Molybdenum, and Chromium-Molybdenum-Vanadium[4]

A 543/A543M Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Nickel-Chromium-Molybdenum[4]

A 553/A553M Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered 8 and 9 Percent Nickel[4]

A 562/A562M Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Titanium for Glass or Diffused Metallic Coatings[4]

A 577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates[4]

A 578/A578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications[4]

A 612/A612M Specification for Pressure Vessel Plates, Carbon Steel, High Strength, for Moderate and Lower Temperature Service[4]

A 645/A645M Specification for Pressure Vessel Plates, Five Percent Nickel Alloy Steel, Specially Heat Treated[4]

A 662/A662M Specification for Pressure Vessel Plates, Carbon-Manganese, for Moderate and Lower Temperature Service[4]

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment[6]

A 724/A724M Specification for Pressure Vessel Plates, Carbon Steel, Quenched and Tempered, for Welded Layered Pressure Vessels[4]

A 734/A734M Specification for Pressure Vessel Plates, Alloy Steel and High-Strength Low-Alloy Steel, Quenched and Tempered[4]

A 735/A735M Specification for Pressure Vessel Plates, Low-Carbon Manganese-Molybdenum-Columbium Alloy Steel, for Moderate and Lower Temperature Service[4]

A 736/A736M Specification for Pressure Vessel Plates, Low-Carbon Age-Hardening Nickel-Copper-Chromium-Molybdenum-Columbium and Nickel-Copper Manganese-Molybdenum-Columbium Alloy Steel[4]

A 737/A737M Specification for Pressure Vessel Plates, High-Strength, Low-Alloy Steel[4]

A 738/A738M Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel, for Moderate and Lower Temperature Service[4]

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products[4]

[4] *Annual Book of ASTM Standards*, Vol 01.04.

[5] *Annual Book of ASTM Standards*, Vol 01.03.

[6] *Annual Book of ASTM Standards*, Vol 01.05.



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A 770/A770M Specification for Through-Thickness Tension Testing of Steel Plates for Special Applications[4]

A 782/A782M Specification for Pressure-Vessel Plates, Quenched and Tempered, Manganese-Chromium-Molybdenum-Silicon-Zirconium Alloy Steel[4]

A 832/A832M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum-Vanadium[4]

A 841/A841M Specification for Steel Plates for Pressure Vessels, Produced by the Thermo-Mechanical Control Process (TMCP)[4]

A 844/A844M Specification for Steel Plates, 9 % Nickel Alloy, for Pressure Vessels, Produced by the Direct-Quenching Process[4]

A 919 Terminology Relating to Heat Treatment of Metals[7]

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys[7]

E 21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials[8]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[9]

E 112 Test Methods for Determining Average Grain Size[8]

E 208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels[8]

E 709 Guide for Magnetic Particle Examination[10]

2.2 *American Society of Mechanical Engineers Code:*

ASME Boiler and Pressure Vessel Code, Section IX, Welding Qualifications[11]

2.3 *U.S. Military Standard:*

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage[12]

2.4 *U.S. Federal Standard:*

Fed. Std. No. 123, Marking for Shipment (Civil Agencies)[12]

2.5 *Automotive Industry Action Group Standard:*

B 1 Bar Code Symbology Standard[13]

## 3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *capped steel*—rimmed steel in which the rimming action is limited by an early capping operation. Capping may be carried out mechanically by using a heavy metal cap on a bottle-top mold or it may be carried out chemically by an addition of aluminum or ferrosilicon to the top of the molten steel in an open-top mold.

3.1.2 *exclusive*—when used in relation to ranges, as for ranges of thicknesses in the tables of permissible variations in dimensions, the term is intended to exclude only the greater value of the range. Thus, a range from 60 to 72 in. [1500 to 18 mm] *exclusive* includes 60 in. [1500 mm], but does not include 72 in. [1800 mm].

3.1.3 *heat treatment terms*—see 3.1.7, 3.1.11, and Terminology A 941.

3.1.4 *hot forming*—a forming operation producing permanent deformation, performed after the plate has been heated to the temperature required to produce grain refinement.

3.1.5 *killed steel*—steel deoxidized, either by addition of strong deoxidizing agents or by vacuum treatment, to reduce the oxygen content to such a level that no reaction occurs between carbon and oxygen during solidification.

3.1.6 *manufacturer (material manufacturer)*—an organization that performs or directly controls one or more operations, such as melting, rolling, coiling, and heat treating, that affect the chemical composition or mechanical properties of the material.

3.1.7 *normalizing*—a heat treating process in which a steel plate is reheated to a uniform temperature above the upper critical temperature and then cooled in air to below the transformation range.

3.1.8 *plate-as-rolled*—when used in relation to the location and number of tests, the term refers to the unit plate rolled from a slab or directly from an ingot. It does not refer to the condition of the plate.

3.1.9 *plate identifier*—the alpha, numeric, or alphanumeric designation used to identify the plate.

3.1.10 *plates*— flat hot-rolled steel, commonly available by size as follows:

| Width, in. [mm] | Thickness, in. [mm] |
|---|---|
| Over 8 [200] | over 0.229 [6.0 mm and over] |
| Over 48 [1200] | over 0.179 [4.6 mm and over] |

3.1.11 *precipitation heat treatment*—a subcritical temperature thermal treatment performed to cause precipitation of submicroscopic constituents, etc., to result in enhancement of some desirable property.

3.1.12 *processor*— an organization that performs operations, such as decoiling, cutting to length, marking, inspecting, examining, and testing.

3.1.13 *rimmed steel*—steel containing sufficient oxygen to give a continuous evolution of carbon monoxide while the ingot is solidifying, resulting in a case or rim of metal virtually free of voids.

3.1.14 *semikilled steel*—incompletely deoxidized steel containing sufficient oxygen to form enough carbon monoxide during solidification to offset solidification shrinkage.

## 4. Ordering Information

4.1 Orders should include the following information, as necessary, to adequately describe the desired material.

4.1.1 Quantity (weight or number of plates),

4.1.2 Dimensions,

4.1.3 Name of material (plates, carbon steel; plates, alloy steel),

4.1.4 Specification designation (including type, class, and grade as applicable) and year of issue,

4.1.5 Condition (as-rolled, normalized, quenched and tempered, etc. If heat treatment of material is to be performed by the fabricator, this must be so stated. Also, if purchaser specifies a heat-treatment cycle, it must be stated),

4.1.6 Impact test requirements, if any (Section 12). (For Charpy V-notch test, include specimen orientation, testing

[7] *Annual Book of ASTM Standards*, Vol 01.01.

[8] *Annual Book of ASTM Standards*, Vol 03.01.

[9] *Annual Book of ASTM Standards*, Vol 14.02.

[10] *Annual Book of ASTM Standards*, Vol 03.03.

[11] Available from ASME, 345 E. 47th St., New York, NY 10017.

[12] Available from the procuring activity or as directed by the contracting office or from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[13] Available from Automotive Industry Action Group, 26200 Lahser Road, Suite 200, Southfield, MI 48034.



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temperature, and acceptance criteria. For drop-weight test give testing temperature),

4.1.7 Either plates from coil or discrete cut lengths of flat product may be supplied unless one is specifically excluded on the order. (See Appendix X1.)

4.1.8 If the processor (see 5.5.2) intends to qualify plates cut from a coiled product as pressure vessel plates, the order to the manufacturer (see 5.5.1) should state the intended ASTM specification designation, grade, and type (as applicable).

4.1.9 Paint marking (see 13.2.1),

4.1.10 Supplementary requirements, if any (test specimen heat treatment, special impact test requirements, etc.), and

4.1.11 Additional requirements, if any.

## 5. Materials and Manufacture

5.1 The steel shall be produced by one of the following primary steelmaking processes: open hearth, basic oxygen, electric furnace. The steel may be further refined by secondary processes, including but not restricted to: vacuum-secondary processes, including but not restricted to: vacuum-arc remelt (VAR), electroslag remelt (ESR), and ladle treatment.

5.2 The steel may be cast in ingots or may be strand cast.

5.2.1 *Strand Cast Slabs*:

5.2.1.1 When heats of the same nominal chemical composition are consecutively strand cast at one time, the heat number assigned to the cast product (slab) may remain unchanged until all of the steel in the slab is from the following heat.

5.2.1.2 When two consecutively strand cast heats have different nominal chemical composition ranges, the manufacturer shall remove the transition material by any established procedure that positively separates the grades.

5.3 The ratio of reduction of thickness from a strand-cast slab to plate shall be at least 3.0:1, except that reduction ratios as low as 2.0:1 are permitted if all of the following limitations are met:.

5.3.1 The purchaser agrees to the use of such reduction ratios.

5.3.2 The applicable material specification is A 299/A 299M, A 515/A 515M, A 516/A 516M, A 537/A 537M, A 662/A 662M, or A 737/A 737M

5.3.3 The specified plate thickness is 3.0 in. [75 mm] or more.

5.3.4 One or more of the following low hydrogen practices are used: vacuum degassing during steelmaking; controlled soaking of the slabs or plates; or controlled slow cooling of the slabs or plates.

5.3.5 The sulfur content is 0.004% or less, based upon heat analysis.

5.3.6 One or more of the following practices are used: electromagnetic stirring during strand casting; soft reduction during strand casting; heavy pass reductions or other special practices during plate rolling; or combined forging and rolling during plate rolling.

5.3.7 The plates are ultrasonically examined in accordance with Specification A 578/A 578M, Level C based on continuous scanning over 100% of the plate surface.

5.3.8 The plates are through thickness tension tested in accordance with Specification A 770/A 770M.

5.4 Plates are produced in either discrete cut lengths of flat product or from coils.

5.4.1 Plates produced from coil means plates that have been leveled or flattened and cut to length from a coiled product and that are furnished without heat treatment. For the purposes of this paragraph, stress relieving is not considered to be a heat treatment.

5.4.2 Plates that are annealed, normalized, normalized-and-tempered, or quenched-and-tempered after decoiling shall be considered to be discrete cut lengths of flat products.

5.5 When plates are produced from coils:

5.5.1 The manufacturer directly controls one or more of the operations (that is, melting, rolling, coiling, etc.) that affect the chemical composition or the mechanical properties, or both, of the material.

5.5.2 The processor decoils, cuts to length, and marks; performs and certifies tests, examination repairs, inspection, or operations not intended to affect the properties of the material. The processor may subsequently heat treat the plates (see Section 6). Specific sections of this specification for which the processor is responsible are 9, 10,11, 12,13, 14, 15, 16, and 20.

5.5.2.1 Coiled product is excluded from qualification to individual material specifications governed by this specification until decoiled, leveled, cut to length and tested by the processor in accordance with the specified requirements.

5.5.3 Plates produced from coils shall not contain splice welds, unless approved by the purchaser.

## 6. Heat Treatment

6.1 When material is required to be heat treated, the heat treatment may be performed either by the manufacturer or processor or by the fabricator unless otherwise specified in the material specification.

6.2 When the heat treatment required by the material specification is to be performed by the purchaser or the purchaser's agent, and the material is to be supplied by the material producer in a condition other than that required by the material specification, the order shall so state.

6.2.1 When plates are ordered without the heat treatment required by the material specification, heat treatment of the plates to conform to the requirements of the material specification shall be the responsibility of the purchaser.

6.3 When heat treatment is to be performed, the material shall be heat treated as specified in the material specification. The purchaser may specify the heat treatment to be used provided it is not in conflict with the requirements of the material specification.

6.4 When normalizing is to be performed by the fabricator, it may be accomplished by heating uniformly for hot forming. The temperature to which the plates are heated for hot forming shall not significantly exceed the normalizing temperature.

6.5 When no heat treatment is required, the manufacturer or processor may opt to heat treat the plates by normalizing, stress relieving, or normalizing and then stress relieving to meet the material specification.

6.6 If approved by the purchaser, cooling rates faster than those obtained by cooling in air are permissible to achieve specified mechanical properties, provided the plates are subsequently tempered in the temperature range from 1100 to



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1300°F [595 to 705°C].

## 7. Chemical Composition

7.1 *Heat Analysis* of each heat shall be made by the manufacturer to determine the percentage of elements specified in the individual material specification. This analysis shall be made from a test specimen preferably taken during the pouring of the heat. The chemical composition thus determined shall be reported to the purchaser, or the purchaser's representative, and shall conform to the heat analysis requirements of the applicable specification.

7.1.1 Unspecified elements may be present. Unless otherwise specified in the material specification, limits on elements shall be as stated in Table 1.

7.1.1.1 Each of the elements listed in Table 1 shall be included in the report of the heat analysis. When the amount of an element present is less than 0.02 %, the analysis may be reported as "<0.02 %."

7.2 *Product Analysis* representing each plate as-rolled may be made by the purchaser from a broken tension test specimen or from a sample taken from the same relative location as that from which the tension test specimen was obtained. The chemical composition thus determined, as to elements required or restricted, shall conform to the product analysis requirements specified in the applicable specification.

7.3 *Referee Analysis*—For referee purposes, Test Methods, Practices, and Terminology A 751 shall be used.

**TABLE 1 Limits on Unspecified Elements (see 7.1.1)**

| | | |
|---|---|---|
| Copper, max %[A] | Heat analysis | 0.40 |
| | Product analysis | 0.43 |
| Nickel, max %[A] | Heat analysis | 0.40 |
| | Product analysis | 0.43 |
| Chromium, max %[AB] | Heat analysis | 0.30 |
| | Product analysis | 0.34 |
| Molybdenum, max %[AB] | Heat analysis | 0.12 |
| | Product analysis | 0.13 |
| Vanadium, max %[C] | Heat analysis | 0.03 |
| | Product analysis | 0.04 |
| Columbium, max %[D] | Heat analysis | 0.02 |
| | Product analysis | 0.03 |
| Titanium, max %[E] | Heat analysis | 0.03 |
| | Product analysis | 0.04 |

[A]The sum of copper, nickel, chromium, and molybdenum shall not exceed 1.00 % on heat analysis. When one or more of these elements are specified, the sum does not apply; in which case, only the individual limits on the remaining unspecified elements will apply.

[B]The sum of chromium and molybdenum shall not exceed 0.32 % on heat analysis. When one or more of these elements are specified, the sum does not apply; in which case, only the individual limits on the remaining unspecified elements will apply.

[C]By agreement between the purchaser and the supplier, the heat analysis limit for vanadium is permitted to be increased to a value not higher than 0.10 %, and the product analysis limit for vanadium is permitted to be increased to a value not higher than 0.11 %.

[D]By agreement between the purchaser and the supplier, the heat analysis limit for columbium is permitted to be increased to a value not higher that 0.05 %, and the product analysis limit for columbium is permitted to be increased to a value not higher than 0.06 %.

[E]By agreement between the purchaser and the supplier, the heat analysis limit for titanium is permitted to be increased to a value not higher than 0.04 %, and the product analysis limit for titanium is permitted to be increased to a value not higher than 0.05 %.

## 8. Metallurgical Structure

8.1 Where coarse austenitic grain size is specified, the steel shall have a carburized austenitic grain size number in the range from 1 to 5, inclusive, as determined by the McQuaid-Ehn Test. Determinations shall be in accordance with Test Methods E 112, Plate IV, by carburizing for 8 h at 1700°F [925°C]. At least 70 % of the grains in the area examined shall conform to the specified grain size requirement. One test per heat shall be made.

8.2 *Fine Austenitic Grain Size*:

8.2.1 When a fine austenitic grain size is specified, aluminum shall be used as the grain refining element unless the order provides otherwise as specified in 8.2.4.

8.2.2 When a fine austenitic grain size is specified, except as otherwise provided in 8.2.2.1, the steel shall have a carburized austenitic grain size number of 5 or higher (finer) as determined by the McQuaid-Ehn test in accordance with Methods E 112, Plate IV. One test per heat shall be made.

8.2.2.1 When aluminum is used as the grain refining element, the fine austenitic grain size requirement shall be deemed to be fulfilled if, on heat analysis, the aluminum content is not less than 0.020 % total aluminum or, alternately, 0.015 % acid soluble aluminum.

8.2.3 When specified on the order, one McQuaid-Ehn test (see 8.1) per heat shall be made and the austenitic grain size of the steel, as represented by the test, shall be Number 5 or finer.

8.2.4 By agreement between the purchaser and the supplier, elements other than aluminum may be used for grain refining. In such instances, the heat analysis limits for the element, or elements, permitted shall be specified on the order. In addition, the McQuaid-Ehn test of 8.2.3 shall be required.

## 9. Quality

9.1 *General*— Plates furnished under this specification shall be free of injurious defects and shall have a workmanlike finish.

9.2 *Surface Imperfections*:

9.2.1 All injurious surface imperfections shall be removed by the manufacturer of discrete cut length plates. For plates provided from coils, the processor shall remove the injurious imperfections, rather than the manufacturer.

9.2.1.1 Shallow imperfections shall be ground to sound metal; the ground area shall be well faired and the thickness of the ground plate shall not be reduced below the minimum thickness permitted.

9.2.1.2 All surface imperfections, the removal of which will reduce the plate thickness below this minimum, shall be cause for rejection of the plate; however, by agreement with the purchaser, the metal so removed may be replaced with weld metal as provided in 9.4.

9.3 *Edge Imperfections*:

9.3.1 Laminar-type discontinuities 1 in. [25 mm] and less in length visible to the unaided eye on the edges of a plate as prepared for shipment by the manufacturer or processor are acceptable and do not require exploration.

9.3.2 All larger discontinuities shall be explored to determine their depth and extent. Discontinuities shall be considered continuous when located in the same plane within 5 % of the



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plate thickness and separated by a distance less than the length of the smaller of two adjacent discontinuities.

9.3.3 Indications visible to the unaided eye on the cut edges of a plate as prepared for shipment by the manufacturer or processor shall not exceed the limits given in columns 1 and 2 of Table A1.14 [A2.14].

9.3.4 Larger indications shall be removed by the manufacturer or processor by grinding provided the resultant cavity does not exceed the limits given in columns 3 and 4 of Table A1.14 [A2.14].

9.3.5 Indications of greater magnitude shall be cause for rejection of a plate; however, by agreement with the purchaser, the defects may be removed and replaced with weld metal as provided in 9.4.

9.3.6 Indications on the edges of a plate cut during the fabrication shall be cause for rejection of the plate at the discretion of the purchaser when the magnitude exceeds the limits given in columns 5 and 6 of Table A1.14 [A2.14]. The defects may be removed and replaced with weld metal as provided in 9.4.

9.3.7 Fabricators should be aware that edge cracks may initiate upon bending a sheared or burned edge during the fabrication process. This is not considered to be a fault of the steel, but is rather a function of the induced cold work or heat affected zone.

9.4 *Repair by Welding*:

9.4.1 Repair welding shall be permitted only with the approval of the purchaser.

9.4.2 Preparation for repair welding shall include inspection to assure complete removal of the defect.

9.4.3 Repairs shall be made utilizing welding procedures qualified in accordance with Section IX of the ASME Code and repair welding shall be done by welders or welding operators meeting the qualification requirements of ASME Section IX.

9.4.4 The weld metal shall have the A-number analysis corresponding to the equivalent ASME P number of the plate material except that A-1 or A-2 analysis weld metal may be employed for *P-1* materials. Other weld metals may be employed that are compatible with the base material being repaired, when so approved by the purchaser. Such weld metals must be qualified in accordance with the requirements of Section IX of the ASME Code.

9.4.5 If Charpy impact tests are required on the plate material, the welding procedure qualification tests shall also include Charpy impact tests of the weld, heat affected zone, and plate material and shall be reported to the purchaser.

9.4.6 If the plate material is subjected to normalizing, quenching and tempering, hot forming, or post-weld heat treating, the welding procedure qualification test plates and the weld repaired plate shall be subjected to the thermal heat treatment as specified by the purchaser.

9.4.7 In addition, repair welds shall meet the requirements of the construction code specified by the purchaser.

## 10. Test Methods

10.1 All tests shall be conducted in accordance with Test Methods and Definitions A 370.

10.2 Yield strength may be determined either by the 0.2 % offset method or the 0.5 % extension under load method unless otherwise stated in the material specification.

10.3 *Rounding Procedures*—For purposes of determining conformance with the specification, a calculated value shall be rounded to the nearest 1 ksi [5 MPa] tensile and yield strength, and to the nearest unit in the right-hand place of figures used in expressing the limiting value for other values in accordance with the rounding method given in Practice E 29.

## 11. Tension Tests

11.1 *Number of Tests*—Except as specified in 11.1.1, one tension test shall be taken from each plate-as-rolled, except for plates subjected to heat treatment by quenching and tempering. Two tension tests shall be taken from each quenched and tempered plate. When plates are furnished by the manufacturer or processor in accordance with 11.4.2 and qualified by heat-treated specimens (including normalized, normalized and tempered, and quenched and tempered), one tension test specimen shall be taken from each plate-as-rolled (see section 3.1.8 for the definition of plate-as-rolled).

11.1.1 *Plates Produced from Coils*—Coiled product is excluded from qualification to individual material specifications governed by this specification until decoiled, leveled, cut to length, and properly tested by the processor in accordance with ASTM specification requirements. When plates are produced from coils, a minimum of three tension tests shall be made from each coil qualified, except as otherwise indicated as follows for qualification of a portion of a coil.

11.1.1.1 The first test coupon shall be taken immediately prior to the first plate produced to the qualifying specification, the second test coupon shall be taken from the approximate center lap, and the third test coupon shall be taken immediately after the last plate produced to the qualifying specification. If, during decoiling, the amount of material decoiled is less than that required to reach the next standard test location, a test for qualification of that particular shipment may be made from a test coupon taken from a location adjacent to the innermost portion shipped.

11.1.1.2 All material between any two test locations that meet the requirements of the material specification is acceptable.

11.1.1.3 All material between a test location that fails to meet the requirements of the material specification and an adjacent acceptable test is rejectable. However, other tests may be made after cutting back the coil in either direction.

11.2 *Orientation of Tests*—The longitudinal axis of the tension-test specimens shall be transverse to the final rolling direction of the plate.

11.3 *Location of Tests*—The tension test specimen shall be taken from a corner of the plate. For quenched and tempered plates, the tension test specimens shall be taken from a corner of the plate at both ends of the plate.

11.4 *Tests from Heat-Treated Plates*:

11.4.1 When heat treatment is performed by the manufacturer or processor, the test specimens shall be taken from the plate in the heat-treated condition or from full-thickness coupons simultaneously heat treated with the plate.

11.4.2 When heat treatment is to be performed by the fabricator, the plates shall be accepted on the basis of tests made on specimens taken from full thickness coupons heat



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treated in accordance with the requirements specified in the material specification or on the order. If the heat-treatment temperatures are not specified, the manufacturer or processor shall heat treat the coupons under conditions he considers appropriate. The purchaser shall be informed of the procedure followed in heat treating the specimens.

11.4.3 When approved by the purchaser, the procedures of paragraph 11.4.2 may be implemented on plates heat treated by the manufacturer or processor.

11.4.4 When the plate is heat treated with a cooling rate faster than still-air cooling from the austenitizing temperature, one of the following shall apply in addition to other requirements specified herein:

11.4.4.1 The gage length of the tension test specimen shall be taken at least 1*T* from any as-heat treated edge where *T* is the thickness of the plate and shall be at least ½ in. [12.5 mm] from flame cut or heat-affected-zone surfaces.

11.4.4.2 A steel thermal buffer pad, 1*T* by 1*T* by at least 3*T*, shall be joined to the plate edge by a partial penetration weld completely sealing the buffered edge prior to heat treatment.

11.4.4.3 Thermal insulation or other thermal barriers shall be used during the heat treatment adjacent to the plate edge where specimens are to be removed. It shall be demonstrated that the cooling rate of the tension test specimen is no faster than, and not substantially slower than, that attained by the method described in 11.4.4.2.

11.4.4.4 When test coupons cut from the plate but heat treated separately are used, the coupon dimensions shall be not less than 3*T* by 3*T* by *T* and each tension specimen cut from it shall meet the requirements of 11.4.4.1.

11.4.4.5 If cooling rate data for the plate and cooling rate control devices for the test specimens are available, the test specimens may be heat treated separately in the device. This method shall require prior approval of the purchaser.

11.5 *Specimen Preparation*:

11.5.1 Tension test specimens for plates ¾ in. [20 mm] and under in thickness shall be the full thickness of the plates. The test specimens shall conform to the requirements for either the 1½-in. [40-mm] wide or the ½-in. [12.5-mm] wide rectangular tension test specimen of Methods and Definitions A 370. The 1½-in. [40-mm] wide specimen may have both edges parallel. The ½-in. [12.5 mm] wide specimen may have a maximum nominal thickness of ¾ in. [20 mm].

11.5.2 For plates up to 4 in. [100 mm], inclusive, in thickness, tension test specimens may be the full thickness of the material and conform to the requirements for the 1½-in. [40 mm] wide rectangular tension test specimen of Methods and Definitions A 370 when adequate testing machine capacity is available.

11.5.3 For plates over ¾ in. [20 mm] in thickness, except as permitted in 11.5.2, tension test specimens shall conform to the requirements for the 0.500-in. [12.5-mm] round specimen of Methods and Definitions A 370. The axis of the specimen shall be located, as nearly as practicable, midway between the center of thickness and the top or bottom surface of the plate.

11.6 *Elongation Requirement Adjustments*:

11.6.1 Due to the specimen geometry effect encountered when using the rectangular tension test specimen for testing thin material, adjustments in elongation requirements must be provided for thicknesses under 0.312 in. [8 mm]. Accordingly, the following deductions shall be made from the base elongation requirements in the individual plate specifications:

| Nominal Thickness Range, in. [mm] | Elongation Deduction, % |
|---|---|
| 0.299–0.311 [7.60–7.89] | 0.5 |
| 0.286–0.298 [7.30–7.59] | 1.0 |
| 0.273–0.285 [7.00–7.29] | 1.5 |
| 0.259–0.272 [6.60–6.99] | 2.0 |
| 0.246–0.258 [6.20–6.59] | 2.5 |
| 0.233–0.245 [5.90–6.19] | 3.0 |
| 0.219–0.232 [5.50–5.89] | 3.5 |
| 0.206–0.218 [5.20–5.49] | 4.0 |
| 0.193–0.205 [4.90–5.19] | 4.5 |
| 0.180–0.192 [4.60–4.89] | 5.0 |

11.6.2 Due to the inherently lower elongation which is obtainable in thicker material, adjustments in elongation requirements in 2-in. [50-mm] gage length must be provided for thicknesses over 3.5 in. [90 mm]. Accordingly, the following deductions shall be made from the base elongation requirements in 2 in. [50 mm] listed in the individual plate specifications:

| Plate Nominal Thickness Range, in. [mm] | Elongation Deduction, % |
|---|---|
| 3.501–3.999 [90.00–102.49] | 0.5 |
| 4.000–4.499 [102.50–114.99] | 1.0 |
| 4.500–4.999 [115.00–127.49] | 1.5 |
| 5.000–5.499 [127.50–139.99] | 2.0 |
| 5.500–5.999 [140.0–152.49] | 2.5 |
| 6.000 and thicker [152.50 and thicker] | 3.0 |

11.6.3 A characteristic of certain types of alloy steels is a local disproportionate increase in the degree of necking down or contraction of the specimens under tension test, resulting in a decrease in the percentage of elongation as the gage length is increased. The effect is not so pronounced in the thicker plates. On such material, when so stated in the material specification for plates up to ¾in. [20 mm], inclusive, in thickness, if the percentage of elongation of an 8-in. [200-mm] gage length test specimen falls not more than 3 % below the amount prescribed, the elongation shall be considered satisfactory provided the percentage of elongation in 2 in. [50 mm] across the break is not less than 25 %.

11.6.4 The tensile requirements tables in many of the plate specifications covered by these general requirements specify elongation requirements in both 8-in. [200-mm] and 2-in. [50-mm] gage lengths. Unless otherwise provided in the individual plate specification, it is not the intent that both requirements apply simultaneously and that the elongation be determined in both gage lengths. Instead, it is intended that the elongation be determined only in the gage length appropriate for the test specimen used. After selection of the appropriate gage length, the elongation requirement for the alternative gage length shall be deemed not applicable.

11.7 This specification does not provide requirements for product tension testing subsequent to shipment (see 15.1). Therefore, the requirements of 11.1 through 11.6 and Section 16 apply only for tests conducted at the place of manufacture prior to shipment. Compliance to Specification A 20/20M and the individual material specifications does not preclude the possibility that product tension test results may vary outside specified ranges. The tensile properties will vary within the



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same plate-as-rolled or piece, be it as-rolled, control-rolled, or heat-treated. The purchaser should, therefore, be aware that tension testing in accordance with the requirements of Specification A 20/A 20M does not provide assurance that all products of a plate-as-rolled will be identical in tensile properties with the products tested. If the purchaser wishes to have more confidence than that provided by Specification A 20/A 20M testing procedures, additional testing or requirements, such as Supplementary Requirement S4, should be imposed.

11.8 Appendix X2 provides additional information on the variability of tensile properties in plates for pressure vessels.

## 12. Notch-Toughness Tests

12.1 *Charpy V-Notch Tests*:

12.1.1 *Number of Tests*—Except for plates subjected to quenching-and-tempering, and except as specified in 12.1.1.1 and 12.1.1.2, one impact test (3 specimens) for each specified orientation (see 12.1.2) shall be made from each plate-asrolled. For plates subjected to quenching-and-tempering, one impact test shall be made from each plate-as-heat-treated.

12.1.1.1 *Plates Ordered Without the Heat Treatment Specified by the Material Specification*—When the material specification requires heat treatment but the plates are ordered without such heat treatment, and when Charpy V-Notch tests are specified, one coupon shall be taken from each plate-as-rolled. The coupon shall be heat treated in accordance with the material specification and the purchase order and the plate qualified by specimens taken from the heat-treated coupon.

12.1.1.2 *Plates Produced from Coils*—When the plates are produced from coils and when Charpy V-Notch tests are specified, the number of impact tests required shall be the same as the number specified in 11.1.1 for tension tests. The test coupons shall be taken from the material after flattening.

12.1.2 *Orientation of Test Specimens*— The long axes of the specimens shall be oriented either longitudinal (parallel to the final direction of rolling) or transverse (transverse to the final direction of rolling) as specified in the material specification or order.

12.1.3 *Location of Test Coupons*—The impact test coupons shall be taken adjacent to the tension test coupons. The impact test coupons shall be subject to the same requirements as those specified for tension tests in 11.4 except that the provisions of 11.4.4.1 apply to the area under the notch of the impact test specimen instead of to the gage length of the tension test specimen.

12.1.4 *Test Method*—Impact testing shall be performed in accordance with Test Methods and Definitions A 370 using Charpy V-notch (Type A) specimens as shown in Test Methods and Definitions A 370. Except as provided in 12.1.4.1, full-size (10 by 10-mm) specimens shall be used when the plate thickness permits, and their central axis shall correspond as near as practical to the $\frac{1}{4}t$ plane in the plate thickness $t$. Where the plate thickness is insufficient to obtain full-size specimens, sub-size specimens shall be used. The sub-size specimens may have a width of full material thickness or may be reduced in thickness to produce the largest possible standard sub-size specimen listed in Test Methods and Definitions A 370.

12.1.4.1 For materials that normally have absorbed energy values in excess of 180 ft-lbf [245 J] when tested using full-size specimens at the specified testing temperature, sub-size 0.4 by 0.268 in. [10 by 6.7 mm] specimens may be used in lieu of full-size specimens. However, when this option is used, the acceptance value shall be 75 ft-lbf [100 J] minimum for each specimen and the lateral expansion in mils [μm] shall be reported.

12.1.5 *Test Temperature*—The test temperature should be specified on the order. At the supplier's option, the actual test temperature may be lower than the specified test temperature. When a test temperature is not specified, tests shall be conducted at a temperature no higher than listed in Table A1.15 [A2.15] for the class, grade, and thickness of the material specified. The actual test temperature shall be reported with the test results.

12.1.6 *Acceptance Criteria*—Unless otherwise agreed upon, the acceptance criteria shall be as listed in Table A1.15 [A2.15] for the class, grade, and thickness of the material specified.

12.1.6.1 When the acceptance criteria is based on energy absorption of a full-size specimen, the acceptance criteria for the various sub-size specimens shall be as shown in Table A1.16 [A2.16] except as otherwise provided in 12.1.4.1.

12.1.6.2 When the acceptance criteria is based on lateral expansion opposite the notch, the acceptance value shall be the same for all sizes of specimens.

12.1.7 *Marking*—The letters "LTV" shall be stenciled or stamped on each plate following the class number, grade, etc.

12.1.8 *Variability*—The impact properties of steel can vary within the same plate-as-rolled or piece, be it as-rolled, control-rolled, or heat-treated. The purchaser should, therefore, be aware that testing of one plate-as-rolled does not provide assurance that all locations within a plate-as-rolled will be identical in toughness with the location tested. Normalizing or quenching and tempering the product will reduce the degree of variation.

12.1.8.1 Appendix X3 provides additional information on the variability of Charpy V-Notch test properties in plates for pressure vessels.

12.2 *Drop-Weight Tests*:

12.2.1 When specified, one drop-weight test, consisting of a set of two specimens, shall be made to the same frequency stated in 12.1.1 in accordance with Method E 208.

12.2.2 The test coupons shall be obtained adjacent to a tension test coupon. For plates produced from coils, the test coupon locations shall be the same as for Charpy V-notch tests. (See 12.1.) The provisions of 11.4 shall also apply.

12.2.3 The testing temperature shall be as specified in the material specification or order.

12.2.4 Acceptance shall be on the basis of *no-break* performance of both specimens at the specified testing temperature.

12.2.5 The plates shall be marked as required in 12.1.7 except that the letters "LTD" shall be used instead of "LTV."

## 13. Identification of Plates

13.1 *Required Markings*:

13.1.1 Except as allowed by 13.4, plates shall be legibly marked with the following information: applicable ASTM designation (see 1.1) (year of issue not required); "G" or" MT" if applicable (see 13.1.2); applicable grade, type and class; heat number; plate identifier; and name, brand, or trademark of the



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manufacturer (for plates produced in discrete cut lengths of flat product) or the processor (for plates produced from coil and for subdivided plates (see 13.4)).

13.1.2 Plates that are required to be heat treated, but have not been so heat treated, shall be marked, by the manufacturer or processor, with the letter "G" (denoting green) following the required ASTM designation mark, except that "G" marking is not necessary if such plates are for shipment, for the purpose of obtaining the required heat treatment, to an organization under the manufacturer's control. Such plates shall have been qualified for shipment on the basis of test specimens that have been so heat treated. Plates that are required to be heat treated, and have been so heat treated, shall be marked, by the party that performed the heat treatment, with the letters "MT" (denoting material treated) following the required ASTM designation mark.

NOTE 1—Any stress relief of test specimens intended to simulate post-weld heat treatment is not included in the above heat treatment.

13.2 *Types of Marking*:

13.2.1 Except as allowed by 13.4, the required markings for plates over ¼ in. [6 mm] in thickness shall be by steel die stamping, unless paint marking is specified in the purchase order.

13.2.2 Except as allowed by 13.4, the required markings for plates ¼ in. [6 mm] and under in thickness shall be by paint marking or by steel die stamping using low-stress (either round-nose or interrupted-dot) impressions.

13.3 *Location of Markings*:

13.3.1 Except as allowed by 13.4, the required markings for plates with a maximum lengthwise or crosswise dimension more than 72 in. [1800 mm] shall be in at least two places on each finished plate, at least 12 in. [300 mm] from the edges of the plate.

13.3.2 Except as allowed by 13.4, the required markings for plates with a maximum lengthwise and crosswise dimension of 72 in. [1800 mm] or less shall be in at least one place on each finished plate, approximately midway between the center and an edge of the plate.

13.4 *Subdivided Plates*:

13.4.1 By agreement between the purchaser and the processor, each subdivided plate (a plate separated from a master plate) shall be legibly marked with the name, brand, or trademark of the processor plus a code traceable to the required markings, provided that the information required in 13.1, cross referenced to that code, is furnished with the plates.

13.4.2 By agreement between the purchaser and the processor, subdivided plates that are from the same master plate and placed in secured lifts shall have the information required in 13.1 paint marked on the top piece of each lift or shown on a substantial tag attached to each lift.

13.5 *Bar Coding*—In addition to the requirements of 13.1 to 13.4 inclusive, the manufacturer or processor shall have the option of using bar coding as a supplementary identification method.

NOTE 2—Bar coding should be consistent with AIAG Standard B 1.

## 14. Permissible Variations in Dimensions or Mass

14.1 One cubic foot of rolled steel shall be assumed to weigh 490 lb, unless otherwise stated in the material specification. One cubic metre of rolled steel is assumed to have a mass of 7850 kg, unless otherwise stated in the material specification.

14.2 For carbon steel plates the permissible variations for dimensions shall not exceed the applicable limits stated in Annex A1, Table A1.1 to Table A1.9 , and Table A1.13 [Annex A2, Table A2.1 to Table A2.9 , and Table A2.13 ].

14.3 For alloy-steel plates the permissible variations for dimensions shall not exceed the applicable limits stated in Annex 1, Table A1.1 to Table A1.4 , Table A1.8 , and Table A1.10 to Table A1.13 . [Annex 2, Table A2.1 to Table A2.4 , Table A2.8 and Table A2.10 to Table A2.13 ].

## 15. Inspection and Testing

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

15.2 When plates are produced from coils, 15.1 shall apply to the "processor" instead of to the" manufacturer" and the "place of process" shall apply instead of the "place of manufacture." When plates are produced from coils and the processor is different from the manufacturer, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered.

## 16. Retests

16.1 *Tension Test*—In addition to the provisions of Test Methods and Definitions A 370, the following retest provisions shall apply:

16.1.1 If any test specimen shows defective machining, or develops flaws, it may be discarded and another specimen substituted.

16.1.2 If the percentage of elongation of any tension test specimen is less than that specified, and any part of the fracture is more than ¾ in. [20 mm] from the center of the gage length of a 2-in. [50-mm] specimen or is outside the middle half of the gage length of an 8-in. [200-mm] specimen as indicated by scribe marks on the specimen before testing, one retest shall be allowed.

16.1.3 If the results from an original tension test specimen fails to meet the specified requirements but are within 2 ksi [14 MPa] of the required tensile strength or within 1 ksi [7 MPa] of the required yield strength or yield point, or within 2 percentage points of the required elongation or reduction in area, one retest shall be permitted to replace the failing test.

16.1.4 The results of the retest shall meet the specified requirements.

16.2 *Charpy V-Notch Tests*:



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16.2.1 The retest provisions of Test Methods and Definitions A 370 shall apply except that the 5 ft·lbf [7 J] absolute minimum for an individual specimen, as specified in Test Methods and Definitions A 370, does not apply when two thirds of the specified minimum average is less than 5 ft·lbf [7 J].

16.2.2 When Charpy V-notch impact test lateral expansion values are specified, if the value of one specimen falls below the specified minimum value and not below ⅔of the specified minimum value, and if the average of the three specimens equals or exceeds the specified minimum value, a retest of three additional specimens may be made. Each of the three retest specimens must equal or exceed the specified minimum value.

16.2.3 If the required values are not obtained on Charpy V-notch retests as specified in 16.2.1 and16.2.2, or if the values in the initial test are below the values required for retest, no further retests are permitted unless the plate is heat treated or reheat treated. After heat treatment or reheat treatment, a set of three specimens shall be tested and each must equal or exceed the specified minimum value.

16.2.4 When the option of 12.1.4.1 is used and the test result falls below the 75 ft·lbf [100 J] minimum specified, another test may be made using full-size specimens.

## 17. Retreatment

17.1 If any heat-treated material fails to meet the mechanical requirements of the applicable specification, the material may be reheat treated. All mechanical-property tests shall be repeated and the plate surface shall be reexamined for defects when the material is resubmitted for inspection.

## 18. Rejection

18.1 Any rejection based on product analysis made in accordance with the material specification shall be reported to the supplier and samples that represent the rejected material shall be preserved for 2 weeks from the date of notification of such rejection. In case of dissatisfaction with the results of the tests, the supplier may make claim for a rehearing within that time.

18.2 Material that shows injurious defects subsequent to its acceptance at the manufacturer's or processor's works may be rejected. In such cases, the manufacturer or processor shall be notified.

## 19. Test Reports

19.1 The manufacturer or processor shall report the results of all tests required by the material specification, applicable supplementary requirements, and the order. The heat number, the plate identifier of the plate tested, and the nominal plate thickness shall be shown on the test report. The year-date of the specification to which the material is furnished shall be included on the test report.

19.1.1 In reporting elongation values, both the percentage increase and the original gage length shall be stated.

19.2 For plates rolled from a strand-cast slab with a reduction ratio in the range from 2.0:1 to 3.0:1, exclusive, the specific practices (see 5.3.4 and 5.3.6) that were used by the manufacturer shall be reported, and the test reports shall state that the limitations of 5.3 have been met.

19.3 All heat treatment, exclusive of subcritical heating to soften thermally cut edges, shall be reported including temperature ranges and time at temperature. This exclusion does not apply to those materials with specified minimum tensile strengths of 95 ksi [655 MPa] or higher unless such subcritical heating is accomplished at temperatures at least 75°F [40°C] below the minimum tempering temperature. The reports shall state whether the plates only, the test specimens only, or both plates and test specimen were heat treated.

19.4 When Charpy V-notch tests are specified, the specimen size used shall be reported.

19.5 When required by the purchaser order, the manufacturer shall also furnish a certification that has material has been manufacturerd and tested in accordance with the requirements of the material specification. For plates provided from coils, the processor shall furnish the required certification.

19.6 For plates produced from coils, both the manufacturer and processor shall be identified on the test report.

19.7 A signature is not required on the test report. However, the document shall clearly identify the organization submitting the report. Notwithstanding the absence of a signature, the organization submitting the report is responsible for the content of the report.

19.8 Copies of the original manufacturer's test report shall be included with any subseqenent test report.

19.9 A Material Test Report, Certificate of Inspection, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document must meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

## 20. Packaging, Marking, and Loading for Shipment

20.1 Packaging, marking, and loading for shipment shall be in accordance with those procedures recommended by Practices A 700.

20.2 *For USA Government Procurement*—Packaging, packing, and marking of material for military procurement shall be in accordance with the requirements of MIL-STD-163, Level A, Level C, or commercial as specified in the contract or purchase order. Marking for shipment of material for civil agencies shall be in accordance with Fed. Std. No. 123.

## 21. Keywords

21.1 general delivery requirement; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessel applications



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## SUPPLEMENTARY REQUIREMENTS

The following standardized supplementary requirements are for use when desired by the purchaser. Several of those that are considered suitable for use with each material specification are listed in the specification. Other tests may be performed by agreement between the supplier and the purchaser. These supplementary requirements shall apply only when specified in the order, in which event the specified tests shall be made by the supplier before shipment of the plates.

### S1. Vacuum Treatment

S1.1 The steel shall be made by a process which includes vacuum degassing while molten. Unless otherwise agreed upon with the purchaser, it is the responsibility of the manufacturer to select suitable process procedures.

### S2. Product Analysis

S2.1 A product analysis shall be made of each plate as rolled. The specimens for analysis shall be taken adjacent to or from a broken tension-test specimen.

### S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons

S3.1 Prior to testing, the test specimens representing the plate for acceptance purposes for mechanical properties shall be thermally treated to simulate a post-weld heat treatment below the critical temperature ($Ac_3$), using the heat treatment parameters (such as temperature range, time, and cooling rates) specified in the order. The test results for such heat-treated test specimens shall meet the applicable product specification requirements.

### S4. Additional Tension Test

S4.1 *Other Than Quenched-and-Tempered Plates*—In addition to the required single-tension test, a second tension test shall be made on a specimen taken from a corner of the plate-as-rolled on the end opposite the single specimen and in a direction parallel to the single specimen. The results obtained on testing this second specimen shall conform to the requirements of the specification.

S4.2 *Quenched-and-Tempered Plates 2 in.* [50 mm] *or Greater in Thickness*—In addition to the required tension tests, two additional specimens shall be taken from the bottom corner of the plate. One shall be taken at the center of the plate thickness and the other immediately beneath the surface. Mandatory conformance of these additional tests with specified properties shall be a matter of agreement between the manufacturer and the purchaser.

S4.3 For plates produced from coils, the additional tension test shall be taken immediately after the last plate produced to the qualifying specification.

### S5. Charpy V-Notch Impact Test

S5.1 Charpy V-notch impact tests shall be conducted in accordance with 12.1.

S5.2 The orientation of the test bars, whether longitudinal or transverse to the direction of rolling, shall be as stated on the order.

S5.3 The test temperature and the required acceptance criteria, if other than those required in 12.1, shall be as stated on the order.

S5.4 The recorded results shall include test-bar orientation, specimen size, test temperature, absorbed energy values, and, when specified on the order for other than Class VI material, lateral expansion opposite the notch. The percent shear fracture appearance shall also be recorded when specified on the order.

### S6. Drop-Weight Test (for Plates 0.625 in. [16 mm] and Over in Thickness)

S6.1 Drop-weight tests shall be made in accordance with the requirements of Test Method E 208. The specimens shall represent the plates in the final condition of heat treatment. Agreement shall be reached between the purchaser and the manufacturer or processor as to the number of plates to be tested and whether a maximum NDT temperature is mandatory or if the test results are for information only.

### S7. High-Temperature Tension Tests

S7.1 A short-time elevated temperature tension test shall be made to represent each plate or each heat of steel as indicated by the purchaser. The material for testing shall be obtained as required for the room temperature tension tests specified in the body of the specification. The hot tests shall be made in accordance with the requirements of Practice E 21. Mandatory conformance of these additional tests with specified properties shall be a matter for agreement between the manufacturer or processor and the purchaser.

### S8. Ultrasonic Examination in Accordance with A 435/A 435M

S8.1 All plates shall be ultrasonically examined in accordance with the requirements of Specification A 435/A 435M .

### S9. Magnetic Particle Examination

S9.1 All plate edges shall be examined by magnetic particles in accordance with the procedures covered in Practice E 709. The acceptability of defects revealed by this examination shall be judged in accordance with the requirements for quality in 9.3.

### S10. Charpy V-Notch Impact Transition Curve

S10.1 Sufficient impact tests of the same specimen size shall be made from the plate test material to establish a transition curve. The test temperature range shall be wide enough to establish the upper and lower shelf energies, with sufficient testing at intermediate temperatures to permit plotting a reasonable smooth curve. A plot of the data is not required. The manufacturer shall report the specimen orientation, test temperature, and absorbed energy for each specimen tested. Lateral expansion and percent shear shall also be reported when specified in the order. The number of plates tested and the



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specimen orientation shall be the same as in 12.1 unless otherwise specified in the order.

**S11. Ultrasonic Examination in Accordance with A 577/ A 577M**

S11.1 All plates shall be ultrasonically examined in accordance with the requirements of Specification A 577/ A 577M.

**S12. Ultrasonic Examination in Accordance with A 578/ A 578M**

S12.1 All plates shall be ultrasonically examined in accordance with the requirements of Specification A 578/ A 578M. The acceptance level shall be as specified on the order.

**S13. NDT Temperature Determination**

S13.1 The NDT temperature shall be established in accordance with Method E 208 using coupons from a single plate. The number of plates to be so tested shall be subject to agreement between the purchaser and the manufacturer or processor.

**S15. Reduction of Area Measurement**

S15.1 A reduction of area measurement shall be taken while making the required tension test. Reduction of area shall be determined only on the 0.500-in. [12.5 mm] round specimen as shown in Fig. 5 of Test Methods and Definitions A 370. The minimum acceptance limit shall be 40 %.

**S16. Thermal Stress Relief of Mechanical Test Coupons**

S16.1 Test coupons representing the plates shall be thermally stress relieved by gradually and uniformly heating them to a temperature between 1100 and 1200°F [595 and 650°C], or a temperature range otherwise agreed upon between the manufacturer or processor and the purchaser, holding at temperature for at least 1 h/in. [2.4 min/mm] of thickness and cooling in still air to a temperature not exceeding 600°F [315°C].

**S17. Vacuum Carbon-Deoxidized Steel**

S17.1 Material shall be vacuum carbon-deoxidized, in which case the silicon content at the time of vacuum deoxidizing shall be 0.12 % maximum, and the content of deoxidizers such as aluminum, zirconium, and titanium should be kept low enough to allow deoxidation by carbon. The test report shall indicate that the steel was vacuum carbon-deoxidized. The minimum heat analysis and product analysis requirements for silicon do not apply to vacuum carbon-deoxidized steel.

**S19. Restricted Chemical Requirements**

S19.1 Restricted heat analysis and product analysis limits are applicable as defined on the order.

**S20. Maximum Carbon Equivalent for Weldability**

S20.1 Plates shall be supplied with a specific maximum carbon equivalent value. This value shall be based on heat analysis. The required chemical analysis as well as the carbon equivalent shall be reported.

S20.2 The carbon equivalent shall be calculated using the following formula:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15.$$

S20.3 The maximum value of the carbon equivalent for carbon steels (including C-Mn, C-Mn-Si, C-Mn-Si-Al steels), are given in Table 2.

**S21. Restricted Unspecified Elements**

S21.1 The maximum limits on certain elements are 0.35 % Cu, 0.25 % Ni, 0.25 % Cr, and 0.08 % Mo on heat analysis. The sum of Cu, Ni, Cr, and Mo shall not exceed 0.70 % on heat analysis.

**S22. Through-Thickness Tension Tests**

S22.1 Through-thickness tension tests shall be made in accordance with the requirements of Specification A 770/ A 770M . (See Ordering Information in Specification A 770/ A 770M for the additional information that may be needed.)

**S24. Strain Age Test**

S24.1 Test coupons shall be given a strain age treatment designated by the purchaser. Charpy V-notch tests shall be conducted on the strain aged specimens. Heat treatment, strain aging, test temperature, and acceptance criteria shall be as agreed upon between the manufacturer and purchaser.

**S25. Weldability**

S25.1 Weldability tests shall
be conducted. The type of test and the acceptance criteria shall be as agreed upon between the manufacturer and purchaser.

**S26. Low-Sulfur Steels**

S26.1 The steel shall be made to 0.010 % sulfur maximum. Lower sulfur levels and sulfide shape control practices can be specified by agreement between purchaser and supplier.

**S27. Restrictive Plate Flatness**

S27.1 Carbon steel plates, as-rolled or normalized, shall conform to the permissible restrictive variations from flatness as detailed in Table 3 or Table 4.

S27.2 High-strength low-alloy steel plates, as-rolled or normalized, shall conform to the permissible restrictive variations from flatness as detailed in Table 5 or Table 6.

**S28. Heat Treatment in the Working Zone of a Surveyed Furnace**

S28.1 Plates shall be heat treated in the working zone of a furnace that has been surveyed in accordance with Test Method A 991/A 991M, provided that such working zone was established using a variation of 25°F [15°C] or less from the furnace set point.

S28.2 The test report shall indicate that S28 applies.



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**TABLE 2 Maximum Carbon Equivalent for Weldability**

| Specified Minimum UTS ksi [MPa] | Maximum Carbon Equivalent Value | |
|---|---|---|
| | Thickness up to 2 in. [50 mm] incl | Thickness over 2 in. [50 mm] |
| 60 ≤ UTS < 70 [415 ≤ UTS < 485] | 0.45 | 0.46 |
| 70 ≤ UTS < 80 [485 ≤ UTS < 550] | 0.47 | 0.48[A] |
| UTS ≥ 80 [UTS ≥ 550] | 0.48[A,B] | ... |

[A] If simulated PWHT of the test coupons is specified (S3), the maximum carbon equivalent value may be increased up to 0.50 upon agreement between purchaser and supplier.

[B] Applicable to quenched-and-tempered material; for other conditions, maximum carbon equivalent shall be by agreement between purchaser and supplier.

**TABLE 3 Permissible Variations from Flatness for Carbon Steel Plates As-Rolled or Normalized Ordered to Restrictive Flatness**

NOTE 1—*Flatness Variations for Length*—The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

NOTE 2—*Flatness Variations for Width*—The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 36 in., the variation in flatness along the length and across the width shall not exceed ¼ in. in each direction. When the longer dimension is from 36 to 72 in., inclusive, the permissible flatness variation shall not exceed 75 % of the tabular amount for the specified width, but in no case less than ¼ in.

NOTE 4—The variations given in this table apply to plates that have a minimum specified tensile strength not over 60 ksi or comparable chemistry or hardness. For plates specified to a higher minimum tensile strength or compatible chemistry or hardness, the permissible variations are 1½ times the amounts shown in the table below.

NOTE 5—This table and these notes cover the flatness variations of circular and sketch plates based on the maximum dimensions of those plates.

NOTE 6—Waviness tolerances for rectangular plates, universal mill plates, and circular and sketch plates do not apply.

NOTE 7—A "Z" indicates that there is no published restricted value for the size.

NOTE 8—Plates shall be in a horizontal position on a flat surface when flatness is measured.

| Specified Thickness, in. | Permissible Variations from a Flat Surface for Specified Widths, in. | | | | | |
|---|---|---|---|---|---|---|
| | 48 to 60, excl | 60 to 72, excl | 72 to 84, excl | 84 to 96, excl | 96 to 108, excl | 108 to 120, incl |
| To ¼, excl | ¾ | 15/16 | Z | 15/16 | 1-1/16 | 1-⅛ |
| ¼ to ⅜, excl | 9/16 | ¾ | ⅞ | 15/16 | 1-1/16 | 1-⅛ |
| ⅜ to ½, excl | 5/16 | 5/16 | ⅜ | 7/16 | ½ | 9/16 |
| ½ to ¾, excl | 5/16 | 5/16 | 5/16 | ⅜ | ½ | ½ |
| ¾ to 1, excl | 5/16 | 5/16 | 5/16 | 5/16 | ⅜ | 7/16 |
| 1 to 2, incl | ¼ | 5/16 | 5/16 | 5/16 | 5/16 | ⅜ |



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**TABLE 4 Permissible Variations from Flatness for Carbon Steel Plates As-Rolled or Normalized Ordered to Restrictive Flatness**

NOTE 1—*Flatness Variations for Length*—The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 3700 mm in length, or in any 3700 mm of longer plates.

NOTE 2—*Flatness Variations for Width*—The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 900 mm, the variation in flatness along the length and across the width shall not exceed 6 mm in each direction. When the longer dimension is from 900 to 1800 mm, inclusive, the permissible flatness variation shall not exceed 75 % of the tabular amount for the specified width, but in no case less than 6 mm.

NOTE 4—The variations given in this table apply to plates that have a minimum specified tensile strength not over 415 mpa or comparable chemistry or hardness. For plates specified to a higher minimum tensile strength or compatible chemistry or hardness, the permissible variations are 1½ times the amounts shown in the table below.

NOTE 5—This table and these notes cover the flatness variations of circular and sketch plates based on the maximum dimensions of those plates.

NOTE 6—Waviness tolerances for rectangular plates, universal mill plates, and circular and sketch plates do not apply.

NOTE 7—A "Z" indicates that there is no published restricted value for the size.

NOTE 8—Plates shall be in horizontal position on a flat surface when flatness is measured.

| Specified Thickness, mm | Permissible Variations from a Flat Surface for Specified Widths, mm | | | | | |
|---|---|---|---|---|---|---|
| | 1200 to 1500, excl | 1500 to 1800, excl | 1800 to 2100, excl | 2100 to 2400, excl | 2400 to 2700, excl | 2700 to 3000, incl |
| To 6, excl | 18 | 24 | Z | Z | Z | Z |
| 6 to 10, excl | 15 | 18 | 22 | 24 | 27 | 29 |
| 10 to 12, excl | 8 | 8 | 10 | 11 | 13 | 15 |
| 12 to 20, excl | 7 | 8 | 8 | 10 | 13 | 13 |
| 20 to 25, excl | 7 | 8 | 8 | 8 | 10 | 11 |
| 25 to 50, excl | 7 | 7 | 7 | 8 | 8 | 8 |

**TABLE 5 Permissible Variations from Flatness for High-Strength Low-Alloy Steel Plates As-Rolled or Normalized Ordered to Restrictive Flatness**

NOTE 1—*Flatness Variations for Length*—The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

NOTE 2—*Flatness Variations for Width*—The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 36 in., the variation in flatness along the length and across the width shall not exceed ⅜ in. in each direction. When the larger dimension is from 36 to 72 in., inclusive, the permissible flatness variation shall not exceed 75 % of the tabular amount for the specified width but in no case less than ⅜ in.

NOTE 4—This table and these notes cover the flatness variations of circular and sketch plates based on the maximum dimensions of those plates.

NOTE 5—Waviness tolerances for rectangular plates, universal mill plates, and circular and sketch plates do not apply.

NOTE 6—A "Z" indicates that there is no published restricted value for the size.

NOTE 7—Plates shall be in horizontal position on a flat surface when flatness is measured.

| Specified Thickness, in. | Permissible Variations from a Flat Surface for Specified Widths, in. | | | | | |
|---|---|---|---|---|---|---|
| | 48 to 60, excl | 60 to 72, excl | 72 to 84, excl | 84 to 96, excl | 96 to 108, excl | 108 to 120, incl |
| To ¼, excl | 1 1/16 | 1 7/16 | Z | Z | Z | Z |
| ¼ to ⅜, excl | ⅞ | 1 1/16 | 1 5/16 | 1 7/16 | 1½ | 1 11/16 |
| ⅜ to ½, excl | ½ | ½ | 9/16 | 11/16 | ¾ | 13/16 |
| ½ to ¾, excl | 7/16 | 7/16 | ½ | 9/16 | ⅝ | 11/16 |
| ¾ to 1, excl | 7/16 | 7/16 | ½ | ½ | 9/16 | 11/16 |
| 1 to 2, incl | ⅜ | 7/16 | 7/16 | ½ | ½ | ½ |



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**TABLE 6 Permissible Variations from Flatness for High-Strength, Low-Alloy Steel Plates As-Rolled or Normalized Ordered to Restrictive Flatness**

NOTE 1—*Flatness Variations for Length*—The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 3700 mm in length, or in any 3700 mm of longer plates.

NOTE 2—*Flatness Variations for Width*—The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 900 mm, the variation in flatness along the length and across the width shall not exceed 10 mm in each direction. When the larger dimension is from 900 to 1800 mm, inclusive, the permissible flatness variation shall not exceed 75 % of the tabular amount for the specified width, but in no case less than 10 mm.

NOTE 4—This table and these notes cover the variations for flatness of circular and sketch plates based on the maximum dimensions of those plates.

NOTE 5—Waviness tolerances for rectangular plates, universal mill plates, and circular and sketch plates do not apply.

NOTE 6—A "Z" indicates that there is no published restricted value for the size.

NOTE 7—Plates shall in a horizontal position on a flat surface when flatness is measured.

| Specified Thickness, mm | Permissible Variations from a Flat Surface for Specified Widths, mm | | | | | |
|---|---|---|---|---|---|---|
| | 1200 to 1500, excl | 1500 to 1800, excl | 1800 to 2100, excl | 2100 to 2400, excl | 2400 to 2700, excl | 2700 to 3000, incl |
| To 6, excl | 27 | 36 | Z | Z | Z | Z |
| 6 to 10, excl | 22 | 27 | 33 | 36 | 39 | 43 |
| 10 to 12, excl | 12 | 12 | 15 | 17 | 19 | 21 |
| 12 to 20, excl | 11 | 11 | 13 | 15 | 16 | 18 |
| 20 to 25, excl | 11 | 11 | 12 | 13 | 15 | 17 |
| 25 to 50, excl | 10 | 11 | 11 | 12 | 13 | 13 |

## ANNEXES

**(Mandatory Information)**

## A1. PERMISSIBLE VARIATIONS IN DIMENSIONS, ETC.—INCH-POUND UNITS

A1.1 Listed below are permissible variations in dimensions, and notch toughness information, expressed in inch-pound units of measurement.

**TABLE A1.1 Permissible Variations in Thickness for Rectangular Plates**

NOTE 1—Permissible variation under specified thickness, 0.01 in.

NOTE 2—Thickness to be measured at ⅜ to ¾ in. from the longitudinal edge.

NOTE 3—For thickness measured at any location other than that specified in Note 2, the permissible maximum over-tolerance shall be increased by 75 %, rounded to the nearest 0.01 in.

| Specified Thickness, in. | Tolerance Over Specified Thickness for Widths Given, in. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 48 and under | Over 48 to 60, excl | 60 to 72, excl | 72 to 84, excl | 84 to 96, excl | 96 to 108, excl | 108 to 120, excl | 120 to 132, excl | 132 to 144, excl | 144 to 168, excl | 168 to 182, excl | 182 and over |
| To ¼, excl | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | ... | ... | ... |
| ¼ to 5/16, excl | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | ... | ... | ... |
| 5/16 to ⅜, excl | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.05 | ... | ... |
| ⅜ to 7/16, excl | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.05 | 0.06 | 0.06 | ... |
| 7/16 to ½, excl | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.05 | 0.06 | 0.06 | ... |
| ½ to ⅝, excl | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.05 | 0.06 | 0.07 | ... |
| ⅝ to ¾, excl | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 | 0.05 | 0.06 | 0.07 | 0.07 |
| ¾ to 1, excl | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.05 | 0.05 | 0.06 | 0.07 | 0.08 | 0.09 |
| 1 to 2, excl | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.07 | 0.08 | 0.10 | 0.10 | 0.11 | 0.13 | 0.16 |
| 2 to 3, excl | 0.09 | 0.09 | 0.09 | 0.10 | 0.10 | 0.11 | 0.12 | 0.13 | 0.14 | 0.15 | 0.15 | ... |
| 3 to 4, excl | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.13 | 0.14 | 0.14 | 0.14 | 0.15 | 0.17 | ... |
| 4 to 6, excl | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.20 | 0.20 | ... |
| 6 to 10, excl | 0.23 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.27 | 0.28 | ... |
| 10 to 12, excl | 0.29 | 0.29 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.35 | ... |
| 12 to 15, incl | 0.29 | 0.29 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | ... |



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**TABLE A1.2 Permissible Variations Over in Width and Length for Sheared Plates (Note 1) and Length Only for Universal Mill Plates (Note 2)**

NOTE 1—Carbon steel and high-strength low-alloy steel plates 1½ in. and under in thickness. Alloy steel plates 1¼ in. and under in thickness.

NOTE 2—Carbon steel and high-strength low-alloy steel plates 2½ in. and under in thickness. Alloy steel plates 2 in. and under in thickness.

NOTE 3—Permissible variation under specified width and length: ¼ in.

| Specified Dimensions, in. | | Variations over Specified Width and Length for Thicknesses, in., Given | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Length | Width | To 3/8, excl | | 3/8 to 5/8, excl | | 5/8 to 1, excl | | 1 to 2, incl[A] | |
| | | Width | Length | Width | Length | Width | Length | Width | Length |
| To 120, excl | over 8 to 60, excl | 3/8 | 1/2 | 7/16 | 5/8 | 1/2 | 3/4 | 5/8 | 1 |
| | 60 to 84, excl | 7/16 | 5/8 | 1/2 | 11/16 | 5/8 | 7/8 | 3/4 | 1 |
| | 84 to 108, excl | 1/2 | 3/4 | 5/8 | 7/8 | 3/4 | 1 | 1 | 1 1/8 |
| | 108 and over | 5/8 | 7/8 | 3/4 | 1 | 7/8 | 1 1/8 | 1 1/8 | 1 1/4 |
| 120 to 240, excl | over 8 to 60, excl | 3/8 | 3/4 | 1/2 | 7/8 | 5/8 | 1 | 3/4 | 1 1/8 |
| | 60 to 84, excl | 1/2 | 3/4 | 5/8 | 7/8 | 3/4 | 1 | 7/8 | 1 1/4 |
| | 84 to 108, excl | 9/16 | 7/8 | 11/16 | 15/16 | 13/16 | 1 1/8 | 1 | 1 3/8 |
| | 108 and over | 5/8 | 1 | 3/4 | 1 1/8 | 7/8 | 1 1/4 | 1 1/8 | 1 3/8 |
| 240 to 360, excl | over 8 to 60, excl | 3/8 | 1 | 1/2 | 1 1/8 | 5/8 | 1 1/4 | 3/4 | 1 1/2 |
| | 60 to 84, excl | 1/2 | 1 | 5/8 | 1 1/8 | 3/4 | 1 1/4 | 7/8 | 1 1/2 |
| | 84 to 108, excl | 9/16 | 1 | 11/16 | 1 1/8 | 7/8 | 1 3/8 | 1 | 1 1/2 |
| | 108 and over | 11/16 | 1 1/8 | 7/8 | 1 1/4 | 1 | 1 3/8 | 1 1/4 | 1 3/4 |
| 360 to 480, excl | over 8 to 60, excl | 7/16 | 1 1/8 | 1/2 | 1 1/4 | 5/8 | 1 3/8 | 3/4 | 1 5/8 |
| | 60 to 84, excl | 1/2 | 1 1/4 | 5/8 | 1 3/8 | 3/4 | 1 1/2 | 7/8 | 1 5/8 |
| | 84 to 108, excl | 9/16 | 1 1/4 | 3/4 | 1 3/8 | 7/8 | 1 1/2 | 1 | 1 7/8 |
| | 108 and over | 3/4 | 1 3/8 | 7/8 | 1 1/2 | 1 | 1 5/8 | 1 1/4 | 1 7/8 |
| 480 to 600, excl | over 8 to 60, excl | 7/16 | 1 1/4 | 1/2 | 1 1/2 | 5/8 | 1 5/8 | 3/4 | 1 7/8 |
| | 60 to 84, excl | 1/2 | 1 3/8 | 5/8 | 1 1/2 | 3/4 | 1 5/8 | 7/8 | 1 7/8 |
| | 84 to 108, excl | 5/8 | 1 3/8 | 3/4 | 1 1/2 | 7/8 | 1 5/8 | 1 | 1 7/8 |
| | 108 and over | 3/4 | 1 1/2 | 7/8 | 1 5/8 | 1 | 1 3/4 | 1 1/4 | 1 7/8 |
| 600 to 720, excl | over 8 to 60, excl | 1/2 | 1 3/4 | 5/8 | 1 7/8 | 3/4 | 1 7/8 | 7/8 | 2 1/4 |
| | 60 to 84, excl | 5/8 | 1 3/4 | 3/4 | 1 7/8 | 7/8 | 1 7/8 | 1 | 2 1/4 |
| | 84 to 108, excl | 5/8 | 1 3/4 | 3/4 | 1 7/8 | 7/8 | 1 7/8 | 1 1/8 | 2 1/4 |
| | 108 and over | 7/8 | 1 3/4 | 1 | 2 | 1 1/8 | 2 1/4 | 1 1/4 | 2 1/2 |
| 720 and over | over 8 to 60, excl | 9/16 | 2 | 3/4 | 2 1/8 | 7/8 | 2 1/4 | 1 | 2 3/4 |
| | 60 to 84, excl | 3/4 | 2 | 7/8 | 2 1/8 | 1 | 2 1/4 | 1 1/8 | 2 3/4 |
| | 84 to 108, excl | 3/4 | 2 | 7/8 | 2 1/8 | 1 | 2 1/4 | 1 1/4 | 2 3/4 |
| | 108 and over | 1 | 2 | 1 1/8 | 2 3/8 | 1 1/4 | 2 1/2 | 1 3/8 | 3 |

[A]Permissible variations in length apply also to carbon-steel and High-Strength Low-Alloy Steel Universal Mill plates up to 12 in. in width for thicknesses over 2 to 2½in., incl.

**TABLE A1.3 Permissible Variations in Rolled Width for Universal Mill Carbon-Steel, High-Strength Low-Alloy Steel and Alloy-Steel Plates 15 in. and under in Thickness**

NOTE 1—Permissible variation under specified width shall be ⅛ in.

| Specified Width, in. | Variations Over Specified Width for Thicknesses Given, in. | | | | | |
|---|---|---|---|---|---|---|
| | To 3/8, excl | 3/8 to 5/8, excl | 5/8 to 1, excl | 1 to 2, incl | Over 2 to 10, incl | Over 10 to 15, incl |
| Over 8 to 20, excl | 1/8 | 1/8 | 3/16 | 1/4 | 3/8 | 1/2 |
| 20 to 36, excl | 3/16 | 1/4 | 5/16 | 3/8 | 7/16 | 9/16 |
| 36 and over | 5/16 | 3/8 | 7/16 | 1/2 | 9/16 | 5/8 |

**TABLE A1.4 Permissible Variations in Diameter for Sheared Circular Carbon-Steel, High-Strength Low-Alloy Steel and Alloy-Steel Plates 1 in. and under in Thickness**

NOTE 1—No permissible variations under specified diameter.

| Specified Diameter, in. | Permissible Variations Over Specified Diameter for Thicknesses Given, in. | | |
|---|---|---|---|
| | To 3/8, excl | 3/8 to 5/8, excl | 5/8 to 1, incl |
| To 32, excl | 1/4 | 3/8 | 1/2 |
| 32 to 84, excl | 5/16 | 7/16 | 9/16 |
| 84 to 108, excl | 3/8 | 1/2 | 5/8 |
| 108 to 130, incl | 7/16 | 9/16 | 11/16 |



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### TABLE A1.5 Permissible Variations in Width and Length for Rectangular Carbon-Steel and High-Strength Low-Alloy Steel Plates when Gas Cutting is Specified or Required

NOTE 1— These variations may be taken all under or divided over and under, if so specified.

NOTE 2—Plates with universal rolled edges will be gas cut to length only.

| Specified Thickness, in. | Variations Over for All Specified Widths or Lengths, in. |
|---|---|
| To 2, excl | ½ |
| 2 to 4, excl | ⅝ |
| 4 to 6, excl | ¾ |
| 6 to 8, excl | ⅞ |
| 8 to 15, incl | 1 |

### TABLE A1.6 Permissible Variations in Diameter for Gas-Cut Circular Carbon-Steel and High-Strength Low-Alloy Steel Plates

NOTE 1—No permissible variations under specified diameter

| Specified Diameter, in. | Variations Over Specified Diameter for Thicknesses Given, in. | | | | | |
|---|---|---|---|---|---|---|
| | To 1, excl | 1 to 2, excl | 2 to 4, excl | 4 to 6, excl | 6 to 8, excl | 8 to 15, incl |
| To 32, excl | ⅜ | ⅜ | ½ | ½ | ⅝ | ¾ |
| 32 to 84, excl | ⅜ | ½ | ½ | ⅝ | ¾ | ⅞ |
| 84 to 108, excl | ½ | 9/16 | ⅝ | ¾ | ⅞ | 1 |
| 108 to 130, excl | ½ | 9/16 | 11/16 | ⅞ | 1 | 1⅛ |
| 130 and over | ⅝ | ¾ | ⅞ | 1 | 1⅛ | 1¼ |

### TABLE A1.7 Permissible Camber for Carbon Steel Sheared or Gas-Cut Rectangular Plates all Thicknesses

NOTE 1—Camber, as it relates to plates, is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

| Maximum permissible camber, in. = ⅛ in. × (number of feet of length/5) |
|---|

### TABLE A1.8 Permissible Camber for Carbon Steel, High-Strength Low-Alloy Steel and Alloy Steel Universal Mill Plates and High-Strength Low-Alloy Steel and Alloy Steel Sheared or Gas-Cut Rectangular Plates

| Dimension, in. | | Camber for Thickness and Widths Given |
|---|---|---|
| Thickness | Width | |
| To 2, incl | all | ⅛ in. × (number of feet of length/5) |
| Over 2 to 15, incl | to 30, incl | 3/16 in. × (number of feet of length/5) |
| Over 2 to 15, incl | over 30 | ¼ in. × (number of feet of length/5) |

### TABLE A1.9 Permissible Variations from Flatness for Carbon-Steel Plates

NOTE 1—*Flatness Variations for Length*—The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

NOTE 2—*Flatness Variations for Width*—The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 36 in., the variation in flatness along the length and across the width shall not exceed ¼ in. in each direction. When the longer dimension is from 36 to 72 in., inclusive, the flatness variation shall not exceed 75 % of the tabular amount for the specified width, but in no case less than ¼ in.

NOTE 4—The tolerances given in this table apply to plates that have a minimum specified tensile strength not over 60 000 psi or compatible chemistry or hardness. For plates specified to a higher minimum tensile strength or compatible chemistry or hardness, the limits given in the table are increased to 1½ times the amounts in the above table.

NOTE 5—This table and notes cover the flatness tolerances of circular and sketch plates, based on the maximum dimensions of those plates.

NOTE 6—Plates shall be in a horizontal position on a flat surface when flatness is measured.

| Specified Thickness, in. | Variations from a Flat Surface for Specified Widths, in. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Over 8 to 36, excl | 36 to 48, excl | 48 to 60, excl | 60 to 72, excl | 72 to 84, excl | 84 to 96, excl | 96 to 108, excl | 108 to 120, excl | 120 to 144, excl | 144 to 168, excl | 168 and over |
| To ¼, excl | 9/16 | ¾ | 15/16 | 1¼ | 1⅜ | 1½ | 1⅝ | 1¾ | 1⅞ | ... | ... |
| ¼ to ⅜, excl | ½ | ⅝ | ¾ | 15/16 | 1⅛ | 1¼ | 1⅜ | 1½ | 1⅝ | ... | ... |
| ⅜ to ½, excl | ½ | 9/16 | ⅝ | ⅝ | ¾ | ⅞ | 1 | 1⅛ | 1¼ | 1⅞ | 2⅛ |
| ½ to ¾, excl | 7/16 | ½ | 9/16 | ⅝ | ⅝ | ¾ | 1 | 1 | 1⅛ | 1½ | 2 |
| ¾ to 1, excl | 7/16 | ½ | 9/16 | ⅝ | ⅝ | ⅝ | ¾ | ⅞ | 1 | 1⅜ | 1¾ |
| 1 to 2, excl | ⅜ | ½ | ½ | 9/16 | 9/16 | ⅝ | ⅝ | ⅝ | 11/16 | 1⅛ | 1½ |
| 2 to 4 excl | 5/16 | ⅜ | 7/16 | ½ | ½ | ½ | ½ | 9/16 | ⅝ | ⅞ | 1⅛ |
| 4 to 6, excl | ⅜ | 7/16 | ½ | ½ | 9/16 | 9/16 | ⅝ | ¾ | ⅞ | ⅞ | 1 |
| 6 to 8, excl | 7/16 | ½ | ½ | ⅝ | 11/16 | ¾ | ⅞ | ⅞ | 1 | 1 | 1 |
| 8 to 10 excl | ½ | ½ | ⅝ | 11/16 | ¾ | 13/16 | ⅞ | 15/16 | 1 | 1 | 1 |
| 10 to 12, excl | ½ | ⅝ | ¾ | 13/16 | ⅞ | 15/16 | 1 | 1 | 1 | 1 | 1 |
| 12 to 15, incl | ⅝ | ¾ | 13/16 | ⅞ | 15/16 | 1 | 1 | 1 | 1 | 1 | ... |



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**TABLE A1.10 Permissible Variations in Width and Length for Rectangular Alloy-Steel Plates when Gas Cutting is Specified or Required**

NOTE 1—These variations may be taken all under or divided over and under, if so specified.

NOTE 2— Plates with universal rolled edges will be gas cut to length only.

| Specified Thickness, in. | Variations Over for All Specified Widths and Lengths, in. |
|---|---|
| To 2, excl | 3/4 |
| 2 to 4, excl | 1 |
| 4 to 6, excl | 1 1/8 |
| 6 to 8, excl | 1 5/16 |
| 8 to 15, incl | 1 1/2 |

**TABLE A1.11 Permissible Variations in Diameter for Gas-Cut Circular Alloy-Steel Plates**

NOTE 1—No permissible variations under specified diameter.

| Specified Diameter, in. | Variations Over Specified Diameter for Thicknesses Given, in. | | | | | |
|---|---|---|---|---|---|---|
| | To 1, excl | 1 to 2, excl | 2 to 4, excl | 4 to 6, excl | 6 to 8, excl | 8 to 15 incl |
| To 32, excl | 1/2 | 3/4 | 3/4 | 3/4 | 1 | 1 |
| 32 to 84, excl | 1/2 | 5/8 | 7/8 | 1 | 1 1/8 | 1 1/4 |
| 84 to 108, excl | 5/8 | 3/4 | 1 | 1 1/8 | 1 1/4 | 1 3/8 |
| 108 to 130, incl | 7/8 | 1 | 1 1/8 | 1 1/4 | 1 3/8 | 1 1/2 |

**TABLE A1.12 Permissible Variations from Flatness for High-Strength Low-Alloy and Alloy-Steel Plates**

NOTE 1—*Flatness Tolerances for Length*—The longer dimension specified is considered the length and variations from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

NOTE 2—*Flatness Tolerances for Width*—The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 36 in., the variation shall not exceed 3/8 in. When the larger dimension is from 36 to 72 in., incl, the variation shall not exceed 75 % of the tabular amount for the specified width.

NOTE 4—This table and notes cover the tolerances for flatness of circular and sketch plates, based on the maximum dimensions of those plates.

NOTE 5—Plates shall be in a horizontal position on a flat surface when flatness is measured.

| Specified Thickness, in. | Variations from a Flat Surface for Specified Widths, in. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Over 8 to 36, excl | 36 to 48, excl | 48 to 60, excl | 60 to 72, excl | 72 to 84, excl | 84 to 96, excl | 96 to 108, excl | 108 to 120, excl | 120 to 144, excl | 144 to 168, excl | 168 and Over |
| To 1/4, excl | 13/16 | 1 1/8 | 1 3/8 | 1 7/8 | 2 | 2 1/4 | 2 3/8 | 2 5/8 | 2 3/4 | ... | ... |
| 1/4 to 3/8, excl | 3/4 | 15/16 | 1 1/8 | 1 3/8 | 1 3/4 | 1 7/8 | 2 | 2 1/4 | 2 3/8 | ... | ... |
| 3/8 to 1/2, excl | 3/4 | 7/8 | 15/16 | 15/16 | 1 1/8 | 1 5/16 | 1 1/2 | 1 5/8 | 1 7/8 | 2 3/4 | 3 1/8 |
| 1/2 to 3/4, excl | 5/8 | 3/4 | 13/16 | 7/8 | 1 | 1 1/8 | 1 1/4 | 1 3/8 | 1 5/8 | 2 1/4 | 3 |
| 3/4 to 1, excl | 5/8 | 3/4 | 7/8 | 7/8 | 15/16 | 1 | 1 1/8 | 1 5/16 | 1 1/2 | 2 | 2 5/8 |
| 1 to 2, excl | 9/16 | 5/8 | 3/4 | 13/16 | 7/8 | 15/16 | 1 | 1 | 1 | 1 5/8 | 2 1/4 |
| 2 to 4, excl | 1/2 | 9/16 | 11/16 | 3/4 | 3/4 | 3/4 | 3/4 | 7/8 | 1 | 1 1/4 | 1 5/8 |
| 4 to 6, excl | 9/16 | 11/16 | 3/4 | 3/4 | 7/8 | 7/8 | 15/16 | 1 1/8 | 1 1/4 | 1 1/4 | 1 1/2 |
| 6 to 8, excl | 5/8 | 3/4 | 3/4 | 15/16 | 1 | 1 1/8 | 1 1/4 | 1 5/16 | 1 1/2 | 1 1/2 | 1 1/2 |
| 8 to 10, excl | 3/4 | 13/16 | 15/16 | 1 | 1 1/8 | 1 1/4 | 1 5/16 | 1 3/8 | 1 1/2 | 1 1/2 | 1 1/2 |
| 10 to 12, excl | 3/4 | 15/16 | 1 1/8 | 1 1/4 | 1 5/16 | 1 3/8 | 1 1/2 | 1 1/2 | 1 1/2 | 1 1/2 | 1 1/2 |
| 12 to 15, incl | 7/8 | 1 | 1 3/16 | 1 5/16 | 1 3/8 | 1 1/2 | 1 1/2 | 1 1/2 | 1 1/2 | 1 1/2 | 1 1/2 |



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**TABLE A1.13 Waviness Tolerances for Rectangular Plates, Universal Mill Plates and Circular and Sketch Plates**

NOTE 1—Waviness denotes the deviation of the top or bottom surface from a horizontal line, when the plate is resting on a flat surface, as measured in an increment of less than 12 ft of length. The waviness tolerance is a function of the flatness tolerance as obtained from Tables A1.9 and A1.12.

| Flatness Tolerance from Tables A1.9 and A1.12 | When Number of Waves in 12 ft is: | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 5/16 | 5/16 | 1/4 | 3/16 | 1/8 | 1/8 | 1/16 | 1/16 |
| 3/8 | 3/8 | 5/16 | 3/16 | 3/16 | 1/8 | 1/16 | 1/16 |
| 7/16 | 7/16 | 5/16 | 1/4 | 3/16 | 1/8 | 1/8 | 1/16 |
| 1/2 | 1/2 | 3/8 | 5/16 | 3/16 | 3/16 | 1/8 | 1/16 |
| 9/16 | 9/16 | 7/16 | 5/16 | 1/4 | 3/16 | 1/8 | 1/8 |
| 5/8 | 5/8 | 1/2 | 3/8 | 1/4 | 3/16 | 1/8 | 1/8 |
| 11/16 | 11/16 | 1/2 | 3/8 | 5/16 | 3/16 | 3/16 | 1/8 |
| 3/4 | 3/4 | 9/16 | 7/16 | 5/16 | 1/4 | 3/16 | 1/8 |
| 13/16 | 13/16 | 5/8 | 7/16 | 5/16 | 1/4 | 3/16 | 1/8 |
| 7/8 | 7/8 | 11/16 | 1/2 | 3/8 | 1/4 | 3/16 | 1/8 |
| 15/16 | 15/16 | 11/16 | 1/2 | 3/8 | 5/16 | 1/4 | 3/16 |
| 1 | 1 | 3/4 | 9/16 | 7/16 | 5/16 | 1/4 | 3/16 |
| 1 1/8 | 1 1/8 | 7/8 | 5/8 | 1/2 | 3/8 | 1/4 | 3/16 |
| 1 1/4 | 1 1/4 | 15/16 | 11/16 | 1/2 | 3/8 | 5/16 | 1/4 |
| 1 3/8 | 1 3/8 | 1 1/16 | 3/4 | 9/16 | 7/16 | 5/16 | 1/4 |
| 1 1/2 | 1 1/2 | 1 1/8 | 7/8 | 5/8 | 1/2 | 3/8 | 1/4 |
| 1 5/8 | 1 5/8 | 1 1/4 | 15/16 | 11/16 | 1/2 | 3/8 | 5/16 |
| 1 3/4 | 1 3/4 | 1 5/16 | 1 | 3/4 | 9/16 | 7/16 | 5/16 |
| 1 7/8 | 1 7/8 | 1 7/16 | 1 1/16 | 13/16 | 9/16 | 7/16 | 5/16 |
| 2 | 2 | 1 1/2 | 1 1/8 | 7/8 | 5/8 | 1/2 | 3/8 |
| 2 1/8 | 2 1/8 | 1 5/8 | 1 3/16 | 7/8 | 11/16 | 1/2 | 3/8 |
| 2 1/4 | 2 1/4 | 1 11/16 | 1 1/4 | 15/16 | 11/16 | 9/16 | 3/8 |
| 2 3/8 | 2 3/8 | 1 13/16 | 1 5/16 | 1 | 3/4 | 9/16 | 7/16 |
| 2 1/2 | 2 1/2 | 1 7/8 | 1 7/16 | 1 1/16 | 13/16 | 9/16 | 7/16 |
| 2 5/8 | 2 5/8 | 2 | 1 1/2 | 1 1/8 | 13/16 | 5/8 | 7/16 |
| 2 3/4 | 2 3/4 | 2 1/16 | 1 9/16 | 1 1/8 | 7/8 | 5/8 | 1/2 |
| 2 7/8 | 2 7/8 | 2 3/16 | 1 5/8 | 1 3/16 | 15/16 | 11/16 | 1/2 |
| 3 | 3 | 2 1/4 | 1 11/16 | 1 1/4 | 15/16 | 11/16 | 9/16 |
| 3 1/8 | 3 1/8 | 2 3/8 | 1 3/4 | 1 5/16 | 1 | 3/4 | 9/16 |



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**TABLE A1.14 Visible Edge Indications Extending Approximately Parallel to Rolled Surfaces**

| Plate Specification and Thickness | Acceptable | | Remove by Grinding | | Acceptable on Edges Cut in Fabrication | |
|---|---|---|---|---|---|---|
| | Depth | Length[A] | Depth | Length[A] | Depth | Length[A] |
| Column | 1 | 2 | 3 | 4 | 5 | 6 |
| Nonkilled,[B] to 2 in., incl | ⅛ in. max | any | over ⅛ in. to ¼ in., incl | over 1 in. | ¼ in. max | any |
| Killed,[C] to 6 in., incl | 1/16 in. max | any | over 1/16 in. to ⅛ in., incl | over 1 in. | ⅛ in. max | any |
| Killed,[C] over 6 in. | ⅛ in. max | any | over ⅛ in. to ½ in., incl | over 1 in. | ½ in. max | any |

[A] Laminar-type discontinuities 1 in. and less in length are acceptable and do not require exploration.
[B] Specifications: A 285; A 433; A 442 in thicknesses to 1 in., incl; or A 455.
[C] The specification in 1.1 of this standard, other than those listed in Footnote *B* of the preceding table.



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**TABLE A1.15 Generally Available Grade-Thickness-Minimum Test Temperature Combinations Meeting Charpy V-Notch Requirements Indicated (Normalized or Quenched and Tempered Condition)**

NOTE 1— The minimum temperatures listed are for longitudinal tests. For transverse tests, the available minimum temperature may be somewhat higher.

| Acceptance Criteria Charpy V-Notch | | | Specification and Grade[A] | Test Temperature, °F for Plate Thicknesses (Unless Otherwise Agreed Upon) | | | |
|---|---|---|---|---|---|---|---|
| Energy Absorption | | | | | | | |
| Class[B] | Average For 3 Specimens[C] ft·lbf, min | Minimum For 1 Specimen[C] ft·lbf | | 1 in. and Under | Over 1 in. to 2 in., incl. | Over 2 in. to 3 in., incl. | Over 3 in. to 5 in., incl. |
| I | 10 | 7 | A 285 Grade A | +40 | +60 | ... | ... |
| | | | A 285 Grade B | +50 | +70 | ... | ... |
| | | | A 285 Grade C | +60 | +80 | ... | ... |
| II | 13 | 10 | A 455 | +25 | ... | ... | ... |
| III | 13 | 10 | A 203 Grade A | −90 | −90 | −75 | ... |
| | | | A 203 Grade D | −150 | −150 | −125 | ... |
| | | | A 442 Grade 55 (1½ in. max thickness | ... | −20 | ... | ... |
| | | | A 442 Grade 60 (1½ in. max thickness) | ... | −15 | ... | ... |
| | | | A 516 Grade 55 | −60 | −60 | −50 | −50 |
| | | | A 516 Grade 60 | −60 | −50 | −50 | −50 |
| | | | A 516 Grade 65 | −60 | −50 | −40 | −25 |
| | | | A 537 Class 1 (Over 2½–4 in.) | ... | ... | −75 | −50 |
| | | | A 662 Grade A | −75 | −75 | ... | ... |
| | | | A 662 Grade B | −60 | −60 | ... | ... |
| IV | 15 | 12 | A 203 Grade B | −90 | −90 | −75 | ... |
| | | | A 203 Grade E | −150 | −150 | −125 | ... |
| | | | A 203 Grade F (4 in. max) | ... | ... | −160 | −160 |
| | | | A 299 | +20 | +30 | +30 | +40 |
| | | | A 516 Grade 70 | −50 | −40 | −30 | −20 |
| | | | A 537 Class 1 (2½ in. max) | −80 | −75 | −75 | ... |
| | | | A 537 Class 2 (Over 2½–4 in.) | ... | ... | −75 | −50 |
| | | | A 662 Grade C | −50 | −50 | ... | ... |
| V | 20 | 15 | A 203 Grade F | −160 | −160 | ... | ... |
| | | | A 537 Class 2 (2½ in. max) | −90 | −90 | −90 | ... |
| | | | A 612 | −50 | ... | ... | ... |
| | | | A 724 Grade A | −50 | ... | ... | ... |
| | Lateral Expansion Mils. Minimum Each Specimen Transverse Test | | | | | | |
| VI | | 15 | A 353 | −320 | −320 | ... | ... |
| | | | A 553 Type I | −320 | −320 | ... | ... |
| | | | A 553 Type II | −275 | −275 | ... | ... |
| | | | A 645 | −275 | −275 | ... | ... |
| | | | A 517 all (2½ in. max thickness) | [A] | [A] | ... | ... |
| | | | A 724 Grade B | −50 | ... | ... | ... |

[A] Testing temperature as specified on order but no higher than 32°F.

[B] Class I is *Other Than Fully Killed* with a specified minimum tensile strength of 65 ksi or lower.
Class II is *Other Than Fully Killed* with a specified minimum tensile strength of over 65 ksi to 75 ksi.
Class III is *Fully Killed* with a specified minimum tensile strength of 65 ksi or lower.
Class IV is *Fully Killed* with a specified minimum tensile strength of over 65 ksi to 75 ksi.
Class V is *Fully Killed* with a specified minimum tensile strength of over 75 ksi to but not including 95 ksi.
Class VI is *Fully Killed* with a specified minimum tensile strength of 95 ksi and over.

[C] Full size (10 by 10-mm) specimens.



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**TABLE A1.16 Charpy V-Notch Test Acceptance Criteria for Various Sub-Size Specimens[A]**

| Full Size, 10 by 10 mm | | ¾ Size, 10 by 7.5 mm | | ⅔ Size, 10 by 6.7 mm | | ½ Size, 10 by 5 mm | | ⅓ Size, 10 by 3.3 mm | | ¼ Size, 10 by 2.5 mm | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ft·lbf | [J] | ft·lbf | [J] | ft·lbf | [J] | ft·lbf | [J] | ft·lbf | [J] | ft·lbf | [J] |
| 40 | [54] | 30 | [41] | 27 | [37] | 20 | [27] | 13 | [18] | 10 | [14] |
| 35 | [48] | 26 | [35] | 23 | [31] | 18 | [24] | 12 | [16] | 9 | [12] |
| 30 | [41] | 22 | [30] | 20 | [27] | 15 | [20] | 10 | [14] | 8 | [11] |
| 25 | [34] | 19 | [26] | 17 | [23] | 12 | [16] | 8 | [11] | 6 | [8] |
| 20 | [27] | 15 | [20] | 13 | [18] | 10 | [14] | 7 | [10] | 5 | [7] |
| 16 | [22] | 12 | [16] | 11 | [15] | 8 | [11] | 5 | [7] | 4 | [5] |
| 15 | [20] | 11 | [15] | 10 | [14] | 8 | [11] | 5 | [7] | 4 | [5] |
| 13 | [18] | 10 | [14] | 9 | [12] | 6 | [8] | 4 | [5] | 3 | [4] |
| 12 | [16] | 9 | [12] | 8 | [11] | 6 | [8] | 4 | [5] | 3 | [4] |
| 10 | [14] | 8 | [11] | 7 | [10] | 5 | [7] | 3 | [4] | 2 | [3] |
| 7 | [10] | 5 | [7] | 5 | [7] | 4 | [5] | 2 | [3] | 2 | [3] |

[A]Interpolation shall be made for specimens with widths intermediate of those listed. Interpolated values shall be rounded to the nearest whole number as prescribed in Practice E 29.

**TABLE A1.17 Permissible Variations in Width for Mill Edge Carbon Steel and High-Strength Low-Alloy Steel Plates Produced on Strip Mills**

NOTE 1— Applies to either plates produced from coils or plates produced in discrete cut lengths of flat product.

| Specified Width, in. | Variations over Specified Width, in[A] |
|---|---|
| To 14, excl | 7/16 |
| 14 to 17, excl | ½ |
| 17 to 19, excl | 9/16 |
| 19 to 21, excl | ⅝ |
| 21 to 24, excl | 11/16 |
| 24 to 26, excl | 13/16 |
| 26 to 28, excl | 15/16 |
| 28 to 35, excl | 1⅛ |
| 35 to 50, excl | 1¼ |
| 50 to 60, excl | 1½ |
| 60 to 65, excl | 1⅝ |
| 65 to 70, excl | 1¾ |
| 70 to 80, excl | 1⅞ |
| 80 and over | 2 |

[A]No permissible variation under specified width.

## A2. PERMISSIBLE VARIATIONS IN DIMENSIONS, ETC.—SI UNITS

A2.1 Listed herein are permissible variations in dimensions, and notch toughness information, expressed in SI units.



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**TABLE A2.1 Permissible Variations in Thickness for Rectangular Plates**

NOTE 1—Permissible variation under specified thickness, 0.3 mm.

NOTE 2—Thickness shall be measured 10 to 20 mm from the longitudinal edge.

NOTE 3—For specified thicknesses other than those shown, the tolerances for the next higher thickness shall apply.

NOTE 4—For thickness measured at any location other than that specified in Note 2, the permissible maximum over tolerance shall be increased by 75 %, rounded to the nearest 0.1 mm.

| Specified Thickness, mm | Tolerance Over Specified Thickness for Widths Given in Millimetres, mm | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1200 and Under | Over 1200 to 1500, excl | 1500 to 1800, excl | 1800 to 2100, excl | 2100 to 2400, excl | 2400 to 2700, excl | 2700 to 3000, excl | 3000 to 3300, excl | 3300 to 3600, excl | 3600 to 4200, excl | 4200 and Over |
| 5.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 1.0 | | |
| 5.5 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 1.0 | | |
| 6.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 1.0 | 1.1 | 1.4 | |
| 7.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 1.0 | 1.2 | 1.4 | |
| 8.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 1.0 | 1.2 | 1.5 | 1.7 |
| 9.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 1.0 | 1.0 | 1.3 | 1.5 | 1.7 |
| 10.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 1.0 | 1.0 | 1.3 | 1.5 | 1.8 |
| 11.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 1.0 | 1.0 | 1.3 | 1.5 | 1.8 |
| 12.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 1.0 | 1.0 | 1.3 | 1.5 | 1.8 |
| 14.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 0.9 | 1.0 | 1.1 | 1.3 | 1.5 | 2.0 |
| 16.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 0.9 | 1.0 | 1.1 | 1.3 | 1.6 | 2.0 |
| 18.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.4 | 1.6 | 2.0 |
| 20.0 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 1.0 | 1.2 | 1.2 | 1.4 | 1.8 | 2.2 |
| 22.0 | 0.8 | 0.9 | 0.9 | 0.9 | 1.0 | 1.1 | 1.3 | 1.3 | 1.5 | 1.8 | 2.2 |
| 25.0 | 0.9 | 0.9 | 1.0 | 1.0 | 1.0 | 1.2 | 1.3 | 1.5 | 1.5 | 2.0 | 2.4 |
| 28.0 | 1.0 | 1.0 | 1.1 | 1.1 | 1.1 | 1.3 | 1.4 | 1.8 | 1.8 | 2.1 | 2.6 |
| 30.0 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.4 | 1.5 | 1.8 | 1.8 | 2.3 | 2.8 |
| 32.0 | 1.2 | 1.2 | 1.3 | 1.3 | 1.3 | 1.5 | 1.6 | 2.0 | 2.0 | 2.5 | 3.0 |
| 35.0 | 1.3 | 1.3 | 1.4 | 1.4 | 1.4 | 1.6 | 1.7 | 2.3 | 2.3 | 2.7 | 3.3 |
| 38.0 | 1.4 | 1.4 | 1.5 | 1.5 | 1.5 | 1.7 | 1.8 | 2.3 | 2.3 | 2.8 | 3.5 |
| 40.0 | 1.5 | 1.5 | 1.6 | 1.6 | 1.6 | 1.8 | 2.0 | 2.5 | 2.5 | 3.0 | 3.8 |
| 45.0 | 1.6 | 1.6 | 1.7 | 1.8 | 1.8 | 2.0 | 2.3 | 2.8 | 2.8 | 3.3 | 3.8 |
| 50.0 | 1.8 | 1.8 | 1.8 | 2.0 | 2.0 | 2.3 | 2.5 | 3.0 | 3.0 | 3.5 | 4.0 |
| 55.0 | 2.0 | 2.0 | 2.0 | 2.2 | 2.2 | 2.5 | 2.8 | 3.3 | 3.3 | 3.8 | 4.0 |
| 60.0 | 2.3 | 2.3 | 2.3 | 2.4 | 2.4 | 2.8 | 3.0 | 3.4 | 3.4 | 4.0 | 4.0 |
| 70.0 | 2.5 | 2.5 | 2.5 | 2.6 | 2.6 | 3.0 | 3.3 | 3.5 | 3.6 | 4.0 | 4.4 |
| 80.0 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 3.3 | 3.5 | 3.5 | 3.6 | 4.0 | 4.4 |
| 90.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.5 | 3.5 | 3.5 | 3.6 | 4.4 | 4.4 |
| 100.0 | 3.3 | 3.3 | 3.3 | 3.3 | 3.5 | 3.8 | 3.8 | 3.8 | 3.8 | 4.4 | 4.8 |
| 110.0 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.8 | 3.8 | 3.8 | 3.8 | 4.8 | 5.2 |
| 120.0 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 5.2 | 5.6 |
| 130.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.6 | 5.6 |
| 140.0 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 5.6 | 5.6 |
| 150.0 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 5.6 | 6.3 |
| 160.0 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 6.3 | 7.0 |
| 180.0 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 7.0 | 8.8 |
| 200.0 | 5.8 | 5.8 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 7.5 | 9.0 |
| 250.0 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 9.0 | |
| 300.0 | 7.5 | 7.5 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | | |



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**TABLE A2.2 Permissible Variations Over in Width and Length for Sheared Plates (Note 1) and Length only for Universal Mill Plates (Note 2)**

NOTE 1— Carbon steel and high-strength low-alloy steel plates 40 mm and under in thickness. Alloy steel plates 30 mm and under in thickness.

NOTE 2— Carbon steel and high-strength low-alloy steel plates 65 mm and under in thickness. Alloy steel plates 50 mm and under in thickness.

NOTE 3—Permissible variation under in specified width and length: 6 mm.

| Specified Dimensions, mm | | Variations over Specified Width and Length for Thicknesses Given, mm | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Length | Width | To 10, excl | | 10 to 16, excl | | 16 to 25, excl | | 25 to 50, incl[A] | |
| | | Width | Length | Width | Length | Width | Length | Width | Length |
| To 3 000 excl | to 1500 excl | 10 | 13 | 11 | 16 | 13 | 19 | 16 | 25 |
| | 1500 to 2100 excl | 11 | 16 | 13 | 17 | 16 | 22 | 19 | 25 |
| | 2100 to 2700 excl | 13 | 19 | 16 | 22 | 19 | 25 | 25 | 29 |
| | 2700 and over | 16 | 22 | 19 | 25 | 22 | 29 | 29 | 32 |
| 3 000 to 6 000 excl | to 1500 excl | 10 | 19 | 13 | 22 | 16 | 25 | 19 | 29 |
| | 1500 to 2100 excl | 13 | 19 | 16 | 22 | 19 | 25 | 22 | 32 |
| | 2100 to 2700 excl | 14 | 22 | 17 | 24 | 21 | 29 | 25 | 35 |
| | 2700 and over | 16 | 25 | 19 | 29 | 22 | 32 | 29 | 35 |
| 6 000 to 9 000 excl | to 1500 excl | 10 | 25 | 13 | 29 | 16 | 32 | 19 | 38 |
| | 1500 to 2100 excl | 13 | 25 | 16 | 29 | 19 | 32 | 22 | 38 |
| | 2100 to 2700 excl | 14 | 25 | 17 | 32 | 22 | 35 | 25 | 38 |
| | 2700 and over | 17 | 29 | 22 | 32 | 25 | 35 | 32 | 44 |
| 9 000 to 12 000 excl | to 1500 excl | 11 | 29 | 13 | 32 | 16 | 35 | 19 | 41 |
| | 1500 to 2100 excl | 13 | 32 | 16 | 35 | 19 | 38 | 22 | 41 |
| | 2100 to 2700 excl | 14 | 32 | 19 | 35 | 22 | 38 | 25 | 48 |
| | 2700 and over | 19 | 35 | 22 | 38 | 25 | 41 | 32 | 48 |
| 12 000 to 15 000 excl | to 1500 excl | 11 | 32 | 13 | 38 | 16 | 41 | 19 | 48 |
| | 1500 to 2100 excl | 13 | 35 | 16 | 38 | 19 | 41 | 22 | 48 |
| | 2100 to 2700 excl | 16 | 35 | 19 | 38 | 22 | 41 | 25 | 48 |
| | 2700 and over | 19 | 38 | 22 | 41 | 25 | 44 | 32 | 48 |
| 15 000 to 18 000 excl | to 1500 excl | 13 | 44 | 16 | 48 | 19 | 48 | 22 | 57 |
| | 1500 to 2100 excl | 16 | 44 | 19 | 48 | 22 | 48 | 25 | 57 |
| | 2100 to 2700 excl | 16 | 44 | 19 | 48 | 22 | 48 | 29 | 57 |
| | 2700 and over | 22 | 44 | 25 | 51 | 29 | 57 | 32 | 64 |
| 18 000 and over | to 1500 excl | 14 | 51 | 19 | 54 | 22 | 57 | 25 | 70 |
| | 1500 to 2100 excl | 19 | 51 | 22 | 54 | 25 | 57 | 29 | 70 |
| | 2100 to 2700 excl | 19 | 51 | 22 | 54 | 25 | 57 | 32 | 70 |
| | 2700 and over | 25 | 51 | 29 | 60 | 32 | 64 | 35 | 76 |

[A]Permissible variations in length apply also to carbon-steel and high-strength low-alloy steel Universal Mill plates up to 300 mm in width for thicknesses over 50 to 65 mm, incl.

**TABLE A2.3 Permissible Variations in Rolled Width for Universal Mill Carbon-Steel, High-Strength Low-Alloy and Alloy-Steel Plates 400 mm and under in Thickness**

NOTE 1— Permissible variation under specified width shall be 3 mm.

| Specified Width, mm | Variations Over Specified Width for Thickness Given, mm | | | | | |
|---|---|---|---|---|---|---|
| | To 10, excl | 10 to 16, excl | 16 to 25, excl | 25 to 50, excl | Over 50 to 250, incl | Over 250 to 400, incl |
| Over 200 to 500, excl | 3 | 3 | 5 | 6 | 10 | 13 |
| 500 to 900, excl | 5 | 6 | 8 | 10 | 11 | 14 |
| 900 and over | 8 | 10 | 11 | 13 | 14 | 16 |

**TABLE A2.4 Permissible Variations in Diameter for Sheared Circular Carbon Steel, High-Strength Low-Alloy Steel and Alloy-Steel Plates 25 mm and under in Thickness**

NOTE 1— No permissible variations under specified diameter.

| Specified Diameters, mm | Permissible Variations Over Specified Diameter for Thicknesses Given, mm | | |
|---|---|---|---|
| | To 10, excl | 10 to 16, excl | 16 to 25, incl |
| To 800, excl | 6 | 10 | 13 |
| 800 to 2100, excl | 8 | 11 | 14 |
| 2100 to 2700, excl | 10 | 13 | 16 |
| 2700 to 3300, excl | 11 | 14 | 17 |
| 3300 and over | 13 | 16 | 19 |



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**TABLE A2.5 Permissible Variations in Width and Length for Rectangular Carbon-Steel and High-Strength Low-Alloy Steel Plates when Gas Cutting Is Specified or Required**

NOTE 1—These variations may be taken all under or divided over and under, if so specified.

NOTE 2— Plates with universal rolled edges will be gas cut to length only.

| Specified Thickness, mm | Variations Over for All Specified Widths or Lengths, mm |
|---|---|
| To 50, excl | 13 |
| 50 to 100, excl | 16 |
| 100 to 150, excl | 19 |
| 150 to 200, excl | 22 |
| 200 to 400, incl | 25 |

**TABLE A2.6 Permissible Variations in Diameter for Gas-Cut Circular Carbon-Steel and High-Strength Low-Alloy Steel Plates**

NOTE 1— No permissible variations under specified diameter.

| Specified Diameters, mm | Variations Over Specified Diameter for Thicknesses Given, mm | | | | | |
|---|---|---|---|---|---|---|
| | To 25, excl | 25 to 50, excl | 50 to 100, excl | 100 to 150, excl | 150 to 200, excl | 200 to 400, excl |
| To 800, excl | 10 | 10 | 13 | 13 | 16 | 19 |
| 800 to 2100, excl | 10 | 13 | 13 | 16 | 19 | 22 |
| 2100 to 2700, excl | 13 | 14 | 16 | 19 | 22 | 25 |
| 2700 to 3300, excl | 13 | 14 | 17 | 22 | 25 | 29 |
| 3300 and over | 16 | 19 | 22 | 25 | 29 | 32 |

**TABLE A2.7 Permissible Camber for Carbon Steel Sheared or Gas-Cut Rectangular Plates all Thicknesses**

NOTE 1— Camber, as it relates to plates, is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

| |
|---|
| Maximum permissible camber, mm = length in millimetres/500 |

**TABLE A2.8 Permissible Camber for Carbon Steel, High-Strength Low-Alloy Steel and Alloy Steel Universal Mill Plates and High-Strength Low-Alloy Steel and Alloy Steel Sheared or Gas-Cut Rectangular Plates**

NOTE 1— Camber, as it relates to plates, is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

| Width, mm | Camber for Width Given, mm |
|---|---|
| To 750, incl | Length/300 |
| Over 750 to 1500 | Length/250 |

**TABLE A2.9 Permissible Variations from Flatness for Carbon-Steel Plates**

NOTE 1—*Flatness Variations for Length*—The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 4000 mm in length, or in any 4000 mm of longer plates.

NOTE 2—*Flatness Variations for Width*—The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 900 mm, the variation in flatness along the length and across the width shall not exceed 6 mm in each direction. When the longer dimension is from 900 to 1800 mm, inclusive, the flatness variation shall not exceed 75 % of the tabular amount for the specified width, but in no case less than 6 mm.

NOTE 4—The tolerances given in this table apply to plates that have a minimum specified tensile strength not over 400 MPa or compatible chemistry or hardness. For plates specified to a higher minimum tensile strength or compatible chemistry or hardness, the limits given in the table are increased to 1½ times the amounts in the above table.

NOTE 5—This table and notes cover the flatness tolerances of circular and sketch plates, based on the maximum dimensions of those plates.

NOTE 6—Plates shall be in a horizontal position on a flat surface when flatness is measured.

| Specified Thickness, mm | Permissible Variations from a Flat Surface for Specified Widths, mm | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | To 900, excl | 900 to 1200 | 1200 to 1500 | 1500 to 1800 | 1800 to 2100 | 2100 to 2400 | 2400 to 2700 | 2700 to 3000 | 3000 to 3600 | 3600 to 4200 | 4200 and Over |
| To 6, excl | 14 | 19 | 24 | 32 | 35 | 38 | 41 | 44 | 48 | ... | ... |
| 6 to 10, excl | 13 | 16 | 19 | 24 | 29 | 32 | 35 | 38 | 41 | ... | ... |
| 10 to 12, excl | 13 | 14 | 16 | 16 | 19 | 22 | 25 | 29 | 32 | 48 | 54 |
| 12 to 20, excl | 11 | 13 | 14 | 16 | 16 | 19 | 25 | 25 | 29 | 38 | 51 |
| 20 to 25, excl | 11 | 13 | 14 | 16 | 16 | 16 | 19 | 22 | 25 | 35 | 44 |
| 25 to 50, excl | 10 | 13 | 13 | 14 | 14 | 16 | 16 | 16 | 18 | 29 | 38 |
| 50 to 100, excl | 8 | 10 | 11 | 13 | 13 | 13 | 13 | 14 | 16 | 22 | 29 |
| 100 to 150, excl | 10 | 11 | 13 | 13 | 14 | 14 | 16 | 19 | 22 | 22 | 25 |
| 150 to 200, excl | 11 | 13 | 13 | 16 | 18 | 19 | 22 | 22 | 25 | 25 | 25 |
| 200 to 250, excl | 13 | 13 | 16 | 18 | 19 | 21 | 22 | 24 | 25 | 25 | 25 |
| 250 to 300, excl | 13 | 16 | 19 | 21 | 22 | 24 | 25 | 25 | 25 | 25 | 25 |
| 300 to 400, incl | 16 | 19 | 21 | 22 | 24 | 25 | 25 | 25 | 25 | 25 | ... |



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**TABLE A2.10 Permissible Variations in Width and Length for Rectangular Alloy-Steel Plates when Gas Cutting is Specified or Required**

NOTE 1— These variations may be taken all under or divided over and under, if so specified.

NOTE 2—Plates with universal rolled edges will be gas cut to length only.

| Specified Thickness, mm | Variations Over for All Specified Widths and Lengths, mm |
|---|---|
| To 50, excl | 19 |
| 50 to 100, excl | 25 |
| 100 to 150, excl | 29 |
| 150 to 200, excl | 33 |
| 200 to 400, incl | 38 |

**TABLE A2.11 Permissible Variations in Diameter for Gas Cut Circular Alloy-Steel Plates**

NOTE 1— No permissible variations under specified diameter.

| Specified Diameter, mm | Variations Over Specified Diameter for Thicknesses Given, mm | | | | | |
|---|---|---|---|---|---|---|
| | To 25, excl | 25 to 50, excl | 50 to 100, excl | 100 to 150, excl | 150 to 200, excl | 200 to 400, incl |
| To 800, excl | 13 | 13 | 19 | 19 | 25 | 25 |
| 800 to 2100, excl | 13 | 16 | 22 | 25 | 29 | 32 |
| 2100 to 2700, excl | 16 | 19 | 25 | 29 | 32 | 35 |
| 2700 to 3300, incl | 22 | 25 | 29 | 32 | 35 | 38 |

**TABLE A2.12 Permissible Variations from Flatness for High-Strength Low-Alloy and Alloy-Steel Plates**

NOTE 1—*Flatness Tolerances for Length*—The longer dimension specified is considered the length and variations from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 4000 mm in length, or in any 4000 mm of longer plates.

NOTE 2—*Flatness Tolerances for Width*—The flatness variation across the width shall not exceed the tabular amount for the specified width.

NOTE 3—When the longer dimension is under 900 mm, the variation shall not exceed 10 mm. When the larger dimension is from 900 to 1800 mm, incl, the variation shall not exceed 75 % of the tabular amount for the specified width.

NOTE 4—This table and notes cover the tolerances for flatness of circular and sketch plates, based on the maximum dimensions of those plates.

NOTE 5—Plates shall be in a horizontal position on a flat surface when flatness is measured.

| Specified Thickness, mm | Flatness Tolerances for Specified Widths, mm | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | To 900, excl | 900 to 1200 | 1200 to 1500 | 1500 to 1800 | 1800 to 2100 | 2100 to 2400 | 2400 to 2700 | 2700 to 3000 | 3000 to 3600 | 3600 to 4200 | 4200 and over |
| To 6, excl | 21 | 29 | 35 | 48 | 51 | 57 | 60 | 67 | 70 | ... | ... |
| 6 to 10, excl | 19 | 24 | 29 | 35 | 44 | 48 | 51 | 57 | 60 | ... | ... |
| 10 to 12, excl | 19 | 22 | 24 | 24 | 29 | 33 | 38 | 41 | 48 | 70 | 79 |
| 12 to 20, excl | 16 | 19 | 21 | 22 | 25 | 29 | 32 | 35 | 41 | 57 | 76 |
| 20 to 25, excl | 16 | 19 | 22 | 22 | 24 | 25 | 29 | 33 | 38 | 51 | 67 |
| 25 to 50, excl | 14 | 16 | 19 | 21 | 22 | 24 | 25 | 25 | 25 | 41 | 57 |
| 50 to 100, excl | 13 | 14 | 18 | 19 | 19 | 19 | 19 | 22 | 25 | 32 | 41 |
| 100 to 150, excl | 14 | 18 | 19 | 19 | 22 | 22 | 24 | 29 | 32 | 32 | 38 |
| 150 to 200, excl | 16 | 19 | 19 | 24 | 25 | 29 | 32 | 33 | 38 | 38 | 38 |
| 200 to 250, excl | 19 | 21 | 24 | 25 | 29 | 32 | 33 | 35 | 38 | 38 | 38 |
| 250 to 300, excl | 19 | 24 | 29 | 32 | 33 | 35 | 38 | 38 | 38 | 38 | 38 |
| 300 to 400, incl | 22 | 25 | 30 | 33 | 35 | 38 | 38 | 38 | 38 | 38 | 38 |



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**TABLE A2.13 Waviness Tolerances for Rectangular Plates, Universal Mill Plates and Circular and Sketch Plates**

NOTE 1— Waviness denotes the deviation of the top or bottom surface from a horizontal line, when the plate is resting on a flat surface, as measured in an increment of less than 4000 mm of length. The waviness tolerance is a function of the flatness tolerance as obtained from Tables A 2.9 and A 2.12.

| Flatness Tolerance from Tables A2.9 and A2.12 | When Number of Waves in 4000 mm is: | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 8 | 6 | 5 | 3 | 3 | 2 | 2 |
| 10 | 10 | 8 | 5 | 5 | 3 | 2 | 2 |
| 11 | 11 | 8 | 6 | 5 | 3 | 3 | 2 |
| 13 | 13 | 10 | 8 | 5 | 5 | 3 | 2 |
| 14 | 14 | 11 | 8 | 6 | 5 | 3 | 2 |
| 16 | 16 | 13 | 10 | 6 | 5 | 3 | 2 |
| 17 | 17 | 13 | 10 | 8 | 5 | 5 | 2 |
| 19 | 19 | 14 | 11 | 8 | 6 | 5 | 2 |
| 21 | 21 | 16 | 11 | 8 | 6 | 5 | 2 |
| 22 | 22 | 17 | 13 | 10 | 6 | 5 | 2 |
| 24 | 24 | 17 | 13 | 10 | 8 | 6 | 5 |
| 25 | 25 | 19 | 14 | 11 | 8 | 6 | 5 |
| 29 | 29 | 22 | 16 | 13 | 10 | 6 | 5 |
| 32 | 32 | 24 | 17 | 13 | 10 | 8 | 6 |
| 35 | 35 | 27 | 19 | 14 | 11 | 8 | 6 |
| 38 | 38 | 29 | 22 | 16 | 13 | 10 | 6 |
| 41 | 41 | 32 | 24 | 17 | 13 | 10 | 8 |
| 44 | 44 | 33 | 25 | 19 | 14 | 11 | 8 |
| 48 | 48 | 37 | 27 | 21 | 14 | 11 | 8 |
| 51 | 51 | 38 | 29 | 22 | 16 | 13 | 10 |
| 54 | 54 | 41 | 30 | 22 | 17 | 13 | 10 |
| 57 | 57 | 43 | 32 | 24 | 17 | 14 | 10 |
| 60 | 60 | 46 | 33 | 25 | 19 | 14 | 11 |
| 64 | 64 | 48 | 37 | 27 | 21 | 14 | 11 |
| 67 | 67 | 51 | 38 | 29 | 21 | 16 | 11 |
| 70 | 70 | 52 | 40 | 29 | 22 | 16 | 13 |
| 73 | 73 | 56 | 41 | 30 | 24 | 17 | 13 |
| 76 | 76 | 57 | 43 | 32 | 24 | 17 | 14 |
| 79 | 79 | 60 | 44 | 33 | 25 | 19 | 14 |

**TABLE A2.14 Visible Edge Indications Extending Approximately Parallel to Rolled Surfaces**

| Plate Specification and Thickness | Acceptable | | Remove by Grinding | | Acceptable on Edges Cut in Fabrication | |
|---|---|---|---|---|---|---|
| | Depth | Length[A] | Depth | Length[A] | Depth | Length[A] |
| Column | 1 | 2 | 3 | 4 | 5 | 6 |
| Nonkilled,[B] to 50 mm, incl | 3 mm, max | any | over 3 to 6 mm, incl | over 25 mm | 6 mm max | any |
| Killed,[C] to 150 mm, incl | 2 mm, max | any | over 2 to 3 mm, incl | over 25 mm | 3 mm max | any |
| Killed,[C] over 150 mm | 3 mm, max | any | over 3 to 13 mm, incl | over 25 mm | 13 mm max | any |

[A] Laminar-type discontinuities 25 mm and less in length are acceptable and do not require exploration.
[B] Specifications: A 285; A 433; A 442 in thicknesses to 25 mm, incl; or A 455.
[C] The specifications in 1.1 Scope, of this document other than those listed in the above footnote *B*.



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**TABLE A2.15 Generally Available Grade-Thickness-Minimum Test Temperature Combinations Meeting Charpy V-Notch Requirements Indicated (Normalized or Quenched and Tempered Condition)**

NOTE 1— The minimum temperatures listed are for longitudinal tests. For transverse tests, the available minimum temperature may be somewhat higher.

| Acceptance Criteria Charpy V-Notch Energy Absorption | | | Specification and Grade | Test Temperature, °C for Plate Thicknesses (Unless Otherwise Agreed Upon) | | | |
|---|---|---|---|---|---|---|---|
| Class[A] | Average For 3 Specimens[B], J, min | Minimum For 1 Specimen[B], J | | 25 mm and Under | Over 25 mm to 50 mm, incl. | Over 50 mm to 75 mm, incl. | Over 75 mm to 125 mm, incl. |
| I | 14 | 10 | A 285 Grade A | +4 | +16 | ... | ... |
| | | | A 285 Grade B | +10 | +21 | ... | ... |
| | | | A 285 Grade C | +16 | +27 | ... | ... |
| II | 18 | 14 | A 455 | −4 | ... | ... | ... |
| III | 18 | 14 | A 203 Grade A | −68 | −68 | −60 | ... |
| | | | A 203 Grade D | −101 | −101 | −87 | ... |
| | | | A 442 Grade 55 (38 mm max thickness) | ... | −29 | ... | ... |
| | | | A 442 Grade 60 (38 mm max thickness) | ... | −26 | ... | ... |
| | | | A 516 Grade 55 | −51 | −51 | −46 | −46 |
| | | | A 516 Grade 60 | −51 | −46 | −46 | −46 |
| | | | A 516 Grade 65 | −51 | −46 | −40 | −32 |
| | | | A 537 Class 1 (Over 64–100 mm) | ... | ... | −60 | −46 |
| | | | A 662 Grade A | −60 | −60 | ... | ... |
| | | | A 662 Grade B | −51 | −51 | ... | ... |
| IV | 20 | 16 | A 203 Grade B | −68 | −68 | −60 | ... |
| | | | A 203 Grade E | −101 | −101 | −87 | ... |
| | | | A 203 Grade F (100 mm max) | ... | ... | −107 | −107 |
| | | | A 299 | −7 | −1 | −1 | +4 |
| | | | A 516 Grade 70 | −46 | −40 | −35 | −29 |
| | | | A 537 Class 1 (64 mm max) | −62 | −60 | −60 | ... |
| | | | A 537 Class 2 (Over 64–100 mm) | ... | ... | −60 | −46 |
| | | | A 662 Grade C | −46 | −46 | ... | ... |
| V | 27 | 20 | A 203 Grade F | −107 | −107 | ... | .. |
| | | | A 537 Class 2 (64 mm max) | −68 | −68 | −68 | ... |
| | | | A 612 | −46 | ... | ... | ... |
| | | | A 724 Grade A | −46 | ... | ... | ... |
| Lateral Expansion mm, Minimum Each Specimen Transverse Test | | | | | | | |
| VI | 0.38 | | A 353 | −196 | −196 | ... | ... |
| | | | A 553 Type I | −196 | −196 | ... | ... |
| | | | A 553 Type II | −170 | −170 | ... | ... |
| | | | A 645 | −170 | −170 | ... | ... |
| | | | A 517 all (64 mm max thickness) | [C] | [C] | ... | ... |
| | | | A 724 Grade B | −46 | ... | ... | ... |

[A]Class I is *Other Than Fully Killed* with a specified minimum tensile strength of 450 MPa or lower.
Class II is *Other Than Fully Killed* with a specified minimum tensile strength of over 450 to 520 MPa, incl.
Class III is *Fully Killed* with a specified minimum tensile strength of 450 MPa or lower.
Class IV is *Fully Killed* with a specified minimum tensile strength of over 450 to 520 MPa, incl.
Class V is *Fully Killed* with a specified minimum tensile strength of over 520 MPa to but not including 655 MPa.
Class VI is *Fully Killed* with a specified minimum tensile strength of 655 MPa and over.
[B]Full size (10 by 10-mm) specimens.
[C]Testing temperature as specified on order but no higher than 0°C.



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**TABLE A2.16 Permissible Variations in Width for Mill Edge Carbon Steel and High-Strength Low-Alloy Steel Plates Produced on Strip Mills**

NOTE 1— Applies to either plates produced from coils or plates produced in discrete cut lengths of flat product.

| Specified Width, mm | Variations Over Specified Width, mm[A] |
|---|---|
| To 360, excl | 11 |
| 360 to 430, excl | 13 |
| 430 to 480, excl | 14 |
| 480 to 530, excl | 16 |
| 530 to 610, excl | 17 |
| 610 to 660, excl | 21 |
| 660 to 710, excl | 24 |
| 710 to 890, excl | 29 |
| 890 to 1270, excl | 32 |
| 1270 to 1520, excl | 38 |
| 1520 to 1650, excl | 41 |
| 1650 to 1780, excl | 44 |
| 1780 to 2030, excl | 47 |
| 2030 and over | 51 |

[A]No permissible variation under specified width.

## APPENDIXES

**(Nonmandatory Information)**

### X1. COILED PRODUCTS

X1.1 Continuous wide hot strip rolling mills are normally equipped with coilers. Regardless of the different types of systems employed during or following the rolling operations, it is common for the steel to be reeled into the coiler at temperatures in the stress-relieving range. In general, these temperatures are higher as material thickness increases. The coils subsequently cool to ambient temperature with outer and inner laps cooling more rapidly than central laps. The difference in cooling rate can result in measurable differences in the mechanical properties throughout a coil. Data confirm reduced yield and tensile strength, and increased percent elongation, for the product with slower cooling rates from the coiling temperature to ambient. These differences are in addition to the effects on mechanical properties caused by differences in heat analysis and chemical segregation.

### X2. VARIATION OF TENSILE PROPERTIES IN PLATES

X2.1 The tension requirements of this specification are intended only to characterize the tensile properties of a plate-as-rolled for determination of conformance to the requirements of the material specifications. These testing procedures are not intended to define the upper or lower limits of tensile properties at all possible test locations within a plate-as-rolled. It is well known and documented that tensile properties vary within a plate-as-rolled or individual piece of steel as a function of chemical composition, processing, testing procedure and other factors. It is, therefore, incumbent on designers and engineers to use sound engineering judgement when using tension test results shown on mill test reports. The testing procedures of this specification have been found to provide material adequate for normal pressure vessel design criteria.

X2.2 A survey of the variation to be expected in tensile properties obtained from plates and structural shapes was conducted by the American Iron and Steel Institute (AISI).[12] The results of this survey are contained in a *Contributions to the Metallurgy of Steel* entitled "The Variation of Product Analysis and Tensile Properties—Carbon Steel Plates, and Wide Flange Shapes" (SU/18, SU/19, and SU/20), published in September 1974. The data are presented in tables of probability that tensile properties at other than the official location may differ from those of the reported test location.

X2.3 This specification contains no requirements applicable to product tension tests; conformance to the material specifications is determined on the basis of tests performed at the place of manufacture prior to shipment, unless otherwise specified.

X2.4 A Task Group of ASTM Subcommittee A01.11 has determined, based on review of the AISI data [12](SU20), that the variation in tensile properties within a plate-as-rolled can be expressed as a function of specified requirements; one standard deviation equals approximately 3 % of required tensile strength, 5 % of required yield strength, and 3 percentage units of required elongation.



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## X3. VARIATION IN CHARPY V-NOTCH TESTS

X3.1 A survey of the variation to be expected in Charpy V-Notch test results obtained from three common fine grain plate steels was conducted by the American Iron and Steel Institute (AISI).[12] The results of the survey are contained in a Contributions to the Metallurgy of Steel entitled, "The Variations of Charpy V-Notch Impact Test Properties in Steel Plates," (SU/24), published January 1979. The survey data consists of test values obtained from six locations in addition to the locations specified in 12.1.3 of this specification. The plate conditions tested involved as-rolled, normalized, and quench and tempered. Sufficient full-size specimens were taken from each sample so that three longitudinal and three transverse specimens could be broken at three test temperatures defined for each grade. The data is presented in tables of probability that impact properties at other than the official location which may differ from those of the reported test location. Additional data of the same type, but utilizing samples from thicker plates, was published by AISI as SU/27.[12]

## X4. RADIUS FOR COLD BENDING

X4.1 Suggested minimum inside bend radii for cold forming are referenced to group Designations A through F as defined in Table X4.1. The suggested radii listed in Table X4.2 should be used as minimums in typical shop fabrication. Material that does not form satisfactorily when fabricated in accordance with Table X4.2 may be subject to rejection pending negotiation with the steel supplier. When tighter bends are required, the manufacturer should be consulted.

X4.2 The bend radius and the radius of the male die should be as liberal as the finished part will permit. The width across the shoulders of the female die should be at least 8 times the plate thickness. Higher strength steels require larger die openings. The surface of the dies in the area of radius should be smooth.

X4.3 Since cracks in cold bending commonly originate from the outside edges, shear burrs and gas cut edges should be removed by grinding. Sharp corners on edges and on punched or gas cut holes should be removed by chamfering or grinding to a radius.

X4.4 If possible, parts should be formed such that the bend line is perpendicular to the direction of final rolling. If it is necessary to bend with the bend line parallel to the direction of final rolling, a more generous radius is suggested (1½ times applicable value given in Table X4.2 for bend lines perpendicular to the direction of rolling).

### X4.5 References

Holt, G. E., et al. "Minimum Cold Bend Radii Project - Final Report," Concurrent Technologies Corporation, January 27, 1997.

Brockenbrough, R. L., "Fabrication Guidelines for Cold Bending," R. L. Brockenbrough & Associates, June 28, 1998.

Both of these references are available from American Iron and Steel Institute, 1101 17th Street NW, Washington, DC 20036-4700.



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**TABLE X4.1 Group Designations for Cold Bending**

| Specification | Class Where Applicable | Grade Where Applicable | Group Designation[A] |
|---|---|---|---|
| A 202/A 202M | | A | D |
| | | B | E |
| A 203/A 203M | | A or D | B |
| | | B or E | C |
| | | F | D |
| A 204/A 204M | | A | B |
| | | B | C |
| | | C | D |
| A 225/A 225M | | C or D | D |
| A 285/A 285M | | any | A |
| A 299/A 299M | | | D |
| A 302/A 302M | | A, C, or D | D |
| | | B | E |
| A 353/A 353M | | | D |
| A 387/A 387M | 1 or 2 | 2, 11, 12 | C |
| | 1 | 5, 9, 21, 21L, 22, 22L | E |
| | 2 | 5, 9, 21, 22, 91 | E |
| A 455/A 455M | | | C |
| A 515/A 515M | | 60 or 65 | B |
| | | 70 | C |
| A 516/A 516M | | 55 | A |
| | | 60 or 65 | B |
| | | 70 | C |
| A 517/A 517M | | any | F |
| A 533/A 533M | any | any | E |
| A 537/A 537M | any[B] | | C |
| | any[C] | | D |
| A 542/A 542M[D] | 1 or 2 | | F |
| | 3 or 4 | | D |
| | 4a | | E |
| A 543/A 543M | any | | F |
| A 553/A 553M[D] | | | D |
| A 562/A 562M | | | A |
| A 612/A 612M | | | C |
| A 645/A 645M | | | D |
| A 662/A 662M | | A or B | B |
| | | C | C |
| A 724/A 724M | | A or C | D |
| | | B | E |
| A 734/A 734M[D] | | | D |
| A 735/A 735M | any | any | E |
| A 736/A 736M | any | any | D |
| A 737/A 737M | | | B |
| A 738/A 738M | | A or B | D |
| | | C[B] | C |
| | | C[C] | D |
| A 782/A 782M | 1 or 2 | | E |
| | 3 | | F |
| A 832/A 832M | | any | E |
| A 841/A 841M | any | any | C |
| A 844/A 844M | | | D |

[A]Steels in Groups A to E inclusive are grouped on the basis of similar specified values for minimum elongation in 2 in. [50 mm]; Group F includes steels which have a specified minimum elongation in 2 in. [50 mm] of 16 or less, and steels which have a ratio of specified minimum tensile strength to specified minimum yield strength of 1.15 or less.

[B]For thicknesses of 4 in. [25 mm] or less.

[C]For thicknesses over 4 in. [25 mm].

[D]For any type.

**TABLE X4.2 Suggested Minimum Inside Radii for Cold Bending[A]**

| Group Designation[B] | Thickness (t), in. [mm] | | | |
|---|---|---|---|---|
| | Up to ¾ in. [20 mm] | Over ¾ in. [20 mm] to 1 in. [25 mm], incl | Over 1 in. [25 mm] to 2 in. [50 mm], incl | Over 2 in. [50 mm] |
| A | 1.5*t* | 1.5*t* | 1.5*t* | 1.5*t* |
| B | 1.5*t* | 1.5*t* | 1.5*t* | 2.0*t* |
| C | 1.5*t* | 1.5*t* | 2.0*t* | 2.5*t* |
| D | 1.5*t* | 1.5*t* | 2.5*t* | 3.0*t* |
| E | 1.5*t* | 1.5*t* | 3.0*t* | 3.5*t* |
| F | 1.75*t* | 2.25*t* | 4.5*t* | 5.5*t* |

[A]Values are for bend lines perpendicular to the direction of final rolling. These radii apply when the precautions listed in X4.2 are followed. If bend lines are parallel to the direction of final rolling, multiply values by 1.5.

[B]Steels specifications included in the group designations may not include the entire thickness range shown in this table.

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Designation: A 202/A 202M – 03

# Standard Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Manganese-Silicon[1]

This standard is issued under the fixed designation A 202/A 202M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope*

1.1 This specification[2] covers chromium-manganese-silicon alloy steel plates, intended particularly for welded boilers and other pressure vessels.

1.2 Plates under this specification are available in two grades having strength levels as follows:

| Grade | Tensile Strength ksi [MPa] |
|---|---|
| A | 75–95 [515–655] |
| B | 85–110 [585–760] |

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements; however, current practice normally limits the maximum thickness of plates furnished under this specification to 2 in. [50 mm].

1.4 Grade A is suitable for rivets and when so used the bars shall be subject to the requirements for rolled bars specified in Specification A 31, except for the chemical and mechanical requirements.

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

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels[3]

A 31 Specification for Steel Rivets and Bars for Rivets, Pressure Vessels[4]

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates[3]

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates[3]

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications[3]

## 3. General Requirements and Ordering Information

3.1 Plates supplied to this product specification shall conform to Specification A 20/A 20M, which outlines the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for ordering information that should be complied with when purchasing plates to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available where additional control, testing, or examination is required to meet end use requirements.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1—For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plates from coil are described in Specification A 20/A 20 M.

3.6 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.11 on Steel Plates for Boilers and Pressure Vessels.

Current edition approved Sept. 10, 2003. Published October 2003. Originally approved in 1937. Last previous edition approved in 1999 as A 202/A 202M – 93 (1999).

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-202/SA-202M in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.04.

[4] *Annual Book of ASTM Standards*, Vol 01.08.

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

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**TABLE 1 Chemical Requirements**

| Elements | Composition, % | |
|---|---|---|
| | Grade A | Grade B |
| Carbon, max[A] | 0.17 | 0.25 |
| Manganese: | | |
| Heat analysis | 1.05–1.40 | 1.05–1.40 |
| Product analysis | 0.97–1.52 | 0.97–1.52 |
| Phosphorus, max[A] | 0.035 | 0.035 |
| Sulfur, max[A] | 0.035 | 0.035 |
| Silicon: | | |
| Heat analysis | 0.60–0.90 | 0.60–0.90 |
| Product analysis | 0.54–0.96 | 0.54–0.96 |
| Chromium: | | |
| Heat analysis | 0.35–0.60 | 0.35–0.60 |
| Product analysis | 0.31–0.64 | 0.31–0.64 |

[A] Applies to both heat and product analyses.

**TABLE 2 Tensile Requirements**

| | Grade A | Grade B |
|---|---|---|
| | ksi [MPa] | ksi [MPa] |
| Tensile strength | 75–95 [515–655] | 85–110 [585–760] |
| Yield strength, min[A] | 45 [310] | 47 [325] |
| Elongation in 8 in. [200 mm], min, %[B] | 16 | 15 |
| Elongation in 2 in. [50 mm], min, %[B] | 19 | 18 |

[A] Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.
[B] See Specification A 20/A 20M for elongation adjustments.

## 4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed.

## 5. Heat Treatment

5.1 Plates are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

## 6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements given in Table 1.

## 7. Mechanical Requirements

7.1 *Tension Test Requirements*—The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Those that are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M, and

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M.

## SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 202/A 202M – 93 (1999)) that may impact the use of this standard.

*(1)* Added 3.5 and Note 1 to be consistent with the terminology and requirements of Specification A 20/A 20M.

*(2)* 3.3 was revised to be more general.

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**Designation: A 203/A 203M – 97(Reapproved 2003)**

# Standard Specification for Pressure Vessel Plates, Alloy Steel, Nickel[1]

This standard is issued under the fixed designation A 203/A 203M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification[2] covers nickel-alloy steel plates intended primarily for welded pressure vessels.

1.2 Plates under this specification are available with four strength levels and two nickel compositions as follows:

| Grade | Nominal Nickel Content % | Yield Strength, min, ksi [MPa] | Tensile Strength, min, ksi [MPa] |
|---|---|---|---|
| A | 2.25 | 37 [255] | 65 [450] |
| B | 2.25 | 40 [275] | 70 [485] |
| D | 3.50 | 37 [255] | 65 [450] |
| E | 3.50 | 40 [275] | 70 [485] |
| F | 3.50 | | |
| 2 in. [50 mm] and under | | 55 [380] | 80 [550] |
| Over 2 in. [50 mm] | | 50 [345] | 75 [515] |

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements. However, current practice normally limits the maximum thickness of plates furnished under this specification as follows:

| Grade | Maximum Thickness, in. [mm] |
|---|---|
| A | 6 [150] |
| B | 6 [150] |
| D | 4 [100] |
| E | 4 [100] |
| F | 4 [100] |

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

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels[3]

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates[3]

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates[3]

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications[3]

## 3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of imperfections, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the basis of purchase that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

## 4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine grain size requirement of Specification A 20/A 20M.

## 5. Heat Treatment

5.1 All plates shall be thermally treated as follows:

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.11 on Steel Plates for Boilers and Pressure Vessels.

Current edition approved Sept. 10, 2003. Published October 2003. Originally approved in 1937. Last previous edition approved in 1997 as A 203/A 203M – 97.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-203/SA-203M in Section II of that Code.

[3] *Annual Book of ASTM Standards,* Vol 01.04.

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5.1.1 All plates of Grades A, B, D, and E shall be normalized except as permitted by 5.1.1.1.

5.1.1.1 If approved by the purchaser for Grades A, B, D, and E, cooling rates faster than air cooling are permissible for improvement of the toughness, provided the plates are subsequently tempered at not less than 1100°F [595°C] for not less than ½ h.

5.1.2 All plates of Grade F shall be heat treated by heating into the austenitic range, quenching in water, and tempering at not less than 1100°F [595°C] for not less than ½ h.

## 6. Chemical Composition

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

## 7. Mechanical Properties

7.1 *Tension Test Requirements*—The material as represented by the tension test specimens shall conform to the requirements shown in Table 2.

7.1.1 For plates that have been heat treated in accordance with 5.1.1.1 or 5.1.2 and have a nominal thickness of ¾ in. [20 mm] and under, the 1½-in. (40-mm) wide rectangular specimen may be used for the tension test, and the elongation may be determined in a 2-in. [50-mm] gage length that includes the fracture and that shows the greatest elongation. When this specimen is used, the elongation shall be not less than 23 %.

7.2 *Impact Test Requirements*:

7.2.1 Plates of Grades A, B, D, and E that have been heat treated in accordance with 5.1.1.1 shall be Charpy V-notch impact tested. The impact test shall meet 20 ft · lbf [27 J]. The test temperature and orientation shall be a matter of agreement between the purchaser and supplier.

7.2.2 Grade F plates shall be impact tested in accordance with Supplementary Requirement S5 in Specification A 20/A 20M.

**TABLE 1 Chemical Requirements**

| Elements | Composition, % | | | |
|---|---|---|---|---|
| | Grade A | Grade B | Grade D | Grades E and F |
| Carbon, max[A]: | | | | |
| Up to 2 in. [50 mm] in thickness | 0.17 | 0.21 | 0.17 | 0.20 |
| Over 2 in. to 4 in. [100 mm] incl. in thickness | 0.20 | 0.24 | 0.20 | 0.23 |
| Over 4 in. [100 mm] in thickness | 0.23 | 0.25 | ... | ... |
| Manganese, max: | | | | |
| Heat analysis: | | | | |
| 2 in. [50 mm] and under | 0.70 | 0.70 | 0.70 | 0.70 |
| Over 2 in. [50 mm] | 0.80 | 0.80 | 0.80 | 0.80 |
| Product analysis: | | | | |
| 2 in. [50 mm] and under | 0.78 | 0.78 | 0.78 | 0.78 |
| Over 2 in. [50 mm] | 0.88 | 0.88 | 0.88 | 0.88 |
| Phosphorus, max[A] | 0.035 | 0.035 | 0.035 | 0.035 |
| Sulfur, max[A] | 0.035 | 0.035 | 0.035 | 0.035 |
| Silicon: | | | | |
| Heat analysis | 0.15–0.40 | 0.15–0.40 | 0.15–0.40 | 0.15–0.40 |
| Product analysis | 0.13–0.45 | 0.13–0.45 | 0.13–0.45 | 0.13–0.45 |
| Nickel: | | | | |
| Heat analysis | 2.10–2.50 | 2.10–2.50 | 3.25–3.75 | 3.25–3.75 |
| Product analysis | 2.03–2.57 | 2.03–2.57 | 3.18–3.82 | 3.18–3.82 |

[A] Applies to both heat and product analyses.

**TABLE 2 Tensile Requirements**

| | Grades A and D | | Grades B and E | | Grade F | |
|---|---|---|---|---|---|---|
| | ksi | [MPa] | ksi | [MPa] | ksi | [MPa] |
| Tensile strength | | | | | | |
| 2 in. [50 mm] and under | 65–85 | [450–585] | 70–90 | [485–620] | 80–100 | [550–690] |
| Over 2 in. [50 mm] | 65–85 | [450–585] | 70–90 | [485–620] | 75–95 | [515–655] |
| Yield strength, min | | | | | | |
| 2 in. [50 mm] and under | 37 | [255] | 40 | [275] | 55 | [380] |
| Over 2 in. [50 mm] | 37 | [255] | 40 | [275] | 50 | [345] |
| Elongation in 8 in. [200 mm] min, %[A] | 19 | | 17 | | ... | |
| Elongation in 2 in. [50 mm] min, %[A,B] | 23 | | 21 | | 20 | |

[A] See Specification A 20/A 20M for elongation adjustments.
[B] See 7.1.1.

**8. Keywords**

8.1 alloy steel plate; nickel alloy steel; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessel applications

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Those which are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

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**Designation: A 225/A 225M – 03**

# Standard Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Vanadium-Nickel[1]

This standard is issued under the fixed designation A 225/A 225M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope*

1.1 This specification[2] covers manganese-vanadium-nickel alloy steel plates intended primarily for welded layered pressure vessels.

1.2 Plates under this specification are available in two grades having different strength levels as follows:

| Grade | Tensile Strength, ksi [MPa] |
|---|---|
| C | 105–135 [725–930] |
| D | |
| 3 in. [75 mm] and under | 80–105 [550–725] |
| Over 3 in. [75 mm] | 75–100 [515–690] |

1.3 The maximum thickness of plates is limited only by the capacity of the chemical composition to meet the specified mechanical property requirements; however, current mill practice normally limits Grade C to 0.58 in. [15 mm] maximum and Grade D to 6 in. [150 mm] maximum.

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

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels[3]

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates[3]

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates[3]

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications[3]

## 3. General Requirements and Ordering Information

3.1 Plates supplied to this product specification shall conform to Specification A 20/A 20M, which outlines the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for ordering information that should be complied with when purchasing plates to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available where additional control, testing, or examination is required to meet end use requirements.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1—For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plates from coil are described in Specification A 20/A 20M.

3.6 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.11 on Steel Plates for Boilers and Pressure Vessels.

Current edition approved Sept. 10, 2003. Published October 2003. Originally approved in 1939. Last previous edition approved in 1999 as A 225/A 225M – 93 (1999).

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-225/SA-225M in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.04.

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

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## 4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

## 5. Heat Treatment

5.1 Grade D plates of all thicknesses and Grade C plates of thicknesses over 2 in. [50 mm] shall be normalized.

5.2 Grade C plates 2 in. [50 mm] and under in thickness are usually supplied in the as-rolled condition. The plates may be ordered normalized or stress-relieved, or both.

## 6. Chemical Composition

6.1 The steel shall conform to the chemical requirements given in Table 1, unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

**TABLE 1 Chemical Requirements**

| Elements | Composition, % | |
|---|---|---|
| | Grade C | Grade D |
| Carbon, max[A] | 0.25 | 0.20 |
| Manganese, max: | | |
| Heat analysis | 1.60 | 1.70 |
| Product analysis | 1.72 | 1.84 |
| Phosphorus, max[A] | 0.035 | 0.035 |
| Sulfur, max[A] | 0.035 | 0.035 |
| Silicon: | | |
| Heat analysis | 0.15–0.40 | 0.10–0.50 |
| Product analysis | 0.13–0.45 | 0.08–0.56 |
| Vanadium: | | |
| Heat analysis | 0.13–0.18 | 0.10–0.18 |
| Product analysis | 0.11–0.20 | 0.08–0.20 |
| Nickel: | | |
| Heat analysis | 0.40–0.70 | 0.40–0.70 |
| Product analysis | 0.37–0.73 | 0.37–0.73 |

[A]Applies to both heat and product analyses.

## 7. Mechanical Properties

7.1 *Tension Test*—The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

7.2 For plates with a nominal thickness of ¾ in. [20 mm] and under, the 1½-in. [40-mm] wide rectangular specimen may be used and the elongation determined in a 2-in. [50-mm] gage length that includes the fracture and that shows the greatest elongation.

**TABLE 2 Tensile Requirements**

| | Grade C | | Grade D | |
|---|---|---|---|---|
| | ksi | [MPa] | ksi | [MPa] |
| Tensile strength | | | | |
| All thicknesses | 105–135 | [725–930] | | |
| 3 in. [75 mm] and under | | | 80–105 | [550–725] |
| Over 3 in. [75 mm] | | | 75–100 | [515–690] |
| Yield strength, min[A] | | | | |
| All thicknesses | 70 | [485] | 60 | [415] |
| 3 in. [75 mm] and under | | | 55 | [380] |
| Over 3 in. [75 mm] | | | | |
| Elongation in 8 in. [200 mm], min, %[B] | | | ... | |
| Elongation in 2 in. [50 mm], min, %[B] | 20 | | 19 | |
| Elongation in 5D, min, %[B] | | | 17 | |

[A]Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.

[B]See Specification A 20/A 20M for elongation adjustment.

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Those that are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M, and

S17. Vacuum Carbon-Deoxidized Steel.

## SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 225/A 225M – 93 (1999)) that may impact the use of this standard.

*(1)* Added 3.5 and Note 1 to be consistent with the terminology and requirements of Specification A 20/A 20M.

*(2)* 3.3 was revised to be more general.

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*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.*

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Designation: A 283/A 283M – 03

# Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates[1]

This standard is issued under the fixed designation A 283/A 283M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

## 1. Scope*

1.1 This specification[2] covers four grades (A, B, C, and D) of carbon steel plates of structural quality for general application.

1.2 When the steel is to be welded, a welding procedure suitable for the grade of steel and intended use or service is to be utilized. See Appendix X3 of Specification A 6/A 6M for information on weldability.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exactly equivalents; therefore, each system is to be used independently of the other, without combining values in any way.

1.4 For plate produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results, of Specification A 6/A 6M apply.

1.5 This specification contains notes or footnotes, or both, that provide explanatory material. Such notes and footnotes, excluding those in tables and figures, do not contain any mandatory requirements.

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling[3]

## 3. General Requirements for Delivery

3.1 Plates furnished under this specification shall con-form to the requirements of the current edition of Specification A 6/A 6M, for the specific date ordered, unless a conflict exists, in which case this specification shall prevail.

3.2 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from a coil. The processor directly controls, or is responsible for, the operations involved in the processing of a coil into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1—For plates produced from coil and furnished without heat treatment or with stress relieving only, two test results are to be reported for each qualifying coil. Additional requirements regarding plate produced from coil are described in Specification A 6/A 6M.

## 4. Process

4.1 The steel shall be made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace.

## 5. Chemical Requirements

5.1 The heat analysis shall conform to the requirements prescribed in Table 1.

5.2 The steel shall conform on product analysis to the requirements prescribed in Table 1, subject to the product analysis tolerances in Specification A 6/A 6M.

## 6. Tensile Requirements

6.1 Material as represented by the test specimens shall conform to the requirements as to tensile properties prescribed in Table 2.

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys, and is the direct responsibility of Subcommittee A01.02 on Structural Steel for Bridges, Buildings, Rolling Stock, and Ships.

Current edition approved April 10, 2003. Published June 2003. Originally approved in 1946. Last previous edition approved in 2000 as A 283/A 283M – 00.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-283/SA 283M in Section II of that Code.

[3] *Annual Book of ASTM Standards,* Vol 01.04.

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

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**TABLE 1 Chemical Requirements**

| Elements | Heat Analysis, % | | | |
|---|---|---|---|---|
| | Grade A | Grade B | Grade C | Grade D |
| Carbon, max | 0.14 | 0.17 | 0.24 | 0.27 |
| Manganese, max | 0.90 | 0.90 | 0.90 | 0.90 |
| Phosphorus, max | 0.035 | 0.035 | 0.035 | 0.035 |
| Sulfur, max | 0.04 | 0.04 | 0.04 | 0.04 |
| Silicon | | | | |
| Plates 1½ in. [40 mm] and under, max | 0.40 | 0.40 | 0.40 | 0.40 |
| Plates over 1½ in. [40 mm] | 0.15–0.40 | 0.15–0.40 | 0.15–0.40 | 0.15–0.40 |
| Copper, min % when copper is specified | 0.20 | 0.20 | 0.20 | 0.20 |

**TABLE 2 Tensile Requirements[A]**

| | Grade A | Grade B | Grade C | Grade D |
|---|---|---|---|---|
| Tensile strength, ksi [MPa] | 45–60 [310–415] | 50–65 [345–450] | 55–75 [380–515] | 60–80 [415–550] |
| Yield point, min, ksi [MPa] | 24 [165] | 27 [185] | 30 [205] | 33 [230] |
| Elongation in 8 in. [200 mm], min, %[B] | 27 | 25 | 22 | 20 |
| Elongation in 2 in. [50 mm], min, %[B] | 30 | 28 | 25 | 23 |

[A] See Specimen Orientation under the Tension Tests section of Specification A 6/A 6 M.

[B] For plates wider than 24 in. [600 mm], the elongation requirement is reduced two percentage points. See elongation requirement adjustments in the Tension Tests section of Specification A 6/A 6M.

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order or contract . Standardized supplementary requirements for use at the option of the purchaser are listed in Specification A 6/A 6M. Those that are considered suitable for use with this specification are listed by title:

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S8. Ultrasonic Examination, and

S15. Reduction of Area.

S97. *Limitation on Rimmed or Capped Steel:*

S97.1 The steel shall be other than rimmed or capped.

## SUMMARY OF CHANGES

Committee A01 has identified the location fo the following changes to this standard since A 283/A 283M-00 that may impact the use of this standard.

*(1)* 1.4, 3.1, 3.1.1 (renumbered as 3.2), and Note 1 have been revised to be consistent with the terminology and requirements of Specification A 6/A 6M.

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Designation: A 285/A285M – 03

# Standard Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength[1]

This standard is issued under the fixed designation A 285/A285M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

## 1. Scope*

1.1 This specification[2] covers carbon steel plates of low- and intermediate-tensile strengths which may be made by killed, semi-killed, capped, or rimmed steel practices at the producer's option. These plates are intended for fusion-welded pressure vessels.

1.2 Plates under this specification are available in three grades having different strength levels as follows:

| Grade | Tensile Strength, ksi [MPa] |
|---|---|
| A | 45–65 [310–450] |
| B | 50–70 [345–485] |
| C | 55–75 [380–515] |

1.3 The maximum thickness of plates under this specification, for reasons of internal soundness, is limited to a maximum thickness of 2 in. [50 mm] for all grades.

NOTE 1—For killed carbon steels only refer to the following ASTM specifications:[3]

A 299/A 299M Pressure Vessel Plates, Carbon Steel, Manganese-Silicon.

A 515/A 515M Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service.

A 516/A 516M Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service.

1.4 For plates produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results, of Specification A 20/A 20M apply.

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

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels[3]

## 3. General Requirements and Ordering Information

3.1 Plates supplied to this product specification shall conform to Specification A 20/A 20M, which outlines the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for ordering information that should be complied with when purchasing plates to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available where additional control, testing, or examination is required to meet end use requirements.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 Coils are excluded from qualification to this specification until they are processed into finished plate. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 2—For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plate produced from coil are described in Specification A 20/A 20M.

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.11 on Steel Plates for Boilers and Pressure Vessels.

Current edition approved Sept. 10, 2003. Published October 2003. Originally approved in 1946. Last previous edition approved in 2001 as A 285/A 285M – 01.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-285/SA-285M in Section II of that Code.

[3] *Annual Book of ASTM Standards,* Vol 01.04.

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

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**TABLE 1 Chemical Requirements**

| Elements | Composition, % | | |
|---|---|---|---|
| | Grade A | Grade B | Grade C |
| Carbon, max[A] | 0.17 | 0.22 | 0.28 |
| Manganese, max | | | |
| Heat analysis | 0.90 | 0.90 | 0.90 |
| Product analysis | 0.98 | 0.98 | 0.98 |
| Phosphorus, max[A] | 0.035 | 0.035 | 0.035 |
| Sulfur, max[A] | 0.035 | 0.035 | 0.035 |

[A]Applies to both heat and product analyses.

**TABLE 2 Tensile Requirements**

| | Grade A | | Grade B | | Grade C | |
|---|---|---|---|---|---|---|
| | ksi | [MPa] | ksi | [MPa] | ksi | [MPa] |
| Tensile strength | 45–65 | [310–450] | 50–70 | [345–485] | 55–75 | [380–515] |
| Yield strength, min[A] | 24 | [165] | 27 | [185] | 30 | [205] |
| Elongation in 8 in. or [200 mm], min, %[B] | 27 | | 25 | | 23 | |
| Elongation in 2 in. or [50 mm], min, %[B] | 30 | | 28 | | 27 | |

[A]Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.
[B]See Specification A 20/A 20M for elongation adjustment.

3.6 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

## 4. Heat Treatment

4.1 Plates are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

## 5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition as given in Table 1.

## 6. Mechanical Properties

6.1 *Tension Test*—The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Those that are considered suitable for use with this specification are listed below by title.

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons, and

S4. Additional Tension Test.

## ADDITIONAL SUPPLEMENTARY REQUIREMENTS

Also listed below are additional optional supplementary requirements suitable for this specification:

### S57. Copper-Bearing

S57.1 The copper content, by heat analysis shall be 0.20–0.35 % and by product analysis 0.18–0.37 %.

### S58. Restricted Copper

S58.1 The maximum incidental copper content by heat analysis shall not exceed 0.25 %.

## SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 285/A 285M – 01) that may impact the use of this standard.

*(1)* 1.4, 3.5, and Note 2 were revised to be consistent with the terminology and requirements of Specification A 20/A 20M.

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Designation: A 299/A 299M – 04

# Standard Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Silicon[1]

This standard is issued under the fixed designation A 299/A 299M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

Note—Grades A and B were added editorially to the entry for Carbon in Table 1 and the year date changed on Feb. 2, 2004.

## 1. Scope*

1.1 This specification[2] covers manganese-silicon carbon steel plates for use in welded boilers and other pressure vessels.

1.2 Plates under this specification are produced in two grades. The specified minimum the yield strength decreases on thicknesses over 1 in. [25 mm].

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements; however, current practice normally limits the maximum thickness of plates furnished under this specification to 8 in. [200 mm].

1.4 For plates produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results, of Specification A 20/A 20M apply.

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

## 2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

## 3. General Requirements and Ordering Information

3.1 Plates supplied to this product specification shall conform to Specification A 20/A 20M, which outlines the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, and so forth.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information that should be complied with when purchasing plates to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available where additional control, testing, or examination is required to meet end use requirements.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1—For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plates from coil are described in Specification A 20/A 20M.

3.6 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

## 4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.11 on Steel Plates for Boilers and Pressure Vessels.

Current edition approved Feb. 2, 2004. Published February 2004. Originally approved in 1947. Last previous edition approved in 2003 as A299/A 299M – 03ε1.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-299/SA-299M in Section II of that Code.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

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## 5. Heat Treatment

5.1 Plates 2 in. [50 mm] and under in thickness are normally supplied in the as-rolled condition. Plates may be ordered normalized or stress relieved, or both.

5.2 Plates over 2 in. [50 mm] in thickness shall be normalized.

## 6. Chemical Composition

6.1 The steel shall conform to the requirements given in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

## 7. Mechanical Properties

7.1 *Tension Test Requirements*—The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

## 8. Keywords

8.1 carbon steel plate; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessel applications

**TABLE 1 Chemical Requirements**

| Elements | Composition, % |
|---|---|
| †Carbon, max[A]: | |
| 1 in. [25 mm] and under | |
| Grade A | 0.26 |
| Grade B | 0.28 |
| Over 1 in. [25 mm] | |
| Grade A | 0.28 |
| Grade B | 0.30 |
| Manganese: | |
| 1 in. [25 mm] and under | |
| Heat analysis | 0.90 to 1.40 |
| Product analysis | 0.84 to 1.52 |
| Over 1 in. [25 mm] | |
| Heat analysis | 0.90 to 1.50 |
| Product analysis | 0.84 to 1.62 |
| Phosphorus, max[A] | 0.035 |
| Sulfur, max[A] | 0.035 |
| Silicon: | |
| Heat analysis | 0.15 to 0.40 |
| Product analysis | 0.13 to 0.45 |

† Editorially corrected.

[A]Applies to both heat and product analyses.

**TABLE 2 Tensile Requirements**

| | Grade A | Grade B |
|---|---|---|
| Tensile strength, ksi [MPa] | 75–95 [515–655] | 80-100 [550-690] |
| Yield strength, min,[A] ksi [MPa]: | | |
| 1 in. [25 mm] and under | 42 [290] | 47 [325] |
| Over 1 in. [25 mm] | 40 [275] | 45 [310] |
| Elongation in 8 in. [200 mm], min, %[B] | 16 | 16 |
| Elongation in 2 in. [50 mm], min, %[B] | 19 | 19 |

[A]Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.

[B]See the Elongation Requirement Adjustments subsection in the Tension Tests section of Specification A 20/A 20M.

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Those that are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,
S2. Product Analysis,
S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,
S4. Additional Tension Test,
S5. Charpy V-Notch Impact Test,
S6. Drop Weight Test,
S7. High-Temperature Tension Test,
S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,
S9. Magnetic Particle Examination,
S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,
S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,
S17. Vacuum Carbon-Deoxidized Steel.

## SUMMARY OF CHANGES

This section identifies the principal changes incorporated since A299/A299M-01 was issued:

(1) Table 1 - The current chemical requirements have been incorporated as a higher strength Grade B listed in Table 2. The current tensile requirements are incorporated with a lower carbon content requirement in Table 1 as Grade A.

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Designation: A 414/A 414M – 04

# Standard Specification for Steel, Sheet, Carbon, for Pressure Vessels[1]

This standard is issued under the fixed designation A 414/A 414M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope*

1.1 This specification[2] covers hot-rolled carbon steel sheet for pressure vessels involving fusion welding or brazing. Welding and brazing technique is of fundamental importance and shall be in accordance with commercial practices.

1.2 The following grades are included in this specification:

Mechanical Requirements

| Grade | Yield Strength, min | | Tensile Strength, min | |
|---|---|---|---|---|
| | ksi | MPa | ksi | MPa |
| A | 25 | 170 | 45 | 310 |
| B | 30 | 205 | 50 | 345 |
| C | 33 | 230 | 55 | 380 |
| D | 35 | 240 | 60 | 415 |
| E | 38 | 260 | 65 | 450 |
| F | 42 | 290 | 70 | 485 |
| G | 45 | 310 | 75 | 515 |

1.3 Hot-rolled carbon steel sheet is generally furnished in cut lengths and to decimal thickness only. Coils may be furnished, provided tension test specimens are taken to represent the middle of the slab as required by 5.1.4. The purchaser should recognize this requires cutting the coils to obtain test samples and results in half-size coils. The sheet is furnished to the following size limits:

| | Width, in. [mm] | |
|---|---|---|
| Thickness, in. [mm] | Over 12 to 48 [Over 300 to 1200] | Over 48 [Over 1200] |
| 0.270 to 0.230 [7.0 to 6.0] | sheet (coils only) | sheet (coils only) |
| Under 0.230 to 0.180 [6.0 to 4.5] | sheet | sheet (coils only) |
| Under 0.180 to 0.057 [under 4.5 to 1.5] | sheet | sheet |

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

1.5 Tolerances are found in General Requirements Specifications A 568/A 568M and A 635/A 635M. The appropriate General Requirements specification is applied based on the thickness and width of the product ordered.

## 2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 568/A 568M Specification for Steel, Sheet, Carbon, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for

A 635/A 635M Specification for Steel, Sheet and Strip, Heavy-Thickness Coils, Carbon, Hot Rolled

## 3. Ordering Information

3.1 Orders for material under this specification shall include the following information, as required, to describe the material adequately:

3.1.1 Designation or specification number, date of issue, and grade,

3.1.2 Copper bearing steel, when required,

3.1.3 Special requirements, if required,

3.1.4 Condition—pickled (or blast cleaned), if required. (Material so ordered will be oiled unless ordered dry.), and

3.1.5 Dimensions, including type of edges.

3.1.5.1 As agreed upon between the purchaser and the producer, material ordered to this specification will be supplied to meet the appropriate standard or restricted thickness tolerance table shown in Specification A 568/A 568M.

NOTE 1—Not all producers are capable of meeting all of the limitations of the thickness tolerance tables in Specification A 568/A 568M. The purchaser should contact the producer regarding possible limitations prior to placing an order.

3.1.6 Cast or heat analysis, or test report request, or both, if required.

NOTE 2—A typical ordering description is as follows: "ASTM A 414,

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.19 on Steel Sheet and Strip.

Current edition approved March 1, 2004. Published March 2004. Originally approved in 1971. Last previous edition approved in 2001 as A 414/A 414M – 01.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-414 in Section 11 of that Code.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

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Grade A, Hot-Rolled Sheet, 0.100 in. [2.54 mm] by 36 in. [914.4 mm] by 96 in. [2438 mm], cut edges."

## 4. Chemical Requirements

4.1 *Cast or Heat Analysis*—The analysis of the steel shall conform to the requirements prescribed in Table 1.

4.1.1 Unspecified elements may be present. Limits on elements shall be as stated in Table 2.

4.1.1.1 Each of the elements listed in Table 2 shall be included in the report of the heat analysis. When the amount of an element present is less than 0.02 %, the analysis may be reported as "<0.02 %."

4.2 *Product, Check, or Verification Analysis*—Analyses may be made by the purchaser from finished material representing each heat.

4.3 *Deoxidation*—For all grades, killed steel is required. See Table 1 and footnotes A and B.

## 5. Mechanical Property Requirements

5.1 *Tensile Strength*:

5.1.1 *Requirements*—Material as represented by the test specimen shall conform to the tensile requirements specified in Table 3.

5.1.2 *Number of Tests*—Two tensile tests shall be made from the product of each slab as rolled.

5.1.3 *Location and Orientation* (see Fig. 1):

5.1.3.1 Tensile test specimens shall be taken at locations representing the middle and back end of each slab as rolled.

5.1.3.2 Tensile test samples shall be taken from the full thickness of the sheet as rolled.

5.1.3.3 Tensile test specimens shall be taken from a location approximately halfway between the center of the sheet and the edge of the material as-rolled.

5.1.3.4 Tensile test specimens shall be taken with the axis of the test specimen perpendicular to the rolling direction (transverse test).

5.1.4 *Test Method*—Yield strength shall be determined by either the 0.2 % offset method or by the 0.5 % extension under load method, unless otherwise specified.

## 6. General Requirements for Delivery

6.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 568/A 568M unless otherwise provided herein.

**TABLE 2 Limits on Unspecified Elements (See 4.1.1)**

| | | |
|---|---|---|
| Copper, max %[A] | Heat analysis | 0.40 |
| | Product analysis | 0.43 |
| Nickel, max %[A] | Heat analysis | 0.40 |
| | Product analysis | 0.43 |
| Chromium, max %[A,B] | Heat analysis | 0.30 |
| | Product analysis | 0.34 |
| Molybdenum, max %[A,B] | Heat analysis | 0.12 |
| | Product analysis | 0.13 |
| Vanadium, max %[C] | Heat analysis | 0.03 |
| | Product analysis | 0.04 |
| Columbium, max %[C] | Heat analysis | 0.02 |
| | Product analysis | 0.03 |

[A] The sum of copper, nickel, chromium, and molybdenum shall not exceed 1.00 % on heat analysis. When one or more of these elements are specified, the sum does not apply, in which case, only the individual limits on the remaining unspecified elements will apply.

[B] The sum of chromium and molybdenum shall not exceed 0.32 % on heat analysis. When one or more of these elements are specified, the sum does not apply, in which case, only the individual limits on the remaining unspecified elements will apply.

[C] By agreement, the heat analysis limits for vanadium or columbium, or both, may be increased up to 0.10 % and 0.05 %, respectively.

## 7. Workmanship

7.1 The material shall be free from injurious defects (see Specifications A 568/A 568M or A 635/A 635M, as appropriate due to thickness).

## 8. Finish and Appearance

8.1 *Surface Finish*:

8.1.1 Unless otherwise specified, the material shall be furnished without removing the hot-rolled oxide or scale.

8.1.2 When required, the material may be specified to be pickled or blast cleaned.

8.2 *Oiling*:

8.2.1 Unless otherwise specified, the material shall be furnished not oiled.

8.2.2 When specified to be pickled or blast cleaned, the material shall be furnished oiled. When required, pickled or blast-cleaned material may be specified to be furnished dry.

8.3 *Edges*—Unless otherwise specified, mill edges shall be furnished on material that has not had the hot-rolled oxide or scale removed and cut edges shall be furnished on material that has had the hot-rolled oxide or scale removed.

## 9. Certification and Reports

9.1 The manufacturer shall furnish copies of a test report showing the results of the heat analysis and mechanical property tests made to determine compliance with this specification. The report shall include the purchase order number,

**TABLE 1 Chemical Requirements**

| Element | Composition — Weight % Heat Analysis | | | | | | |
|---|---|---|---|---|---|---|---|
| | Grade A | Grade B | Grade C | Grade D | Grade E | Grade F | Grade G |
| Carbon, max | 0.15 | 0.22 | 0.25 | 0.25 | 0.27 | 0.31 | 0.31 |
| Manganese, max | 0.90 | 0.90 | 0.90 | 1.20 | 1.20 | 1.20 | 1.35 |
| Phosphorus, max | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 |
| Sulfur, max | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 |
| Aluminum | 0.02–0.08 | 0.02–0.08 | 0.02–0.08 | 0.02–0.08 | 0.02–0.08 | 0.02–0.08 | 0.02–0.08 |
| Silicon[A,B] | . . . | . . . | . . . | . . . | . . . | . . . | . . . |
| Copper, when copper steel is specified, min | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |

[A] Where an ellipsis (. . .) appears in this table, there is no requirement, but the analysis shall be reported.

[B] When silicon or aluminum-silicon killed steel is specified, a range of 0.15 to 0.30 shall apply to the silicon and a range of 0.02 to 0.08 shall apply to the aluminum.

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**TABLE 3 Tensile Requirements**

| | Grade A | Grade B | Grade C | Grade D | Grade E | Grade F | Grade G |
|---|---|---|---|---|---|---|---|
| Tensile strength: | | | | | | | |
| min, ksi [MPa] | 45 [310] | 50 [345] | 55 [380] | 60 [415] | 65 [450] | 70 [485] | 75 [515] |
| max, ksi [MPa] | 60 [415] | 65 [450] | 70 [485] | 75 [515] | 85 [585] | 90 [620] | 95 [655] |
| Yield strength, min, ksi [MPa][A] | 25 [170] | 30 [205] | 33 [230] | 35 [240] | 38 [260] | 42 [290] | 45 [310] |
| Elongation in 2 in. [50 mm], min, percent: | | | | | | | |
| Under 0.270 to 0.145 [Under 7.0 to 3.8] | 26 | 24 | 22 | 20 | 18 | 16 | 16 |
| Under 0.145 to 0.089 [Under 3.8 to 2.2] | 24 | 22 | 20 | 18 | 16 | 14 | 14 |
| Under 0.089 to 0.057 [Under 2.2 to 1.5] | 23 | 21 | 19 | 17 | 15 | 13 | 13 |
| Elongation in 8 in. [200 mm], min, percent: | | | | | | | |
| Under 0.270 to 0.145 [Under 7.0 to 3.8] | 20 | 18 | 16 | 14 | 12 | 10 | 10 |

[A] Yield strength determined by the 0.2 % offset or 0.5 % extension under load methods.

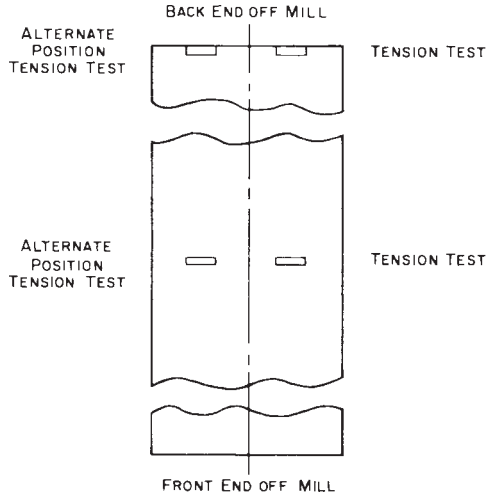


**FIG. 1 Location of Test Specimens**

specification number, and test identification number correlating the test results with material represented.

## 10. Product Marking

10.1 The name or brand of the manufacturer, heat and slab number, specification designation number, and grade shall be legibly and durably marked on each cut length sheet in two places not less than 12 in. [300 mm] from the edges. Cut length sheets, the maximum lengthwise and crosswise, dimensions of which do not exceed 72 in. [1800 mm], shall be legibly and durably marked in one place approximately midway between the center and a side edge. The manufacturer's test identification number shall be legibly and durably marked on each test specimen. Steel-die marking of sheets is prohibited.

10.2 For coil product, the information required in 10.1 shall be legibly and durably marked both on each coil and on a tag affixed to each coil.

## 11. Keywords

11.1 carbon steel sheet; pressure vessel steels; steel sheet

## SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue, A 414/A 414M-01, that may impact the use of this standard. (Approved March 1, 2004.)

(*1*) Deleted Footnote A in Section 1.3.
(*2*) Added new Section 1.5 to replace Footnote A and to emphasize the use of the appropriate standard based on the ordered material size.

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Designation: A 516/A 516M – 06

# Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service[1]

This standard is issued under the fixed designation A 516/A 516M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

## 1. Scope*

1.1 This specification[2] covers carbon steel plates intended primarily for service in welded pressure vessels where improved notch toughness is important.

1.2 Plates under this specification are available in four grades having different strength levels as follows:

| Grade U.S. [SI] | Tensile Strength, ksi [MPa] |
|---|---|
| 55 [380] | 55–75 [380–515] |
| 60 [415] | 60–80 [415–550] |
| 65 [450] | 65–85 [450–585] |
| 70 [485] | 70–90 [485–620] |

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements; however, current practice normally limits the maximum thickness of plates furnished under this specification as follows:

| Grade U.S. [SI] | Maximum Thickness, in. [mm] |
|---|---|
| 55 [380] | 12 [305] |
| 60 [415] | 8 [205] |
| 65 [450] | 8 [205] |
| 70 [485] | 8 [205] |

1.4 For plates produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results of Specification A 20/A 20M apply.

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

## 2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

## 3. General Requirements and Ordering Information

3.1 Plates supplied to this product specification shall conform to Specification A 20/A 20M, which outlines the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, and so forth.

3.2 Specification A 20/A20M also establishes the rules for ordering information that should be complied with when purchasing plates to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available where additional control, testing, or examination is required to meet end use requirements.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A20M.

3.5 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.11 on Steel Plates for Boilers and Pressure Vessels.

Current edition approved March 1, 2006. Published March 2006. Originally approved in 1964. Last previous edition approved in 2005 as A 516/A 516M – 05$^{\epsilon 1}$.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-516/SA-516M in Section II of that Code.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

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NOTE 1—For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plate produced from coil are described in Specification A 20/A 20M.

3.6 If the requirements of this specification are in conflict with the requirements of Specification A 20/A20M, the requirements of this specification shall prevail.

## 4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

## 5. Heat Treatment

5.1 Plates 1.50 in. [40 mm] and under in thickness are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

5.2 Plates over 1.50 in. [40 mm] in thickness shall be normalized.

5.3 When notch-toughness tests are required on plates 1½ in. [40 mm] and under in thickness, the plates shall be normalized unless otherwise specified by the purchaser.

5.4 If approved by the purchaser, cooling rates faster than those obtained by cooling in air are permissible for improvement of the toughness, provided the plates are subsequently tempered in the temperature range 1100 to 1300 °F [595 to 705 °C].

## 6. Chemical Composition

6.1 The steel shall conform to the chemical requirements given in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A20M.

## 7. Mechanical Properties

7.1 *Tension Test*—The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

## 8. Keywords

8.1 carbon steel; carbon steel plate; pressure containing parts; pressure vessel steels; steel plates for pressure vessels

**TABLE 1 Chemical Requirements**

| Elements | Composition, % | | | |
|---|---|---|---|---|
| | Grade 55 [Grade 380] | Grade 60 [Grade 415] | Grade 65 [Grade 450] | Grade 70 [Grade 485] |
| Carbon, max[A,B]: | | | | |
| ½ in. [12.5 mm] and under | 0.18 | 0.21 | 0.24 | 0.27 |
| Over ½ in. to 2 in. [12.5 to 50 mm], incl | 0.20 | 0.23 | 0.26 | 0.28 |
| Over 2 in. to 4 in. [50 to 100 mm], incl | 0.22 | 0.25 | 0.28 | 0.30 |
| Over 4 to 8 in. [100 to 200 mm], incl | 0.24 | 0.27 | 0.29 | 0.31 |
| Over 8 in. [200 mm] | 0.26 | 0.27 | 0.29 | 0.31 |
| Manganese[B]: | | | | |
| ½ in. [12.5 mm] and under: | | | | |
| Heat analysis | 0.60–0.90 | 0.60–0.90[C] | 0.85–1.20 | 0.85–1.20 |
| Product analysis | 0.55–0.98 | 0.55–0.98[C] | 0.79–1.30 | 0.79–1.30 |
| Over ½ in. [12.5 mm]: | | | | |
| Heat analysis | 0.60–1.20 | 0.85–1.20 | 0.85–1.20 | 0.85–1.20 |
| Product analysis | 0.55–1.30 | 0.79–1.30 | 0.79–1.30 | 0.79–1.30 |
| Phosphorus,max[A] | 0.035 | 0.035 | 0.035 | 0.035 |
| Sulfur, max[A] | 0.035 | 0.035 | 0.035 | 0.035 |
| Silicon: | | | | |
| Heat analysis | 0.15–0.40 | 0.15–0.40 | 0.15–0.40 | 0.15–0.40 |
| Product analysis | 0.13–0.45 | 0.13–0.45 | 0.13–0.45 | 0.13–0.45 |

[A] Applies to both heat and product analyses.
[B] For each reduction of 0.01 percentage point below the specified maximum for carbon, an increase of 0.06 percentage point above the specified maximum for manganese is permitted, up to a maximum of 1.50 % by heat analysis and 1.60 % by product analysis.
[C] Grade 60 plates ½ in. [12.5 mm] and under in thickness may have 0.85–1.20 % manganese on heat analysis, and 0.79–1.30 % manganese on product analysis.

**TABLE 2 Tensile Requirements**

| | Grade | | | |
|---|---|---|---|---|
| | 55 [380] | 60 [415] | 65 [450] | 70 [485] |
| Tensile strength, ksi [MPa] | 55–75 [380–515] | 60–80 [415–550] | 65–85 [450–585] | 70–90 [485–620] |
| Yield strength, min,[A] ksi [MPa] | 30 [205] | 32 [220] | 35 [240] | 38 [260] |
| Elongation in 8 in. [200 mm], min, %[B] | 23 | 21 | 19 | 17 |
| Elongation in 2 in. [50 mm], min, %[B] | 27 | 25 | 23 | 21 |

[A] Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.
[B] See Specification A 20/A20M for elongation adjustment.

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in ASTM Specification A 20/A 20M. Those that are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test (for Material 0.625 in. [16 mm] and over in Thickness),

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M, and

S17. Vacuum Carbon-Deoxidized Steel.

## ADDITIONAL SUPPLEMENTARY REQUIREMENTS

In addition, the following supplementary requirement is suitable for this application.

### S54. Requirements for Carbon Steel Plate for Hydrofluoric Acid Alkylation Service

S54.1 Plates shall be provided in the normalized heat-treated condition.

S54.2 The maximum carbon equivalent shall be as follows:
Plate thickness less than or equal to 1 in. [25 mm]: CE maximum = 0.43
Plate thickness greater than 1 in. [25 mm]: CE maximum = 0.45

S54.3 Determine the carbon equivalent (CE) as follows:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S54.4 Vanadium and niobium maximum content based on heat analysis shall be:
Maximum vanadium = 0.02 %
Maximum niobium = 0.02 %
Maximum vanadium plus niobium = 0.03 %
(Note: niobium = columbium)

S54.5 The maximum composition based on heat analysis of Ni + Cu shall be 0.15 %.

S54.6 The minimum C content based on heat analysis shall be 0.18 %. The maximum C content shall be as specified for the ordered grade.

S54.7 Welding consumables for repair welds shall be of the low-hydrogen type. E60XX electrodes shall not be used and the resulting weld chemistry shall meet the same chemistry requirements as the base metal.

S54.8 In addition to the requirements for product marking in the specification, an "HF-N" stamp or marking shall be provided on each plate to identify that the plate complies with this supplementary requirement.

## SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 516/A 516M – 05$^{\epsilon 1}$) that may impact the use of this standard. (Approved March 1, 2006.)

*(1)* Footnote C was added to Table 1.

Committee A01 has identified the location of selected changes to this standard since the last issue (A 516/A 516M – 03) that may impact the use of this standard. (Approved March 1, 2005.)

*(1)* Keywords were added.
*(2)* Supplementary Requirement S1, for plates for HF alkylation service, was added.
*(3)* Table 1 was corrected editorially.

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Designation: A 537/A 537M – 95 (Reapproved 2000)

# Standard Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel[1]

This standard is issued under the fixed designation A 537/A 537M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

## 1. Scope

1.1 This specification[2] covers heat-treated carbon-manganese-silicon steel plates intended for fusion welded pressure vessels and structures.

1.2 Material under this specification is available in the following three classes:

| Class | Heat Treatment | Thickness, | Yield Strength, min, ksi [MPa] | Tensile Strength, min, ksi [MPa] |
|---|---|---|---|---|
| 1 | Normalized | 2½ in. and under | 50 | 70 |
| | | [65 mm and under] | [345] | [485] |
| | | Over 2½ to 4 in. | 45 | 65 |
| | | [Over 65 to 100 mm] | [310] | [450] |
| 2 | Quenched and tempered | 2½ in. and under | 60 | 80 |
| | | [65 mm and under] | [415] | [550] |
| | | Over 2½ to 4 in. | 55 | 75 |
| | | [Over 65 to 100 mm] | [380] | [515] |
| | | Over 4 to 6 in. | 46 | 70 |
| | | [Over 100 to 150 mm] | [315] | [485] |
| 3 | Quenched and tempered | 2½ in. and under | 55 | 80 |
| | | [65 mm and under] | [380] | [550] |
| | | Over 2½ to 4 in. | 50 | 75 |
| | | [Over 65 to 100 mm] | [345] | [515] |
| | | Over 4 to 6 in. | 40 | 70 |
| | | [Over 100 to 150 mm] | [275] | [485] |

1.3 The maximum thickness of plates furnished under this specification is 4 in. [100 mm] for Class 1 and 6 in. [150 mm] for Class 2 and Class 3.

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

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels[3]

A 435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates[3]

A 577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates[3]

A 578/A578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications[3]

## 3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information which should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

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[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.11 on Steel Plates for Boilers and Pressure Vessels.

Current edition approved June 15, 1995. Published August 1995. Originally published as A 537 – 65. Last previous edition A 537/A 537M – 91.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-537/SA-537M in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.04.

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## 4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

## 5. Heat Treatment

5.1 All plates shall be thermally treated as follows:

5.1.1 Class 1 plates shall be normalized.

5.1.2 Class 2 and Class 3 plates shall be quenched and tempered. The tempering temperature for Class 2 plates shall not be less than 1100°F [595°C] for not less than ½ h and 1150°F [620°C] for Class 3 plates for not less than ½ h.

## 6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

## 7. Mechanical Requirements

7.1 *Tension Tests*:

7.1.1 *Requirements*—The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

7.1.2 For Class 2 and Class 3 plates with a nominal thickness of ¾ in. [20 mm] and under, the 1½-in. [40-mm] wide rectangular specimen may be used for the tension test, and the elongation may be determined in a 2-in. [50-mm] gage length that includes the fracture and that shows the greatest elongation.

## 8. Keywords

8.1 carbon steel plate; pressure containing parts; pressure vessel steels; steel plates for pressure vessel application

**TABLE 1 Chemical Requirements**

| Element | Composition, % |
|---|---|
| Carbon, max[A] | 0.24 |
| Manganese: | |
| 1½ in. [40 mm] and under in thickness:[B] | |
| Heat analysis | 0.70–1.35 |
| Product analysis | 0.64–1.46 |
| Over 1½ in. [40 mm] in thickness: | |
| Heat analysis | 1.00–1.60 |
| Product analysis | 0.92–1.72 |
| Phosphorus, max[A] | 0.035 |
| Sulfur, max[A] | 0.035 |
| Silicon: | |
| Heat analysis | 0.15–0.50 |
| Product analysis | 0.13–0.55 |
| Copper, max: | |
| Heat analysis | 0.35 |
| Product analysis | 0.38 |
| Nickel, max:[B] | |
| Heat analysis | 0.25 |
| Product analysis | 0.28 |
| Chromium, max: | |
| Heat analysis | 0.25 |
| Product analysis | 0.29 |
| Molybdenum, max: | |
| Heat analysis | 0.08 |
| Product analysis | 0.09 |

[A] Applies to both heat and product analyses.

[B] Manganese may exceed 1.35 % on heat analysis, up to a maximum of 1.60 %, and nickel may exceed 0.25 % on heat analysis, up to a maximum of 0.50 %, provided the heat analysis carbon equivalent does not exceed 0.57 % when based upon the following equation:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

When this option is exercised, the manganese and nickel contents on product analysis shall not exceed the heat analysis content by more than 0.12 % and 0.03 %, respectively.



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**TABLE 2 Tensile Requirements**

| | Class 1 | Class 2 | Class 3 |
|---|---|---|---|
| | ksi [MPa] | ksi [MPa] | ksi [MPa] |
| Tensile strength: | | | |
| 2½ in. and under | 70–90 | 80–100 | 80–100 |
| [65 mm and under] | [485–620] | [550–690] | [550–690] |
| Over 2½ to 4 in., incl | 65–85 | 75–95 | 75–95 |
| [Over 65 to 100 mm, incl] | [450–585] | [515–655] | [515–655] |
| Over 4 to 6 in., incl | [A] | 70–90 | 70–90 |
| [Over 100 to 150 mm, incl] | [A] | [485–620] | [485–620] |
| Yield strength, min: | | | |
| 2½ in. and under | 50 | 60 | 55 |
| [65 mm and under] | [345] | [415] | [380] |
| Over 2½ to 4 in., incl | 45 | 55 | 50 |
| [Over 65 to 100 mm, incl] | [310] | [380] | [345] |
| Over 4 in. to 6 in., incl | [A] | 46 | 40 |
| [Over 100 to 150 mm, incl] | [A] | [315] | [275] |
| Elongation in 2 in. | | | |
| [50 mm], min, %:[B] | | | |
| 4 in. [100 mm] and under | 22 | 22 | 22 |
| Over 4 in. [100 mm] | [A] | 20 | 20 |
| Elongation in 8 in. | | | |
| [200 mm], min, %[B] | 18 | [C] | [C] |

[A] Product is not available in this size range.
[B] See Specification A 20/A 20M for elongation adjustments.
[C] There is no requirement for elongation in 8 in.

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

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Designation: A 572/A 572M – 07

American Association State
Highway and Transportation
Officals Standard
AASHTO No.: M223

# Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel[1]

This standard is issued under the fixed designation A 572/A 572M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

## 1. Scope*

1.1 This specification covers five grades of high-strength low-alloy structural steel shapes, plates, sheet piling, and bars. Grades 42 [290], 50 [345], and 55 [380] are intended for riveted, bolted, or welded structures. Grades 60 [415] and 65 [450] are intended for riveted or bolted construction of bridges, or for riveted, bolted, or welded construction in other applications.

1.2 For applications, such as welded bridge construction, where notch toughness is important, notch toughness requirements are to be negotiated between the purchaser and the producer.

1.3 Specification A 588/A 588M shall not be substituted for Specification A 572/A 572M without agreement between the purchaser and the supplier.

1.4 The use of columbium, vanadium, titanium, nitrogen, or combinations thereof, within the limitations noted in Section 5, is required; the selection of type (1, 2, 3, or 5) is at the option of the producer, unless otherwise specified by the purchaser. (See Supplementary Requirement S90.)

1.5 The maximum thicknesses available in the grades and products covered by this specification are shown in Table 1.

1.6 When the steel is to be welded, a welding procedure suitable for the grade of steel and intended use or service is to be utilized. See Appendix X3 of Specification A 6/A 6M for information on weldability.

1.7 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system is to be used independently of the other, without combining values in any way.

1.8 The text of this specification contains notes or footnotes, or both, that provide explanatory material. Such notes and footnotes, excluding those in tables and figures, do not contain any mandatory requirements.

1.9 For structural products produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional tests, of A 6/A 6M apply.

## 2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling

A 36/A 36M Specification for Carbon Structural Steel

A 514/A 514M Specification for High-Yield-Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Welding

A 588/A 588M Specification for High-Strength Low-Alloy Structural Steel, up to 50 ksi [345 MPa] Minimum Yield Point, with Atmospheric Corrosion Resistance

## 3. General Requirements for Delivery

3.1 Structural products furnished under this specification shall conform to the requirements of the current edition of Specification A 6/A 6M, for the specific structural product ordered, unless a conflict exists in which case this specification shall prevail.

3.2 Coils are excluded from qualification to this specification until they are processed into a finished structural product. Structural products produced from coil means structural products that have been cut to individual lengths from a coil. The processor directly controls, or is responsible for, the operations involved in the processing of a coil into a finished structural product. Such operations include decoiling, leveling or straightening, hot-forming or cold-forming (if applicable), cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1—For structural products produced from coil and furnished without heat treatment or with stress relieving only, two test results are to

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.02 on Structural Steel for Bridges, Buildings, Rolling Stock and Ships.

Current edition approved March 1, 2007. Published March 2007. Originally approved in 1966. Last previous edition approved in 2006 as A 572/A 572M – 06.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

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**TABLE 1 Maximum Product Thickness or Size**

| Grade | Yield Point, min | | Maximum Thickness or Size | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Plates and Bars | | Structural Shape Flange or Leg Thickness | | Sheet Piling | Zees and Rolled Tees |
| | ksi | [MPa] | in. | [mm] | in. | [mm] | | |
| 42 [290][A] | 42 | [290] | 6 | [150] | all | all | all | all |
| 50 [345][A] | 50 | [345] | 4[B] | [100][B] | all | all | all | all |
| 55 [380] | 55 | [380] | 2 | [50] | all | all | all | all |
| 60 [415][A] | 60 | [415] | 1¼[C] | [32][C] | 2 | [50] | all | all |
| 65 [450] | 65 | [450] | 1¼ | [32] | 2 | [50] | not available | all |

[A] In the above tabulation, Grades 42, 50, and 60 [290, 345, and 415], are the yield point levels most closely approximating a geometric progression pattern between 36 ksi [250 MPa], min, yield point steels covered by Specification A 36/A 36M and 100 ksi [690 MPa], min, yield strength steels covered by Specification A 514/A 514M.
[B] Round bars up to and including 11 in. [275 mm] in diameter are permitted.
[C] Round bars up to and including 3½ in. [90 mm] in diameter are permitted.

**TABLE 2 Chemical Requirements[A] (Heat Analysis)**

| Diameter, Thickness, or Distance Between Parallel Faces, in. [mm] Plates and Bars | Structural Shape Flange or Leg Thickness, in. [mm] | Grade | Carbon, max, % | Manganese,[B] max, % | Phosphorus, max, % | Sulfur, max, % | Silicon | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Plates to 1½ in. [40 mm] Thick, Shapes with Flange or Leg Thickness to 3 in. [75 mm] inclusive, Sheet Piling, Bars, Zees, and Rolled Tees[C] | Plates Over 1½ in. [40 mm] Thick and Shapes with Flange Thickness Over 3 in. [75 mm] |
| | | | | | | | max, % | range, % |
| 6 [150] | all | 42 [290] | 0.21 | 1.35[D] | 0.04 | 0.05 | 0.40 | 0.15–0.40 |
| 4 [100][E] | all | 50 [345] | 0.23 | 1.35[D] | 0.04 | 0.05 | 0.40 | 0.15–0.40 |
| 2 [50][F] | all | 55 [380] | 0.25 | 1.35[D] | 0.04 | 0.05 | 0.40 | 0.15-0.40 |
| 1¼ [32][F] | ≤2 [50] | 60 [415] | 0.26 | 1.35[D] | 0.04 | 0.05 | 0.40 | [G] |
| >½ – 1¼ [13–32] | >1-2 [25-50] | 65 [450] | 0.23 | 1.65 | 0.04 | 0.05 | 0.40 | [G] |
| ≤½ [13][H] | ≤ 1[H] | 65 [450] | 0.26 | 1.35 | 0.04 | 0.05 | 0.40 | [G] |

[A] Copper when specified shall have a minimum content of 0.20 % by heat analysis (0.18 % by product analysis).
[B] Manganese, minimum, by heat analysis of 0.80 % (0.75 % by product analysis) shall be required for all plates over ⅜ in. [10 mm] in thickness; a minimum of 0.50 % (0.45 % by product analysis) shall be required for plates ⅜ in. [10 mm] and less in thickness, and for all other products. The manganese to carbon ratio shall not be less than 2 to 1.
[C] Bars over 1½ in. [40 mm] in diameter, thickness, or distance between parallel faces shall be made by a killed steel practice.
[D] For each reduction of 0.01 percentage point below the specified carbon maximum, an increase of 0.06 percentage point manganese above the specified maximum is permitted, up to a maximum of 1.60 %.
[E] Round bars up to and including 11 in. [275 mm] in diameter are permitted.
[F] Round bars up to and including 3½ in. [90 mm] in diameter are permitted.
[G] The size and grade is not described in this specification.
[H] An alternative chemical requirement with a maximum carbon of 0.21 % and a maximum manganese of 1.65 % is permitted, with the balance of the elements as shown in Table 2.

be reported for each qualifying coil. Additional requirements regarding structural products produced from coil are described in A 6/A 6M.

## 4. Materials and Manufacture

4.1 The steel shall be semi-killed or killed

## 5. Chemical Composition

5.1 The heat analysis shall conform to the requirements prescribed in Table 2 and Table 3.

5.2 The steel shall conform on product analysis to the requirements prescribed in Table 2 and Table 3, subject to the product analysis tolerances in Specification A 6/A 6M.

## 6. Mechanical Properties

6.1 *Tensile Properties*:

6.1.1 The material as represented by the test specimens shall conform to the tensile properties given in Table 4.

## 7. Test Reports

7.1 In addition to the Test Reports requirements in Specification A 6/A 6M, when Specification A 588/A 588M is substituted for Specification A 572/A 572M, the test report shall include the statement "Specification A 588/A 588M substituted" and the heat analysis of all elements required in Specification A 588/A 588M.

**TABLE 3 Alloy Content**

| Type[A] | Elements | Heat Analysis, % |
|---|---|---|
| 1 | Columbium[B] | 0.005–0.05[C] |
| 2 | Vanadium | 0.01–0.15 |
| 3 | Columbium[B] | 0.005-0.05[C] |
| | Vanadium | 0.01–0.15 |
| | Columbium plus vanadium | 0.02–0.15[D] |
| 5 | Titanium | 0.006-0.04 |
| | Nitrogen | 0.003–0.015 |
| | Vanadium | 0.06 max |

[A] Alloy content shall be in accordance with Type 1, 2, 3, or 5 and the contents of the applicable elements shall be reported on the test report.

[B] Columbium shall be restricted to the following thicknesses and sizes unless killed steel is furnished. Killed steel shall be confirmed by a statement of killed steel on the test report, or by a report on the presence of a sufficient quantity of a strong deoxidizing element, such as silicon at 0.10 % or higher, or aluminum at 0.015 % or higher. See table below.

[C] Product analysis limits = 0.004 to 0.06 %.

[D] Product analysis limits = 0.01 to 0.16 %.

| Grades | Maximum Plate, Bar, Sheet Piling, Zees, and Rolled Tee Thicknesses, in. [mm] | Maximum Structural Shape Flange or Leg Thickness, in. [mm] |
|---|---|---|
| 42, 50, and 55 [290, 345, and 380] | ¾ [20] | 1.5 [40] |
| 60 and 65 [415 and 450] | ½ [13] | 1 [25] |

**TABLE 4 Tensile Requirements[A]**

| Grade | Yield Point, min | | Tensile Strength, min | | Minimum Elongation, %[B,C,D] | |
|---|---|---|---|---|---|---|
| | ksi | [MPa] | ksi | [MPa] | in 8 in. [200 mm] | in 2 in. [50 mm] |
| 42 [290] | 42 | [290] | 60 | [415] | 20 | 24 |
| 50 [345] | 50 | [345] | 65 | [450] | 18 | 21 |
| 55 [380] | 55 | [380] | 70 | [485] | 17 | 20 |
| 60 [415] | 60 | [415] | 75 | [520] | 16 | 18 |
| 65 [450] | 65 | [450] | 80 | [550] | 15 | 17 |

[A] See specimen Orientation under the Tension Tests section of Specification A 6/A 6M.

[B] Elongation not required to be determined for floor plate.

[C] For wide flange shapes over 426 lb/ft [634 kg/m], elongation in 2 in. [50 mm] of 19 % minimum applies.

[D] For plates wider than 24 in. [600 mm], the elongation requirement is reduced two percentage points for Grades 42, 50, and 55 [290, 345, and 380], and three percentage points for Grades 60 and 65 [415 and 450]. See elongation requirement adjustments in the Tension Tests section of Specification A 6/A 6M.

## 8. Keywords

8.1 bars; bolted construction; bridges; buildings; columbium-vanadium; high-strength; low-alloy; plates; riveted construction; shapes; sheet piling; steel; structural steel; welded construction

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order or contract. Standardized supplementary requirements for use at the option of the purchaser are listed in Specification A 6/A 6M. Those that are considered suitable for use with this specification are listed by title:

S5. Charpy V-Notch Impact Test.
S18. Maximum Tensile Strength
S30. Charpy V-Notch Impact Test for Structural Shapes: Alternate Core Location
S32. Single Heat Bundles.

In addition, the following supplementary requirements are suitable for use:

### S81. Tensile Strength

S81.1 For Grade 50 [345] steel of thicknesses ¾ in. [20 mm] and less, the tensile strength shall be a minimum of 70 ksi [485 MPa].

### S90. Type

S90.1 The specific type of steel shall be as specified by the purchaser in the order or contract.

--`,,`,,`-`-`,,`,,`,`,,`---

## SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 572/A 572M – 06) that may impact the use of this standard. (Approved March 1, 2007.)

*(1)* Added 1.3 and new Section 7.

Committee A01 has identified the location of selected changes to this standard since the last issue (A 572/A 572M – 04) that may impact the use of this standard. (Approved March 1, 2006.)

*(1)* The maximum permitted manganese was changed from 1.50 % to 1.60 % for grades 42, 50, 55, and 60 in Table 2.

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**Designation: A 573/A 573M – 00a**

# Standard Specification for Structural Carbon Steel Plates of Improved Toughness[1]

This standard is issued under the fixed designation A 573/A 573M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers structural quality carbon-manganese-silicon steel plates in three tensile strength ranges intended primarily for service at atmospheric temperatures where improved notch toughness is important.

1.2 Plates covered by this specification are limited to a maximum thickness of 1.5 in. [40 mm].

1.3 When the steel is to be welded, it is presupposed that a welding procedure suitable for the grade of steel and intended use or service will be utilized. See Appendix X 3 of Specification A 6/A 6M for information on weldability.

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

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling[2]

## 3. General Requirements for Delivery

3.1 Material furnished under this specification shall conform to the requirements of the current edition of Specification A 6/A 6M, for the ordered material, unless a conflict exists in which case this specification shall prevail.

## 4. Materials and Manufacture

4.1 The steel shall be made to fine grain practice.

**TABLE 1 Chemical Requirements (Heat Analysis)**

| | Composition, % | | |
|---|---|---|---|
| | Grade 58 [400] | Grade 65 [450] | Grade 70 [485] |
| Carbon, max: | | | |
| ½ in. [13 mm] and under | 0.23 | 0.24 | 0.27 |
| Over ½ in. to 1½in., [13 to 40 mm], incl | 0.23 | 0.26 | 0.28 |
| Manganese | 0.60–0.90[A] | 0.85–1.20 | 0.85–1.20 |
| Phosphorus, max | 0.035 | 0.035 | 0.035 |
| Sulfur, max | 0.04 | 0.04 | 0.04 |
| Silicon | 0.10–0.35 | 0.15–0.40 | 0.15–0.40 |

[A]The upper limit of manganese may be exceeded, provided that the carbon content plus ⅛manganese content does not exceed 0.40 % based on heat analysis.

## 5. Chemical Composition

5.1 The heat analysis shall conform to the requirements prescribed in Table 1.

5.2 The steel shall conform on product analysis to the requirements as prescribed in Table 1 subject to the product analysis tolerances in Specification A 6/A 6M.

## 6. Tension Test

6.1 The steel, as represented by the tension test specimens, shall conform to the requirements as to tensile properties prescribed in Table 2.

**TABLE 2 Tensile Requirements[A]**

| | Grade 58 [400] | Grade 65 [450] | Grade 70 [485] |
|---|---|---|---|
| Tensile strength, ksi [MPa] | 58–71 [400–490] | 65–77 [450–530] | 70–90 [485–620] |
| Yield point, min, ksi [MPa] | 32 [220] | 35 [240] | 42 [290] |
| Elongation in 8 in. [200 mm][B,C] min, % | 21 | 20 | 18 |
| Elongation in 2 in. [50 mm][B,C], min, % | 24 | 23 | 21 |

[A]See the Orientation subsection in the Tension Tests section of Specification A 6/A 6M.

[B]Elongation not required to be determined for floor plate.

[C]For plates wider than 24 in. [600 mm], the elongation requirement is reduced two percentage points. See the Elongation Requirement Adjustments subsection under the Tension Tests section of Specification A 6/A 6M.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.02 on Structural Steel for Bridges, Buildings, Rolling Stock, and Ships.

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[2] *Annual Book of ASTM Standards,* Vol 01.04.

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## SUPPLEMENTARY REQUIREMENTS

Standardized supplementary requirements for use at the option of the purchaser are listed in Specification A 6/A 6M.

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**Designation: A 588/A 588M – 97a**

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American Association State
Highway and Transportation Officials Standard
AASHTO No.: M 222

# Standard Specification for High-Strength Low-Alloy Structural Steel with 50 ksi [345 MPa] Minimum Yield Point to 4 in. [100 mm] Thick[1]

This standard is issued under the fixed designation A 588/A 588M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

## 1. Scope

1.1 This specification covers high-strength low-alloy structural steel shapes, plates, and bars for welded, riveted, or bolted construction but intended primarily for use in welded bridges and buildings where savings in weight or added durability are important. The atmospheric corrosion resistance of this steel in most environments is substantially better than that of carbon structural steels with or without copper addition (see Note 1). When properly exposed to the atmosphere, this steel is suitable for many applications in the bare (unpainted) condition. This specification is limited to material up to 8 in. [200 mm] inclusive in thickness.

NOTE 1—For methods of estimating the atmospheric corrosion resistance of low-alloy steels, see Guide G 101.

1.2 When the steel is to be welded, a welding procedure suitable for the grade of steel and intended use or service is to be utilized. See Appendix X3 of Specification A 6/A 6M for information on weldability.

1.3 Supplementary requirements are provided for use where additional testing or additional restrictions are desired by the purchaser. Such requirements apply only when specified in the purchase order.

1.4 For Group 4 and Group 5 wide-flange shapes for use in tension, it is recommended that the purchaser consider specifying supplemenatary requirements, such as fine austenitic grain size and Charpy V-notch impact testing.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other, without combining values in any way.

1.6 The text of this specification contains notes, footnotes, or both, that provide explanatory material. Such notes and footnotes, excluding those in tables and figures, do not contain any mandatory requirements.

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes and Sheet Piling[2]

G 101 Guide for Estimating Atmospheric Corrosion Resistance of Low-Alloy Steels[3]

## 3. General Requirements for Delivery

3.1 Material furnished under this specification shall conform to the requirements of the current edition of Specification A 6/A 6M, for the ordered material, unless a conflict exists in which case this specification shall prevail.

## 4. Process

4.1 The steel shall be made by one of the following processes: open-hearth, basic-oxygen, or electric-furnace.

4.2 The steel shall be made to fine grain practice.

## 5. Chemical Composition

5.1 The heat analysis shall conform to the requirements prescribed in Table 1.

5.2 The steel shall conform on product analysis to the requirements prescribed in Table 1, subject to the product analysis tolerances in Specification A 6/A 6M.

5.3 The atmospheric corrosion-resistance index, calculated on the basis of the chemical composition of the steel, as described in Guide G 101, shall be 6.0 or higher.

NOTE 2—The user is cautioned that the Guide G 101 predictive equation for calculation of an atmospheric corrosion-resistance index has only been verifed for the composition limits stated in the guide.

5.4 When required, the manufacturer shall supply evidence of corrosion resistance satisfactory to the purchaser.

## 6. Tensile Requirements

6.1 The material as represented by the test specimens shall

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.02 on Structural Steel for Bridges, Buildings, Rolling Stock, and Ships.

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[2] *Annual Book of ASTM Standards*, Vol 01.04.

[3] *Annual Book of ASTM Standards*, Vol 03.02.

conform to the requirements for tensile properties prescribed in Table 2.

## 7. Keywords

7.1 atmospheric corrosion resistance; bars; bolted construction; bridges; buildings; durability; high-strength; low-alloy; plates; riveted construction; shapes; steel; structural steel; weight; welded construction

**TABLE 1 Chemical Requirements (Heat Analysis)**

NOTE 1—Where "..." appears in this table there is no requirement.

| Element | Composition, % | | | |
|---|---|---|---|---|
| | Grade A | Grade B | Grade C | Grade K |
| Carbon | 0.19 max | 0.20 max | 0.15 max | 0.17 max |
| Manganese | 0.80–1.25 | 0.75–1.35 | 0.80–1.35 | 0.50–1.20 |
| Phosphorus | 0.04 max | 0.04 max | 0.04 max | 0.04 max |
| Sulfur | 0.05 max | 0.05 max | 0.05 max | 0.05 max |
| Silicon | 0.30–0.65 | 0.15–0.50 | 0.15–0.40 | 0.25–0.50 |
| Nickel | 0.40 max | 0.50 max | 0.25–0.50 | 0.40 max |
| Chromium | 0.40–0.65 | 0.40–0.70 | 0.30–0.50 | 0.40–0.70 |
| Molybdenum | ... | ... | ... | 0.10 max |
| Copper | 0.25–0.40 | 0.20–0.40 | 0.20–0.50 | 0.30–0.50 |
| Vanadium | 0.02–0.10 | 0.01–0.10 | 0.01–0.10 | ... |
| Columbium | ... | ... | ... | 0.005–0.05[A] |

[A]For plates under ½ in. in thickness, the minimum columbium is waived.

**TABLE 2 Tensile Requirements[A]**

NOTE 1—Where "..." appears in this table there is no requirement.

| | Plates and Bars | | | Structural Shapes |
|---|---|---|---|---|
| | For Thicknesses 4 in. and Under [100 mm] | For Thicknesses Over 4 in. to 5 in. incl [100 to 125 mm] | For Thicknesses Over 5 in. to 8 in. incl [125 to 200 mm] | All Groups[B] |
| Tensile strength, min,ksi [MPa] | 70 [485] | 67 [460] | 63 [435] | 70 [485] |
| Yield point, min, ksi [MPa] | 50 [345] | 46 [315] | 42 [290] | 50 [345] |
| Elongation in 8 in. [200 mm], min, % | 18[C,D] | ... | ... | 18[D] |
| Elongation in 2 in. [50 mm], min, % | 21[C,D] | 21[C,D] | 21[C,D] | 21[E] |

[A]See specimen Orientation under the Tension Tests section of Specification A 6/A 6M.
[B]See Specification A 6/A 6M.
[C]Elongation not required to be determined for floor plate.
[D]For plates wider than 24 in. [600 mm], the elongation requirement is reduced two percentage points. See elongation requirement adjustments in the Tension Tests section of Specification A 6/A 6M.
[E]For wide flange shapes over 426 lb/ft [634 kg/m] elongation in 2 in. [50 mm] of 18 % minimum applies.

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order or contract. Standardized supplementary requirements for use at the option of the purchaser are listed in Specification A 6/A 6M. Those that are considered suitable for use with this specification are listed by title:

S2. Product Analysis,
S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,
S5. Charpy V-Notch Impact Test,
S6. Drop Weight Test,
S8. Ultrasonic Examination,
S14. Bend Test,
S15. Reduction of Area, and
S18. Maximum Tensile Strength.

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Designation: A 633/A633M – 01

# Standard Specification for Normalized High-Strength Low-Alloy Structural Steel Plates[1]

This standard is issued under the fixed designation A 633/A633M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

## 1. Scope

1.1 This specification covers normalized high-strength low-alloy structural steel plates for welded, riveted, or bolted construction.

1.2 This material is particularly suited for service at low ambient temperatures of −50°F [−45°C] and higher where notch toughness better than that expected in as-rolled material of a comparable strength level is desired.

1.3 Four grades, designated Grades A, C, D, and E (essentially former Specification A 633 without a grade designation) are covered by this specification. Grade A provides a minimum yield point of 42 ksi [290 MPa] in thicknesses through 4 in. [100 mm], inclusive. Grades C and D provide a minimum yield point of 50 ksi [345 MPa] in thicknesses up to 2.50 in. [65 mm], inclusive and 46.0 ksi [315 MPa] in thicknesses over 2.50 in. to 4.0 in. [65 to 100 mm], inclusive. Grade E provides a minimum yield point of 60 ksi [415 MPa] in thicknesses up to 4.0 in. [100 mm], inclusive and 55 ksi [380 MPa] in thicknesses over 4 in. to 6 in. [100 to 150 mm], inclusive.

1.4 Current practice normally limits plates furnished under this specification to the maximum thicknesses shown in 1.3. The individual manufacturer should be consulted on size limitations for other product forms.

1.5 When the steel is to be welded, it is presupposed that a welding procedure suitable for the grade of steel and intended use or service will be utilized. See Appendix X3 no id found of Specification A 6/A 6M for information on weldability.

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

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 6/A6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling[2]

A 673/A673M Specification for Sampling Procedure for Impact Testing of Structural Steel[2]

## 3. General Requirements for Delivery

3.1 Material furnished under this specification shall conform to the requirements of the current edition of Specification A 6/A 6M, for the ordered material, unless a conflict exists in which case this specification shall prevail.

## 4. Manufacture

4.1 The requirements for fine austenitic grain size in Specification A 6/A 6M shall be met.

## 5. Heat Treatment

5.1 The material shall be normalized by heating to a suitable temperature which produces an austenitic structure, but not exceeding 1700°F [925°C], holding a sufficient time to attain uniform heat throughout the material and cooling in air.

5.1.1 Grade E material over 3 in. [75 mm] in thickness shall be double normalized.

5.2 If the purchaser elects to perform the required heat treatment, the material shall be accepted on the basis of mill tests made from test coupons heat treated in accordance with the purchase order requirements. If the test coupon heat treatment requirements are not indicated on the purchase order, the manufacturer shall heat treat the test coupons under conditions considered appropriate. The manufacturer shall inform the purchaser of the heat-treatment procedure followed in heat treating the test coupons at the mill.

## 6. Chemical Composition

6.1 The heat analysis shall conform to the chemical composition requirements listed in Table 1.

6.2 The steel shall conform on product analysis to the requirements prescribed in Table 1, subject to the product analysis tolerances in Specification A 6/A 6M.

## 7. Tension Test

7.1 The material as represented by the test specimens shall

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.02 on Structural Steel for Bridges, Buildings, Rolling Stock, and Ships.

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[2] *Annual Book of ASTM Standards*, Vol 01.04.

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**TABLE 1 Chemical Requirements**

NOTE—Where "..." appears in this table, there is no requirement.

| Element | Grade A, % | Grade C, % | Grade D, % | Grade E, %[A] |
|---|---|---|---|---|
| Carbon, max | 0.18 | 0.20 | 0.20 | 0.22 |
| Manganese: | | | | |
| 1 1/2 in. [40 mm] and under in thickness | 1.00–1.35 | 1.15–1.50[B] | 0.70–1.35 | 1.15–1.50 |
| Over 1 1/2 in. to 4 in. [40 to 100 mm], incl | 1.00–1.35 | 1.15–1.50[B] | 1.00–1.60 | 1.15–1.50 |
| Over 4 in. to 6 in. [100 to 150 mm], incl | [C] | [C] | [C] | 1.15–1.50 |
| Phosphorus, max | 0.035 | 0.035 | 0.035 | 0.035 |
| Sulfur, max | 0.04 | 0.04 | 0.04 | 0.04 |
| Silicon | 0.15–0.50 | 0.15–0.50 | 0.15–0.50 | 0.15–0.50 |
| Vanadium | ... | ... | ... | 0.04–0.11 |
| Columbium | 0.05 max | 0.01–0.05 | ... | [D] |
| Nitrogen, max | ... | ... | ... | 0.03 |
| Copper, max | ... | ... | 0.35 | ... |
| Nickel, max | ... | ... | 0.25 | ... |
| Chromium, max | ... | ... | 0.25 | ... |
| Molybdenum, max | ... | ... | 0.08 | ... |

[A] For Grade E the minimum total aluminum content shall be 0.018 %, or the vanadium nitrogen ratio shall be 4:1 minimum.
[B] For Grade C manganese content may be increased to 1.60 % maximum provided the carbon content does not exceed 0.18 %.
[C] The size and grade is not described in this specification.
[D] Columbium may be present in the amount of 0.01 to 0.05 %.

conform to the requirements listed in Table 2.

## 8. Keywords

8.1 bolted construction; high-strength; low-alloy; low ambient temperatures; normalized; notch toughness; plates; riveted construction; steel; structural steel; welded construction

## SUPPLEMENTARY REQUIREMENTS

Standardized supplementary requirements for use at the option of the purchaser are listed in Specification A 6/A 6M. Those that are considered suitable for use with this specification are listed by title:

S5. Charpy V-Notch Impact Test.
S23. Copper-Bearing Steel (for improved atmospheric corrosion resistance).

**TABLE 2 Tensile Requirements[A]**

| | Grade A | Grades C and D | Grade E |
|---|---|---|---|
| Yield point, min, ksi [MPa]: | | | |
| 2.5 in. [65 mm] and under | 42 [290] | 50 [345] | 60 [415] |
| Over 2.5 in. to 4 in. [65 to 100 mm], incl | 42 [290] | 46 [315] | 60 [415] |
| Over 4 in. to 6 in. [100 to 150 mm], incl | [B] | [B] | 55 [380] |
| Tensile strength, ksi [MPa]: | | | |
| 2.5 in. [65 mm] and under | 63 to 83 [430 to 570] | 70 to 90 [485 to 620] | 80 to 100 [550 to 690] |
| Over 2.5 in. to 4 in. [65 to 100 mm], incl | 63 to 83 [430 to 570] | 65 to 85 [450 to 590] | 80 to 100 [550 to 690] |
| Over 4 in. to 6 in. [100 to 150 mm], incl | [B] | [B] | 75 to 95 [515 to 655] |
| Elongation in 8 in. [200 mm], min, %[C] | 18 | 18 | 18 |
| Elongation in 2 in. [50 mm], min, %[C] | 23 | 23 | 23 |

[A] See specimen Orientation under the Tension Tests of Specification A 6/A 6 M.
[B] The size and grade is not described in this specification.
[C] For plates wider than 24 in. (610 mm), the elongation requirement is reduced two percentage points. See elongation requirement adjustments in the Tension Tests section of Specification A 6/A 6M.

## APPENDIX

**(Nonmandatory Information)**

### X1. CHARPY V-NOTCH IMPACT TEST

X1.1 The values shown in Table X1.1 are included only as information as to the guarantees that are generally available. Mandatory conformance to any of the values listed is a matter for agreement between the purchaser and the manufacturer.

**TABLE X1.1 Charpy V-Notch Impact Test Minimum Energy Values (Average of Three Specimens)**

| Test Temperature, °F [°C] | Longitudinal Specimens, ft·lbf [J] | Transverse Specimens, ft·lbf [J] |
|---|---|---|
| −75 [−60] | 15 [20] | 15 [20] |
| −60 [−50] | 20 [27] | 15 [20] |
| −50 [−45] | 25 [34] | 20 [27] |
| −40 [−40] | 25 [34] | 20 [27] |
| −30 [−35] | 30 [41] | 25 [34] |
| 0 [−20] | 40 [54] | 30 [41] |
| 32 [0] | 45 [61] | 30 [41] |
| 75 [25] | 50 [68] | 30 [41] |

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Designation: A 662/A 662M – 03

# Standard Specification for Pressure Vessel Plates, Carbon-Manganese-Silicon Steel, for Moderate and Lower Temperature Service[1]

This standard is issued under the fixed designation A 662/A 662M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope*

1.1 This specification[2] covers three grades of carbon-manganese-silicon steel plates intended primarily for service in welded pressure vessels where improved low temperature notch toughness is important.

1.2 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements; however, current practice normally limits the maximum thickness of plates furnished under this specification to 2 in. [50 mm].

1.3 Grades A, B, and C comply substantially with the requirements of ISO Pressure Vessel Steels P9, P15, and P18, respectively.

1.4 For plates produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results, of Specification A 20/A 20M apply.

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

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels[3]

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates[3]

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates[3]

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications[3]

## 3. General Requirements and Ordering Information

3.1 Plates supplied to this product specification shall conform to Specification A 20/A 20M, which outlines the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality, and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for ordering information that should be complied with when purchasing plates to this specification.

3.3 In addition to the basic requirements of this specification certain supplementary requirements are available where additional control, testing, or examination is required to meet the end use requirements.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1—For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plates from coil are described in Specification A 20/A 20M.

3.6 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

[1] This specification is under the jurisdiction of Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.11 on Steel Plates for Boilers and Pressure Vessels.

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[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-662/SA-662M in Section II of that Code.

[3] *Annual Book of ASTM Standards,* Vol 01.04.

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

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**TABLE 1 Chemical Requirements**

| Element | Composition, % | | | | | |
|---|---|---|---|---|---|---|
| | Grade A | | Grade B | | Grade C | |
| | Heat Analysis | Product Analysis | Heat Analysis | Product Analysis | Heat Analysis | Product Analysis |
| Carbon, max | 0.14 | 0.17 | 0.19 | 0.22 | 0.20 | 0.24 |
| Manganese | 0.90–1.35 | 0.84–1.46 | 0.85–1.50 | 0.79–1.62 | 1.00–1.60 | 0.92–1.72 |
| Phosphorus, max | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 |
| Sulfur, max | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 |
| Silicon | 0.15–0.40 | 0.13–0.45 | 0.15–0.40 | 0.13–0.45 | 0.15–0.50 | 0.13–0.55 |

**TABLE 2 Tensile Properties**

| | Grade A | Grade B | Grade C |
|---|---|---|---|
| Tensile strength, ksi [MPa] | 58–78 [400–540] | 65–85 [450–585] | 70–90 [485–620] |
| Yield strength,[A] min, ksi [MPa] | 40 [275] | 40 [275] | 43 [295] |
| Elongation in 8 in. [200 mm], min, %[B] | 20 | 20 | 18 |
| Elongation in 2 in. [50 mm], min, %[B] | 23 | 23 | 22 |

[A] Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.
[B] See Specification A 20/A 20M for elongation adjustments.

## 4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

## 5. Heat Treatment

5.1 All plates of Grade A and plates of Grades B and C over 1½ in. [40 mm] in thickness shall be normalized.

5.2 Plates of Grades B and C, 1½ in. [40 mm] and under in thickness, are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

## 6. Chemical Requirements

6.1 The steel shall conform to the requirements as to chemical composition given in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

## 7. Mechanical Requirements

7.1 *Tension Test Requirements*—The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Those that are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test (see Appendix X1),

S6. Drop Weight Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M, and

S17. Vacuum Carbon-Deoxidized Steel.

## APPENDIX

**(Nonmandatory Information)**

### X1. NOTCH TOUGHNESS

X1.1 When Charpy V-notch testing is required, the minimum values listed in Table X1.1 will be guaranteed onnormalized material for the temperature specified by the purchaser.

**TABLE X1.1 Charpy V-Notch Requirements**[A]

| Testing Temperature, °F [°C] | Grade A | | Grades B and C | |
|---|---|---|---|---|
| | Longitudinal Specimens, ft·lbf [J] | Transverse Specimens, ft·lbf [J] | Longitudinal Specimens, ft·lbf [J] | Transverse Specimens, ft·lbf [J] |
| −75 [−60] | 20 [27] | 15 [20] | 15 [20] | ... |
| −60 [−50] | 30 [41] | 18 [24] | 20 [27] | ... |
| −50 [−45] | 35 [47] | 19 [26] | 22 [30] | 15 [20] |
| −40 [−40] | 40 [54] | 20 [27] | 25 [34] | 20 [27] |
| −25 [−32] | 45 [61] | 25 [34] | 30 [41] | 20 [27] |
| 0 [18] | 55 [75] | 30 [41] | 35 [47] | 25 [34] |
| 32 [0] | 70 [95] | 35 [47] | 40 [54] | 25 [34] |
| 75 [25] | 75 [102] | 40 [54] | 50 [68] | 30 [41] |

[A] The above values apply to the average of three full size specimens. Values for subsize specimens are denoted as listed in Specification A 20/A 20M.

## SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 662/A 662M – 01$^{\epsilon 1}$) that may impact the use of this standard.

*(1)* 1.4, 3.5, and Note 1 were revised to be consistent with the terminology and requirements of Specification A 20/A 20M.

*(2)* 3.3 was revised to be more general.

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Designation: A 709/A 709M – 05

# Standard Specification for Structural Steel for Bridges[1]

This standard is issued under the fixed designation A 709/A 709M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope*

1.1 This specification covers carbon and high-strength low-alloy steel structural shapes, plates, and bars and quenched and tempered alloy steel for structural plates intended for use in bridges. Nine grades are available in four yield strength levels as follows:

| Grade U.S. [SI] | Yield Strength, ksi [MPa] |
|---|---|
| 36 [250] | 36 [250] |
| 50 [345] | 50 [345] |
| 50S [345S] | 50 [345] |
| 50W [345W] | 50 [345] |
| HPS 50W [HPS 345W] | 50 [345] |
| HPS 70W [HPS 485W] | 70 [485] |
| 100 [690] | 100 [690] |
| 100W [690W] | 100 [690] |
| HPS 100W [HPS 690W] | 100 [690] |

1.1.1 Grades 36 [250], 50 [345], 50S [345S], 50W [345W], 100 [690], and 100W [690W] are also included in Specifications A 36/A 36M, A 572/A 572M, A 992/A 992M, A 588/A 588M, and A 514/A 514M, respectively. When the supplementary requirements of this specification are specified, they exceed the requirements of Specifications A 36/A 36M, A 572/A 572M, A 992/A 992M, A 588/A 588M, and A 514/A 514M.

1.1.2 Grades 50W [345W], HPS 50W [HPS 345W], HPS 70W [HPS 485W], 100W [690W], and HPS 100W [HPS 690W] have enhanced atmospheric corrosion resistance (see 14.1.2). Product availability is shown in Table 1.

1.2 Grade HPS 70W [HPS 485W], 100 [690], 100W [690W], or HPS 100W [HPS 690W] shall not be substituted for Grades 36 [250], 50 [345], 50S [345S], 50W [345W], or HPS 50W [HPS 345W]. Grade 50W [345W], or HPS 50W [HPS 345W] shall not be substituted for Grades 36 [250], 50 [345] or 50S [345S] without agreement between the purchaser and the supplier.

1.3 When the steel is to be welded, it is presupposed that a welding procedure suitable for the grade of steel and intended use or service will be utilized. See Appendix X3 of Specification A 6/A 6M for information on weldability.

1.4 For structural products to be used as tension components requiring notch toughness testing, standardized requirements are provided in this standard, and they are based upon American Association of State Highway and Transportation Officials (AASHTO) requirements for both fracture critical and non-fracture critical members.

1.5 Supplementary requirements are available but shall apply only if specified in the purchase order.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system is to be used independently of the other, without combining values in any way.

1.7 For structural products produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results, of Specification A 6/A 6M apply.

## 2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling

A 36/A 36M Specification for Carbon Structural Steel

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

A 514/A 514M Specification for High-Yield-Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Welding

A 572/A 572M Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel

A 588/A 588M Specification for High-Strength Low-Alloy Structural Steel with 50 ksi [345 MPa] Minimum Yield Point to 4 in. [100 mm] Thick

A 673/A 673M Specification for Sampling Procedure for Impact Testing of Structural Steel

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.02 on Structural Steel for Bridges, Buildings, Rolling Stock, and Ships.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

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**TABLE 1 Tensile and Hardness Requirements[A]**

NOTE 1— Where ". . ." appears in this table, there is no requirement.

| Grade | Plate Thickness, in. [mm] | Structural Shape Flange or Leg Thickness, in. [mm] | Yield Point or Yield Strength,[B] ksi [MPa] | Tensile Strength, ksi [MPa] | Minimum Elongation, % | | | | Reduction of Area[C,D] min, % | Brinell Hardness Number |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Plates and Bars[C,E] | | Shapes[E] | | | |
| | | | | | 8 in. or 200 mm | 2 in. or 50 mm | 8 in. or 200 mm | 2 in. or 50 mm | | |
| 36 [250] | to 4 [100], incl | to 3 in. [75 mm], incl | 36 [250] min | 58–80 [400–550] | 20 | 23 | 20 | 21[F] | ... | ... |
| | | over 3 in. [75 mm] | 36 [250] min | 58 [400] min | ... | ... | 20 | 19 | ... | ... |
| 50 [345] | to 4 [100], incl | all | 50 [345] min | 65 [450] min | 18 | 21 | 18 | 21[F] | ... | ... |
| 50S [345S] | [G] | all | 50–65 [345–450][H] | 65 [450][H] min | ... | ... | 18 | 21 | ... | ... |
| 50W [345W] and HPS 50W [HPS 345W] | to 4 [100], incl | all | 50 [345] min | 70 [485] min | 18 | 21 | 18 | 21[I] | ... | ... |
| HPS 70W [HPS 485 W] | to 4 [100], incl | [G] | 70 [485] min[B] | 85–110 [585–760] | . . . | 19[J] | . . . | . . . | . . . | ... |
| 100 [690] , 100W [690W], and HPS 100W [HPS 690W] | to 2½ [65], incl | [G] | 100 [690] min[B] | 110–130 [760–895] | ... | 18[J] | ... | ... | [K] | 235–293[L] |
| 100 [690] and 100W [690 W] | over 2½ to 4 [65 to 100] | [G] | 90 [620] min[B] | 100–130 [690–895] | ... | 16[J] | ... | ... | [K] | ... |

[A] See specimen orientation and preparation subsection in the Tension Tests section of Specification A 6/A 6 M.
[B] Measured at 0.2 % offset or 0.5 % extension under load as described in Section 13 of Test Methods A 370.
[C] Elongation and reduction of area not required to be determined for floor plates.
[D] For plates wider than 24 in. [600 mm], the reduction of area requirement, where applicable, is reduced by five percentage points.
[E] For plates wider than 24 in. [600 mm], the elongation requirement is reduced by two percentage points. See elongation requirement adjustments in the Tension Tests section of Specification A 6/A 6M.
[F] Elongation in 2 in. or 50 mm: 19 % for shapes with flange thickness over 3 in. [75 mm].
[G] Not applicable.
[H] The yield to tensile ratio shall be 0.85 or less.
[I] For wide flange shapes with flange thickness over 3 in. [75 mm], elongation in 2 in. or 50 mm. of 18 % minimum applies.
[J] If measured on the Fig. 3 (Test Methods A 370) 1½ –in. [40–mm] wide specimen, the elongation is determined in a 2-in. or 50-mm. gage length that includes the fracture and shows the greatest elongation.
[K] 40 % minimum applies if measured on the Fig 3 (Test Methods A 370) 1 ½ –in. [40-mm] wide specimen; 50 % minimum applies if measured on the Fig. 4 (Test Methods A 370) ½ –in. [12.5-mm] round specimen.
[L] Applies only to Grades 100 [690] and 100W [690W] plates that are ⅜ in. [10 mm] or less in thickness and are not tension tested (See 8.1).

**TABLE 2 Grade 36 [250] Chemical Requirements (Heat Analysis)**

NOTE 1— Where ". . ." appears in this table there is no requirement. The heat analysis for manganese shall be determined and reported as described in the Heat Analysis section of Specification A 6/A 6M.

| Product Thickness, in. (mm) | Shapes[A] All | Plates[B] | | | | Bars[B] | | |
|---|---|---|---|---|---|---|---|---|
| | | To ¾ [20], incl | Over ¾ to 1½ [20 to 40], incl | Over 1½ to 2½ [40 to 65], incl | Over 2½ to 4 [65 to 100], incl | To ¾ [20], incl | Over ¾ to 1½ [20 to 40], incl | Over 1½ to 4 [100], incl |
| Carbon, max, % | 0.26 | 0.25 | 0.25 | 0.26 | 0.27 | 0.26 | 0.27 | 0.28 |
| Manganese, % | ... | ... | 0.80–1.20 | 0.80–1.20 | 0.85–1.20 | ... | 0.60–0.90 | 0.60–0.90 |
| Phosphorus, max, % | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| Sulfur, max, % | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Silicon, % | 0.40 max | 0.40 max | 0.40 max | 0.15–0.40 | 0.15–0.40 | 0.40 max | 0.40 max | 0.40 max |
| Copper, min, % when copper steel is specified | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |

[A] Manganese content of 0.85 to 1.35 % and silicon content of 0.15 to 0.40 % is required for shapes with flange thickness over 3 in. [75 mm].
[B] For each reduction of 0.01 % below the specified carbon maximum, an increase of 0.06 % manganese above the specified maximum will be permitted up to a maximum of 1.35 %.

A 992/A 992M Specification for Structural Steel Shapes
G 101 Guide for Estimating the Atmospheric Corrosion Resistance of Low-Alloy Steels

## 3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

**TABLE 3 Grade 50 [345] Chemical Requirements[A] (Heat Analysis)**

| Maximum Diameter, Thickness, or Distance Between Parallel Faces, in. [mm] | Carbon, max, % | Manganese,[B] max, % | Phosphorus, max, % | Sulfur, max, % | Silicon[C] | | Columbium, Vanadium and Nitrogen |
|---|---|---|---|---|---|---|---|
| | | | | | Plates to 1½-in. [40–mm] Thick, Shapes with flange or leg thickness to 3 in. [75 mm] inclusive, Sheet Piling, Bars, Zees, and Rolled Tees, max, %[D] | Plates Over 1½ –in. [40-mm] Thick and Shapes with flange thickness over 3 in. [75 mm], % | |
| 4 [100] | 0.23 | 1.35 | 0.04 | 0.05 | 0.40 | 0.15–0.40 | [E] |

[A]Copper when specified shall have a minimum content of 0.20 % by heat analysis (0.18 % by product analysis).
[B]Manganese, minimum by heat analysis of 0.80 % (0.75 % by product analysis) shall be required for all plates over ⅜ in. [10 mm] in thickness; a minimum of 0.50 % (0.45 % by product analysis) shall be required for plates ⅜ in. [10 mm] and less in thickness, and for all other products. The manganese to carbon ratio shall not be less than 2 to 1. For each reduction of 0.01 percentage point below the specified carbon maximum, an increase of 0.06 percentage point manganese above the specified maximum is permitted, up to a maximum of 1.50 %.
[C]Silicon content in excess of 0.40 % by heat analysis must be negotiated.
[D]Bars over 1 ½ in. [40 mm] in diameter, thickness, or distance between parallel faces, shall be made by a killed steel practice.
[E]Alloy content shall be in accordance with Type 1, 2, 3, or 5 and the contents of the applicable elements shall be reported on the test report.

| Type | Elements | Heat Analysis, % |
|---|---|---|
| 1 | Columbium[A] | 0.005–0.05[B] |
| 2 | Vanadium | 0.01–0.15 |
| 3 | Columbium[A] | 0.005–0.05[B] |
| | Vanadium | 0.01–0.15 |
| | Columbium plus vanadium | 0.02–0.15[C] |
| 5 | Titanium | 0.006–0.04 |
| | Nitrogen | 0.003–0.015 |
| | Vanadium | 0.06 max |

[A] Columbium shall be restricted to Grade 50 [345] plate, bar, zee, and rolled tee thickness of ¾ in. [20 mm] max, and to shapes with flange or leg thickness to 1½ in. [40 mm] inclusive unless killed steel if furnished. Killed steel shall be confirmed by a statement of killed steel on the test report, or by a report of the presence of a sufficient quantity of a strong deoxidizing element, such as silicon at 0.10 % or higher, or aluminum at 0.015 % or higher.
[B] Product analysis limits = 0.004 to 0.06 %.
[C] Product analysis limits = 0.01 to 0.16 %

**TABLE 4 Grade 50W [345 W] Chemical Requirements (Heat Analysis)**

NOTE 1—Types A, B, and C are equivalent to Specification A 588/A 588M Grades A, B, and C, respectively.

| Element | Composition, %[A] | | |
|---|---|---|---|
| | Type A | Type B | Type C |
| Carbon[B] | 0.19 max | 0.20 max | 0.15 max |
| Manganese[B] | 0.80–1.25 | 0.75–1.35 | 0.80–1.35 |
| Phosphorus | 0.04 max | 0.04 max | 0.04 max |
| Sulfur | 0.05 max | 0.05 max | 0.05 max |
| Silicon | 0.30–0.65 | 0.15–0.50 | 0.15–0.40 |
| Nickel | 0.40 max | 0.50 max | 0.25–0.50 |
| Chromium | 0.40–0.65 | 0.40–0.70 | 0.30–0.50 |
| Copper | 0.25–0.40 | 0.20–0.40 | 0.20–0.50 |
| Vanadium | 0.02–0.10 | 0.01–0.10 | 0.01–0.10 |

[A] Weldability data for these types have been qualified by FHWA for use in bridge construction.
[B] For each reduction of 0.01 percentage point below the specified maximum for carbon, an increase of 0.06 percentage point above the specified maximum for manganese is permitted, up to a maximum of 1.50 %.

3.1.1 *fracture critical member*—a main load-carrying tension member or tension component of a bending member whose failure would be expected to cause collapse of a structure or bridge without multiple, redundant load paths.

3.1.2 *main load-carrying member*—a steel member designed to carry primary design loads, including dead, live, impact, and other loads.

3.1.3 *non-fracture critical member*—a main load-carrying member whose failure would not be expected to cause collapse of a structure or bridge with multiple, redundant load paths.

3.1.4 *secondary member*—a steel member used for aligning and bracing of main load-carrying members, or for attaching utilities, signs, or other items to them, but not to directly support primary design loads

3.1.5 *tension component*—a part or element of a fracture critical or non-fracture critical member that is in tension under various design loadings.

## 4. Ordering Requirements

4.1 In addition to the items listed in the ordering information section of Specification A 6/A 6M, the following items should be considered if applicable:

4.1.1 Type of tension component, non-fracture critical or fracture critical (see Section 10).

**TABLE 5 Grade 100 [690] and 100W [690W] Chemical Requirements (Heat Analysis)**

NOTE 1— Where ". . ." appears in this table there is no requirement.
NOTE 2—Types A, B, C, E, F, H, J, M, P, and Q are equivalent to Specification A 514/A 514M Grades A, B, C, E, F, H, J, M, P, and Q, respectively.

| | Type A, % | Type B, % | Type C, % | Type E[A], % | Type F[A], % | Type H, % | Type J, % | Type M, % | Type P[A], % | Type Q[A], % |
|---|---|---|---|---|---|---|---|---|---|---|
| Maximum Thickness, in. [mm] | 1¼ [32] | 1¼ [32] | 1¼ [32] | 4 [100] | 2½ [65] | 2 [50] | 1¼ [32] | 2 [50] | 4 [100] | 4 [100] |
| Carbon | 0.15–0.21 | 0.12–0.21 | 0.10–0.20 | 0.12–0.20 | 0.10–0.20 | 0.12–0.21 | 0.12–0.21 | 0.12–0.21 | 0.12–0.21 | 0.14–0.21 |
| Manganese | 0.80–1.10 | 0.70–1.00 | 1.10–1.50 | 0.40–0.70 | 0.60–1.00 | 0.95–1.30 | 0.45–0.70 | 0.45–0.70 | 0.45–0.70 | 0.95–1.30 |
| Phosphorus, max | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 |
| Sulfur, max | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 |
| Silicon | 0.40–0.80 | 0.20–0.35 | 0.15–0.30 | 0.20–0.40 | 0.15–0.35 | 0.20–0.35 | 0.20–0.35 | 0.20–0.35 | 0.20–0.35 | 0.15–0.35 |
| Nickel | ... | ... | ... | ... | 0.70–1.00 | 0.30–0.70 | ... | 1.20–1.50 | 1.20–1.50 | 1.20–1.50 |
| Chromium | 0.50–0.80 | 0.40–0.65 | ... | 1.40–2.00 | 0.40–0.65 | 0.40–0.65 | ... | ... | 0.85–1.20 | 1.00–1.50 |
| Molybdenum | 0.18–0.28 | 0.15–0.25 | 0.15–0.30 | 0.40–0.60 | 0.40–0.60 | 0.20–0.30 | 0.50–0.65 | 0.45–0.60 | 0.45–0.60 | 0.40–0.60 |
| Vanadium | ... | 0.03–0.08 | ... | [B] | 0.03–0.08 | 0.03–0.08 | ... | ... | ... | 0.03–0.08 |
| Titanium | ... | 0.01–0.03 | ... | 0.01–0.10 | ... | ... | ... | ... | ... | . .. |
| Zirconium | 0.05–0.15[C] | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Copper | ... | ... | ... | ... | 0.15–0.50 | ... | ... | ... | ... | ... |
| Boron | 0.0025–max | 0.0005–0.005 | 0.001–0.005 | 0.001–0.005 | 0.0005–0.006 | 0.0005–0.005 | 0.001–0.005 | 0.001–0.005 | 0.001–0.005 | ... |

[A] Types E, F, P, and Q meet the requirements of atmospheric corrosion resistance in accordance with 11.1.2.
[B] May be substituted for part or all of titanium content on a one for one basis.
[C] Zirconium may be replaced by cerium. When cerium is added, the cerium/sulfur ratio should be approximately 1.5 to 1, based upon heat analysis.

**TABLE 6 Grades HPS 50W [HPS 345W] and HPS 70W [HPS 485 W], and HPS 100W [HPS 690W] Chemical Requirements (Heat Analysis)**

NOTE 1— Where ". . ." appears in this table, there is no requirement.

| Element | Composition, % | |
|---|---|---|
| | Grades HPS 50W [HPS 345W], HPS 70W [HPS 485W] | Grade HPS 100W [HPS 690W] |
| Carbon | 0.11 max | 0.08 max |
| Manganese | 1.10–1.35[A] | 0.95–1.50 |
| Phosphorus | 0.020 max | 0.015 max |
| Sulfur[B] | 0.006 max | 0.006 max |
| Silicon | 0.30–0.50 | 0.15–0.35 |
| Copper | 0.25–0.40 | 0.90–1.20 |
| Nickel | 0.25–0.40 | 0.65–0.90 |
| Chromium | 0.45–0.70 | 0.40–0.65 |
| Molybdenum | 0.02–0.08 | 0.40–0.65 |
| Vanadium | 0.04–0.08 | 0.04–0.08 |
| Columbium (Niobium) | . . . | 0.01–0.03 |
| Aluminum | 0.010–0.040 | 0.020–0.050 |
| Nitrogen | 0.015 max | 0.015 max |

[A] For Grade HPS 70W [HPS 485W] plates over 2.5 in. [65 mm] in thickness, the manganese content may be increased to a maximum of 1.50 %.
[B] The steel shall be calcium treated for sulfide shape control.

**TABLE 7 Grade 50S [345S] Chemical Requirements (Heat Analysis)**

| Element | Composition, % |
|---|---|
| Carbon, max | 0.23 |
| Manganese | 0.50 to 1.50[A] |
| Silicon, max | 0.40 |
| Vanadium, max | 0.11[B] |
| Columbium, max | 0.05[B] |
| Phosphorus, max | 0.035 |
| Sulfur, max | 0.045 |
| Copper, max | 0.60 |
| Nickel, max | 0.45 |
| Chromium, max | 0.35 |
| Molybdenum, max | 0.15 |

[A] Provided that the ratio of manganese to sulfur is not less than 20 to 1, the minimum limit for manganese for Group 1 shapes shall be 0.30 %.
[B] The sum of columbium and vanadium shall not exceed 0.15 %.

**TABLE 8 Relationship Between Impact Testing Temperature Zones and Minimum Service Temperature**

| Zone | Minimum Service Temperature, °F [°C] |
|---|---|
| 1 | 0 [–18] |
| 2 | below 0 to –30 [–18 to –34] |
| 3 | below –30 to –60 [–34 to –51] |

4.2 Impact testing temperature zone (see Table 8).

## 5. General Requirements for Delivery

5.1 Structural products furnished under this specification shall conform to the requirements of the current edition of Specification A 6/A 6M, for the specific structural product ordered, unless a conflict exists in which case this specification shall prevail.

5.2 Coils are excluded from qualification to this specification until they are processed into a finished structural product. Structural products produced from coil means structural products that have been cut to individual lengths from a coil. The processor directly controls, or is responsible for, the operations involved in the processing of a coil into a finished structural product. Such operations include decoiling, leveling or straightening, hot-forming or cold-forming (if applicable), cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1—For structural products produced from coil and furnished without heat treatment or with stress relieving only, two test results are to be reported for each qualifying coil. Additional requirements regarding structural products produced from coil are described in Specification A 6/A 6M.

## 6. Materials and Manufacture

6.1 For Grades 36 [250] and 50 [345], the steel shall be semi-killed or killed.

6.2 For Grades 50W [345W], HPS 50W [HPS 345W], and HPS 70W [HPS 485W], the steel shall be made to fine grain practice.

6.3 For Grade 50S [345S], the steel shall be killed and such shall be affirmed in the test report by a statement of *killed steel*, a value of 0.10 % or more for the silicon content, or a value of 0.015 % or more for the total aluminum content.

6.4 For Grade 50S [345S], the steelmaking practice used shall be one that produces steel having a nitrogen content not greater than 0.015 % and includes the addition of one or more nitrogen-binding elements, or one that produces steel having a nitrogen content of not greater than 0.012 % (with or without the addition of nitrogen-binding elements). The nitrogen content need not be reported, regardless of which steelmaking practice was used.

6.5 For Grades HPS 50W [HPS 345W], HPS 70W [HPS 485W], and HPS 100W [HPS 690W], the steel shall be made using a low-hydrogen practice, such as vacuum degassing during steel making; controlled soaking of the ingots, slabs; controlled slow cooling of the ingots, slabs, or plates, or a combination thereof.

6.6 For Grades 100 [690], 100W [690W],and HPS 100W [HPS 690W], the requirements for fine austenitic grain size in Specification A 6/A 6M shall be met.

6.7 Grades HPS 50W [HPS 345W] and HPS 70W [HPS 485W] shall be furnished in one of the following conditions: as-rolled, control-rolled, thermo-mechanical control processed (TMCP) with or without accelerated cooling, or quenched and tempered.

## 7. Heat Treatment

7.1 For quenched and tempered Grades HPS 50W [HPS 345W] and HPS 70W [HPS 485W], the heat treatment shall be performed by the manufacturer and shall consist of heating the steel to not less than 1650 °F [900 °C], quenching it in water or oil, and tempering it at not less than 1100 °F [590 °C]. The heat-treating temperatures shall be reported on the test certificates.

7.2 For Grades 100 [690] and 100W [690W], the heat treatment shall be performed by the manufacturer and shall consist of heating the steel to not less than 1650 °F [900 °C], quenching it in water or oil, and tempering it at not less than 1150 °F [620 °C]. The heat-treating temperatures shall be reported on the test certificates.

7.3 For Grade HPS 100W [HPS 690W], the heat treatment shall be performed by the manufacturer and shall consist of heating the steel to a temperature in the range from 1600 to 1700°F [870 to 925°C], quenching it in water, and tempering it at not less than 1050°F [565°C] for a time to be determined by the manufacturer. The heat-treating temperatures shall be reported on the test certificates.

## 8. Chemical Requirements

8.1 The heat analysis shall conform to the requirements for the specified grade, as given in Tables 2-7.

8.2 For Grade 50S [345S], in addition to the elements listed in Table 7, test reports shall include, for information, the chemical analysis for tin. Where the amount of tin is less than 0.02 %, it shall be permissible for the analysis to be reported as < 0.02 %.

8.3 For Grade 50S [345S], the maximum permissible carbon equivalent value shall be 0.47 % for structural shapes with flange thickness over 2 in. [50 mm], and 0.45 % for other structural shapes. The carbon equivalent shall be based on heat analysis. The required chemical analysis as well as the carbon equivalent shall be reported. The carbon equivalent shall be calculated using the following formula:

$$CE = C + \frac{Mn}{6} + \frac{(Cr + Mo + V)}{5} + \frac{(Ni + Cu)}{15} \quad (1)$$

## 9. Tensile Requirements

9.1 The material as represented by test specimens, except as specified in 9.2, shall conform to the requirements for tensile properties given in Table 1.

9.2 For Grade 36 [250], shapes less than 1 in. $^2$[645 mm$^2$] in cross section and bars, other than flats, less than ½ in. [12.5 mm] in thickness or diameter need not be subjected to tension tests by the manufacturer.

## 10. Impact Testing Requirements

10.1 *Non-Fracture-Critical, T, Tension Components*—Structural products ordered for use as tension components of non-fracture-critical members shall be impact tested in accordance with Specification A 673/A 673M and as given in Table 9. The test results shall meet the requirements given in Table 9.

10.2 *Fracture-Critical, F, Tension Components*—Structural products ordered for use as tension components of fracture-critical members shall be impact tested in accordance with Specification A 673/A 673M and as given in Table 10. The test results shall meet the requirements given in Table 10.

## 11. Brinell Hardness Requirements for Grades 100 [690] and 100W [690W]

11.1 For plates ⅜ in. [10 mm] and under in thickness, a Brinell hardness test may be used instead of tension testing each plate, in which case a tension test specimen shall be taken from a corner of each of two plates per lot. A lot shall consist of plates from the same heat and thickness, same prior condition and scheduled heat treatment and shall not exceed 15 tons [15 Mg] in weight [mass]. A Brinell hardness test shall be made on each plate not tension tested and shall meet the requirements given in Table 1.

## 12. Test Specimens and Number of Tension Tests

12.1 For Grades 36 [250], 50 [345], and 50W [345W], and non-quenched and tempered Grades HPS 50W [HPS 345W] and HPS 70W [HPS 485W], location and condition, number of tests, and preparation of test specimens shall meet the requirements of Specification A 6/A 6M.

12.2 The following requirements, which are in addition to those of Specification A 6/A 6M, shall apply only to Grades 100 [690], 100W [690W], and HPS 100W [HPS 690W], and quenched and tempered Grades HPS 50W [HPS 345W] and HPS 70W [HPS 485 W].

**TABLE 9 Non-Fracture Critical Tension Component Impact Test Requirements**

| Grade | Thickness, in. [mm] and Joining Method | Minimum Average Energy, ft·lbf [J] | | |
|---|---|---|---|---|
| | | Zone 1 | Zone 2 | Zone 3 |
| 36T [250T][A] | to 4 [100] incl, mechanically fastened or welded | 15 [20] at 70°F [21°C] | 15 [20] at 40°F [4°C] | 15 [20] at 10°F [–12°C] |
| 50T [345T][AB], 50ST [345ST][A], 50WT [345WT][AB] | to 2 [50] incl, mechanically fastened or welded | 15 [20] at 70°F [21°C] | 15 [20] at 40°F [4°C] | 15 [20] at 10°F [–12°C] |
| | over 2 to to 4 [50 to 100] incl, mechanically fastened | 15 [20] at 70°F [21°C] | 15 [20] at 40°F [4°C] | 15 [20] at 10°F [–12°C] |
| | over 2 to 4 [50 to 100] incl, welded | 20 [27] at 70°F [21°C] | 20 [27] at 40°F [4°C] | 20 [27] at 10°F [–12°C] |
| HPS 50WT [HPS 345WT][AB] | to 4 [100] incl, mechanically fastened or welded | 20 [27] at 10°F [–12°C] | 20 [27] at 10°F [–12°C] | 20 [27] at 10°F [–12°C] |
| HPS 70WT [HPS 485WT][CD] | to 4 [100] incl, mechanically fastened or welded | 25 [34] at –10°F [–23°C] | 25 [34] at –10°F [–23°C] | 25 [34] at –10°F [–23°C] |
| 100T [690T][C], 100WT [690WT][C] | to 2 ½ [65] incl, mechanically fastened or welded | 25 [34] at 30°F [–1°C] | 25 [34] at 0°F [–18°C] | 25 [34] at –30°F [–34°C] |
| | over 2 ½ to 4 [65 to 100] incl, mechanically fastened | 25 [34] at 30°F [–1°C] | 25 [34] at 0°F [–18°C] | 25 [34] at –30°F [–34°C] |
| | over 2 ½ to 4 [65 to 100] incl, welded | 35 [48] at 30°F [–1°C] | 35 [48] at 0°F [–18°C] | 35 [48] at –30°F [–34°C] |
| HPS 100WT [HPS 690WT][C] | to 2 ½ [65] incl, mechanically fastened or welded | 25 [34] at –30°F [–34°C] | 25 [34] at –30°F [–34°C] | 25 [34] at –30°F [–34°C] |

[A] The CVN-impact testing shall be at "H" frequency in accordance with Specification A 673/A 673M.
[B] If the yield point of the structural product exceeds 65 ksi [450 MPa], the testing temperature for the minimum average energy required shall be reduced by 15 °F [8 °C] for each increment of 10 ksi [70 MPa] above 65 ksi [450 MPa]. The yield point is the value given in the test report.
[C] The CVN-impact testing shall be at "P" frequency in accordance with Specification A 673/A 673M.
[D] If the yield strength of the structural product exceeds 85 ksi [585 MPa], the testing temperature for the minimum average energy required shall be reduced by 15 °F [8 °C] for each increment of 10 ksi [70 MPa] above 85 ksi [585 MPa]. The yield strength is the value given in the test report.

**TABLE 10 Fracture Critical Tension Component Impact Test Requirements**

| Grade | Thickness, in. [mm] and Joining Method | Minimum Test Value Energy,[A] ft-lbf [J] | Minimum Average Energy[A], ft·lbf [J] | | |
|---|---|---|---|---|---|
| | | | Zone 1 | Zone 2 | Zone 3 |
| 36F [250F] | to 4 [100] incl, mechanically fastened or welded | 20 [27] | 25 [34] at 70°F [21°C] | 25 [34] at 40°F [4°C] | 25 [34] at 10°F [–12°C] |
| 50F [345F][B], 50SF [345SF], 50WF [345WF] | to 2 [50] incl, mechanically fastened or welded | 20 [27] | 25 [34] at 70°F [21°C] | 25 [34] at 40°F [4°C] | 25 [34] at 10°F [–12°C] |
| | over 2 to 4 [50 to 100] incl, mechanically fastened | 20 [27] | 25 [34] at 70°F [21°C] | 25 [34] at 40°F [4°C] | 25 [34] at 10°F [–12°C] |
| | over 2 to 4 [50 to 100], welded | 24 [33] | 30 [41] at 70°F [21°C] | 30 [41] at 40°F [4°C] | 30 [41] at 10°F [–12°C] |
| HPS 50WF [HPS 345WF][B] | to 4 [100] incl, mechanically fastened or welded | 24 [33] | 30 [41] at 10°F [–12°C] | 30 [41] at 10°F [–12°C] | 30 [41] at 10°F [–12°C] |
| HPS 70WF [HPS 485WF][C] | to 4 [100] incl, mechanically fastened or welded | 28 [38] | 35 [48] at –10°F [–23°C] | 35 [48] at –10°F [–23°C] | 35 [48] at –10°F [–23°C] |
| 100F [690F], 100WF [690WF] | to 2½ [65] incl, mechanically fastened or welded | 28 [38] | 35 [48] at 30°F [–1°C] | 35 [48] at 0°F [–18°C] | 35 [48] at –30°F [–34°C] |
| | over 2 ½ to 4 [65 to 100] incl, mechanically fastened | 28 [38] | 35 [48] at 30°F [–1°C] | 35 [48] at 0°F [–18°C] | 35 [48] at –30°F [–34°C] |
| | over 2 ½ to 4 [65 to 100] incl, welded | 36 [49] | 45 [61] at 30°F [–1°C] | 45 [61] at 0°F [–18°C] | not permitted |
| HPS 100WF [HPS 690WF] | to 2 ½ [65] incl, mechanically fastened or welded | 28 [38] | 35 [48] at –30°F [–34°C] | 35 [48] at –30°F [–34°C] | not permitted |

[A] The CVN-impact testing shall be at "P" frequency in accordance with Specification A 673/A 673M except for plates of Grades 36F [250F], 50F [345F], 50WF [345WF], HPS 50WF [HPS 345WF], and HPS 70WF [HPS 485WF], for which the sampling shall be as follows:
(1) As-rolled (including control-rolled and TMCP) plates shall be sampled at each end of each plate-as-rolled.
(2) Normalized plates shall be sampled at one end of each plate, as heat treated.
(3) Quenched and tempered plates shall be sampled at each end of each plate, as heat treated.
[B] If the yield point of the structural product exceeds 65 ksi [450 MPa], the testing temperature for the minimum average energy and minimum test value energy required shall be reduced by 15 °F [8 °C] for each increment of 10 ksi [70 MPa] above 65 ksi [450 MPa]. The yield point is the value given in the test report.
[C] If the yield strength of the structural product exceeds 85 ksi [585 MPa], the testing temperature for the minimum average energy and minimum test value energy required shall be reduced by 15 °F [8 °C] for each increment of 10 ksi [70 MPa] above 85 ksi [585 MPa]. The yield strength is the value given in the test report.

12.2.1 When possible, all test specimens shall be cut from the plate in its heat-treated condition. If it is necessary to prepare test specimens from separate pieces, all of these pieces shall be full thickness, and shall be similarly and simultaneously heat treated with the material. All such separate pieces shall be of such size that the prepared test specimens are free of any variation in properties due to edge effects.

12.2.2 After final heat treatment of the plates, one tension test specimen shall be taken from a corner of each plate as heat treated (except as specified in 11.1).

NOTE 2—The term "plate" identifies the "plate as heat treated."

## 13. Retests

13.1 Grades 36 [250], 50 [345], 50S [345S], and 50W [345W], and non-quenched and tempered HPS 50W [HPS 345W] and HPS 70W [HPS 485W] shall be retested in accordance with Specification A 6/A 6M.

13.2 Grades 100 [690], 100W [690W], and HPS 100W [HPS 690W] plates that are subjected to Brinell hardness tests and fail to meet the hardness requirements, at the manufacturer's option, may be subjected to tension testing and shall be accepted if the results conform to the requirements given in Table 1.

13.3 The manufacturer may reheat treat quenched and tempered plates that fail to meet the mechanical property requirements of this specification. All mechanical property tests shall be repeated when the material is resubmitted for inspection.

## 14. Atmospheric Corrosion Resistance

14.1 Steels meeting this specification provide two levels of atmospheric corrosion resistance:

14.1.1 Steel grades without suffix provide a level of atmospheric corrosion resistance typical of carbon or alloy steel without copper.

14.1.2 The steel for Grades 50W [345W], HPS 50W [HPS 345W], and HPS 70W [HPS 485W] shall have an atmospheric corrosion resistance index of 6.0 or higher, calculated from the heat analysis in accordance with Guide G 101-Predictive Method Based on the Data of Larabee and Coburn (see Note 3). When properly exposed to the atmosphere, these steels can be used bare (unpainted) for many applications. The steel for Grades 100W [690W] and HPS 100W [HPS 690W] provides an improved level of atmospheric corrosion resistance over alloy steel without copper.

NOTE 3—For methods of estimating the atmospheric corrosion resistance of low-alloy steels, see Guide G 101.
The user is cautioned that the Guide G 101 predictive equation (Predictive Method Based on the Data of Larabee and Coburn) for calculation of an atmospheric corrosion resistance index has only been verified for the composition limits stated in that guide.

## 15. Marking

15.1 In addition to the marking requirements of Specification A 6/A 6M, the structural product shall be marked as follows:

15.1.1 For Grades 50W [345W], 100 [690], and 100W [690W], the composition type shall be included.

15.1.2 For structural products that conform to the requirements of 10.1, the letter *T* and the applicable zone number (1, 2, or 3) shall follow the grade designation.

15.1.3 For structural products that conform to the requirements of 10.2, the letter *F* and the applicable zone number (1, 2, or 3) shall follow the grade designation.

## 16. Keywords

16.1 alloy; atmospheric corrosion resistance; bars; bridges; carbon; fracture-critical; high-strength; low-alloy; non-fracture critical; plates; quenched; shapes; steel; structural steel; tempered

# SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order or contract. Standardized supplementary requirements for use at the option of the purchaser are listed in Specification A 6/A 6M. Those that are considered suitable for use with this specification are listed by title:

## S8. Ultrasonic Examination

S5.1 Refer to S8 of Specification A 6/A 6M.

## S32. Single Heat Bundles

S32.1 Bundles containing shapes or bars shall be from a single heat of steel.

## S60. Frequency of Tension Tests

S60.1 Tension testing that is additional to the tension testing required by Specification A 6/A 6M shall be made, as follows:

S60.1.1 *Plate*—One tension test shall be made using a test specimen taken from each as-rolled or as-heat treated plate.

S60.1.2 *Structural Shapes*—One tension test shall be made using a test specimen taken from each 5 tons [5 Mg] of material produced on the same mill of the same nominal size, excluding length, from each heat of steel. For single pieces that weigh more than 5 tons [5 Mg] individually, each piece shall be tested. If shapes are heat treated, one test shall be made on specimens taken from each heat of the same nominal size, excluding length, in each furnace lot.

S60.1.3 *Bars*—One tension test shall be made using a test specimen taken from each 5 tons [5 Mg] of the same heat and same diameter or thickness if the material is furnished as-rolled or is heat treated in a continuous-type furnace. For material heat treated in other than a continuous-type furnace, one test shall be taken from each heat of the same bar diameter or thickness for each furnace charge.

## S92. Atmospheric Corrosion Resistance

S92.1 When specified, the material manufacturer shall supply to the purchaser evidence of atmospheric corrosion resistance satisfactory to the purchaser.

S92.2 Refer to S23 of Specification A 6/A 6M (applicable only to Grades 36 [250], 50 [345], and 100 [690]).

**S93. Limitation on Weld Repair (Fracture Critical Material Only)**

S93.1 Weld repair of the base metal by the material manufacturer or supplier is not permitted.

## ADDITIONAL SUPPLEMENTARY REQUIREMENTS

Standardized supplementary requirements for use at the option of the purchaser are listed in Specification A 6/A 6M as follows:

S18. Maximum Tensile Strength (Grades 50 [345], 50S [345S], 50W [345W], and HPS 50W [HPS 345W]).

## SUMMARY OF CHANGES

Committee A01 has identified the location of the following changes to this standard since A 709/A 709M-04a that may impact the use of this standard. (Approved April 1, 2005.)

*(1)* Sections 1.4, 3, 4, and 10 were added.
*(2)* Sections 1.5, 1.6, 15, and 16 were revised.
*(3)* Supplemental Requirements S83 and S84 were deleted.

Committee A01 has identified the location of the following changes to this standard since A 709/A 709M-04 that may impact the use of this standard. (Approved Sept. 1, 2004.)

*(1)* The title has been revised.
*(2)* Paragraphs 1.1, 1.1.2, 1.2, 6.5, 6.6, 12.2, 13.2, and 14.1.2 have been revised.
*(3)* Tables 1, 6, S1.2, and S1.3 have been revised.
*(4)* Paragraph 7.3 was added.

Committee A01 has identified the location of the following changes to this standard since A 709/A 709M-03a that may impact the use of this standard. (Approved April 1, 2004.)

*(1)* Supplementary Requirement S32 has been added.
*(2)* Table 2 has been revised to make Footnote B also apply to bars.
*(3)* Table 3 has been revised to remove Type 4.
*(4)* 6.3, 6.4, and Table 7 have been revised.

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Designation: A 737/A 737M – 99 (Reapproved 2004)

# Standard Specification for Pressure Vessel Plates, High-Strength, Low-Alloy Steel[1]

This standard is issued under the fixed designation A 737/A 737M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification[2] covers high-strength low-alloy steel plates for service in welded pressure vessels and piping components.

1.2 This material is particularly intended for piping and pressure vessel applications where high strength and improved toughness are required.

1.3 Two grades, designated B and C, are covered by this specification. Grade B provides a minimum yield strength of 50 ksi [345 MPa]. Grade C provides a minimum yield strength of 60 ksi [415 MPa].

1.4 The maximum thickness of plates is limited only by the capacity of the chemical composition and heat treatment to meet the specified mechanical property requirements. Individual manufacturers should be consulted on thickness limitations since current industry limitations have not been ascertained to date.

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

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels[3]

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates[3]

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates[3]

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications[3]

## 3. General Requirements and Ordering Information

3.1 Material supplied to this specification shall conform to the requirements of Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality, repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for compliance to the ordering information when purchasing material to this specification.

3.3 Certain supplementary requirements considered suitable for use with this specification are listed at the end of the specification. These include some of the standardized supplementary requirements listed in Specification A 20/A 20M as well as additional ones unique to this specification.

## 4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

## 5. Heat Treatment

5.1 The material shall be normalized by heating to a suitable temperature which produces an austenitic structure, but not exceeding 1700°F [925°C], holding a sufficient time to attain uniform heat throughout the material, and cooling in air.

5.2 If approved by the purchaser, cooling rates faster than air cooling are permitted for improvement of strength or toughness, provided the plates are subsequently tempered in the temperature range from 1100 to 1300°F [595 to 705°C].

5.3 If the purchaser elects to perform the required heat treatment, the material shall be accepted on the basis of mill tests made from test coupons heat treated in accordance with the purchase order requirements. If the test coupon heat-treatment requirements are not indicated on the purchase order, the manufacturer shall heat treat the test coupons under conditions he considers appropriate. The manufacturer shall

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys, and is the direct responsibility of Subcommittee A01.11 on Steel for Boilers and Pressure Vessels.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-737 in Section II of that code.

[3] *Annual Book of ASTM Standards*, Vol 01.04.

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inform the purchaser of the heat-treatment procedure followed in heat treating the test coupon at the mill.

## 6. Chemical Requirements

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

**TABLE 1 Chemical Requirements**

| Element | Composition, % | | | |
|---|---|---|---|---|
| | Grade B | | Grade C | |
| | Heat | Product | Heat | Product |
| Carbon, max | 0.20 | 0.22 | 0.22 | 0.24 |
| Manganese | 1.15–1.50[A] | 1.07–1.62[A] | 1.15–1.50 | 1.07–1.62 |
| Phosphorus, max | 0.035 | 0.035 | 0.035 | 0.035 |
| Sulfur, max | 0.030 | 0.035 | 0.030 | 0.035 |
| Silicon | 0.15–0.50 | 0.10–0.55 | 0.15–0.50 | 0.10–0.55 |
| Vanadium | . . . | . . . | 0.04–0.11 | 0.03–0.12 |
| Columbium, max | 0.05 | 0.05 | [B] | . . . |
| Nitrogen, max | . . . | . . . | 0.03 | 0.03 |

[A] The maximum manganese may be increased to 1.60 % on heat analysis and 1.72 % on product analysis, provided that the carbon content on heat analysis does not exceed 0.18 %.

[B] Columbium may be present in the amount of 0.05 maximum.

## 7. Mechanical Requirements

7.1 *Tension Tests*—The material as represented by the tension test specimens shall conform to the requirements shown in Table 2.

7.1.1 For nominal plate thicknesses of ¾ in. [20 mm] and under, when requirements for elongation in 2 in. [50 mm] are to be determined, the 1½-in. [40-mm] wide rectangular specimen may be used for the tension test, and the elongation may be determined in a 2-in. [50-mm] gage length that includes the fracture and that shows the greatest elongation.

**TABLE 2 Tensile Requirements**

| | Grade B | Grade C |
|---|---|---|
| Yield strength, min, ksi [MPa] | 50 [345] | 60 [415] |
| Tensile strength, ksi [MPa] | 70–90 [485–620] | 80–100 [550–690] |
| Elongation in 8 in. [200 mm], min, %[A] | 18 | 18 |
| Elongation in 2 in. [50 mm], min, %[A] | 23 | 23 |

[A] See Specification A 20/A 20M for elongation adjustment.

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S5. Charpy V-Notch Impact Tests,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M, and

S17. Vacuum Carbon-Deoxidized Steel.

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Designation: A 36/A 36M – 01

# Standard Specification for Carbon Structural Steel[1]

This standard is issued under the fixed designation A 36/A 36M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

## 1. Scope

1.1 This specification[2] covers carbon steel shapes, plates, and bars of structural quality for use in riveted, bolted, or welded construction of bridges and buildings, and for general structural purposes.

1.2 Supplementary requirements are provided for use where additional testing or additional restrictions are required by the purchaser. Such requirements apply only when specified in the purchase order.

1.3 When the steel is to be welded, a welding procedure suitable for the grade of steel and intended use or service is to be utilized. See Appendix X3 of Specification A 6/A 6M for information on weldability.

1.4 For Group 4 and 5 wide flange shapes for use in tension, it is recommended that the purchaser consider specifying supplementary requirements, such as fine austenitic grain size and Charpy V-notch impact testing.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system is to be used independently of the other, without combining values in any way.

1.6 The text of this specification contains notes or footnotes, or both, that provide explanatory material. Such notes and footnotes, excluding those in tables and figures, do not contain any mandatory requirements.

1.7 For structural products cut from coiled product, the additional requirements, including additional testing requirements and the reporting of additional test results, of A 6/A 6M apply.

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling[3]

A 27/A 27M Specification for Steel Castings, Carbon, for General Application[4]

A 307 Specification for Carbon Steel Bolts and Studs, 60 000 psi Tensile Strength[5]

A 325 Specification for High-Strength Bolts for Structural Steel Joints[5]

A 325M Specification for High-Strength Bolts for Structural Steel Joints [Metric][5]

A 500 Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes[6]

A 501 Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing[6]

A 502 Specification for Steel Structural Rivets[5]

A 563 Specification for Carbon and Alloy Steel Nuts[5]

A 563M Specification for Carbon and Alloy Steel Nuts [Metric][5]

A 570/A 570M Specification for Steel, Sheet and Strip, Carbon, Hot-Rolled, Structural Quality[7]

A 668/A 668M Specification for Steel Forgings, Carbon and Alloy, for General Industrial Use[8]

F 568M Specification for Carbon and Alloy Steel Externally Threaded Metric Fasteners[5]

## 3. Appurtenant Materials

3.1 When components of a steel structure are identified with this ASTM designation but the product form is not listed in the scope of this specification, the material shall conform to one of the standards listed in Table 1 unless otherwise specified by the purchaser.

## 4. General Requirements for Delivery

4.1 Material furnished under this specification shall conform to the requirements of the current edition of Specification A 6/A 6M, for the ordered material, unless a conflict exists in which case this specification shall prevail.

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys, and is the direct responsibility of Subcommittee A01.02 on Structural Steel for Bridges, Buildings, Rolling Stock, and Ships.

Current edition approved Sept. 10, 2001. Published September 2001. Originally published as A 36 – 60 T. Last previous edition A 36/A 36M – 00a.

[2] For ASME Boiler and Pressure Vessel Code Applications, see related Specifications SA-36 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.04.

[4] *Annual Book of ASTM Standards*, Vol 01.02.

[5] *Annual Book of ASTM Standards*, Vol 15.08.

[6] *Annual Book of ASTM Standards*, Vol 01.01.

[7] *Annual Book of ASTM Standards*, Vol 01.03.

[8] *Annual Book of ASTM Standards*, Vol 01.05.

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**TABLE 1 Appurtenant Material Specifications**

NOTE 1—The specifier should be satisfied of the suitability of these materials for the intended application. Chemical composition and/or mechanical properties may be different than specified in A 36/A 36M.

| Material | ASTM Designation |
|---|---|
| Steel rivets | A 502, Grade 1 |
| Bolts | A 307, Grade A or F 568M, Class 4.6 |
| High-strength bolts | A 325 or A 325M |
| Steel nuts | A 563 or A 563M |
| Cast steel | A 27/A 27M, Grade 65–35 [450–240] |
| Forgings (carbon steel) | A 668, Class D |
| Hot-rolled sheets and strip | A 570/A 570M, Grade 36 |
| Cold-formed tubing | A 500, Grade B |
| Hot-formed tubing | A 501 |
| Anchor bolts | F 1554 |

4.1.1 Coiled product is excluded from qualification to this specification until decoiled, leveled, and cut to length. Structural products produced from coil means structural products that have been cut to individual lengths from a coiled product and are furnished without heat treatment. The processor decoils, levels, cuts to length, and marks the product. The processor is responsible for performing and certifying all tests, examinations, repairs, inspections, or operations not intended to affect the properties of the material. For structural products produced from coils, two test results shall be reported for each qualifying coil. See Note 1.

NOTE 1—Additional requirements regarding structural products from coil are described in Specification A 6/A 6M.

## 5. Bearing Plates

5.1 Unless otherwise specified, plates used as bearing plates for bridges shall be subjected to mechanical tests and shall conform to the tensile requirements of Section 8.

5.2 Unless otherwise specified, mechanical tests shall not be required for plates over 1½ in. [40 mm] in thickness used as bearing plates in structures other than bridges, subject to the requirement that they shall contain 0.20 to 0.33 % carbon by heat analysis, that the chemical composition shall conform to the requirements of Table 2 in phosphorus and sulfur content, and that a sufficient discard shall be made to secure sound plates.

## 6. Materials and Manufacture

6.1 The steel for plates and bars over ½ in. [12.5 mm] in thickness and shapes other than Group 1 shall be semi-killed or killed.

## 7. Chemical Composition

7.1 The heat analysis shall conform to the requirements prescribed in Table 2, except as specified in 5.2.

7.2 The steel shall conform on product analysis to the requirements prescribed in Table 2, subject to the product analysis tolerances in Specification A 6/A 6M.

## 8. Tension Test

8.1 The material as represented by the test specimen, except as specified in 5.2 and 8.2, shall conform to the requirements as to the tensile properties prescribed in Table 3.

8.2 Shapes less than 1 in.$^2$[645 mm $^2$] in cross section and bars, other than flats, less than ½ in. [12.5 mm] in thickness or diameter need not be subjected to tension tests by the manufacturer, provided that the chemical composition used is appropriate for obtaining the tensile properties in Table 3.

**TABLE 2 Chemical Requirements**

NOTE 1— Where "..." appears in this table, there is no requirement. The heat analysis for manganese shall be determined and reported as described in the heat analysis section of Specification A 6/A 6M.

| Product | Shapes[A] | Plates[B] | | | | | Bars | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Thickness, in. [mm] | All | To ¾ [20], incl | Over ¾ to 1½ [20 to 40], incl | Over 1½ to 2½ [40 to 65], incl | Over 2½ to 4 [65 to 100], incl | Over 4 [100] | To ¾ [20], incl | Over ¾ to 1½ [20 to 40], incl | Over 1½ to 4 [100], incl | Over 4 [100] |
| Carbon, max, % | 0.26 | 0.25 | 0.25 | 0.26 | 0.27 | 0.29 | 0.26 | 0.27 | 0.28 | 0.29 |
| Manganese, % | ... | ... | 0.80–1.20 | 0.80–1.20 | 0.85–1.20 | 0.85–1.20 | ... | 0.60–0.90 | 0.60–0.90 | 0.60–0.90 |
| Phosphorus, max, % | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| Sulfur, max, % | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Silicon, % | 0.40 max | 0.40 max | 0.40 max | 0.15–0.40 | 0.15–0.40 | 0.15–0.40 | 0.40 max | 0.40 max | 0.40 max | 0.40 max |
| Copper, min, % when copper steel is specified | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |

[A] Manganese content of 0.85–1.35 % and silicon content of 0.15–0.40 % is required for shapes over 426 lb/ft [634 kg/m].

[B] For each reduction of 0.01 percentage point below the specified carbon maximum, an increase of 0.06 percentage point manganese above the specified maximum will be permitted, up to the maximum of 1.35 %.



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**TABLE 3 Tensile Requirements[A]**

| | |
|---|---|
| Plates, Shapes,[B] and Bars: | |
| Tensile strength, ksi [MPa] | 58–80 [400–550] |
| Yield point, min, ksi [MPa] | 36 [250][C] |
| Plates and Bars[D,E]: | |
| Elongation in 8 in. [200 mm], min, % | 20 |
| Elongation in 2 in. [50 mm], min, % | 23 |
| Shapes: | |
| Elongation in 8 in. [200 mm], min, % | 20 |
| Elongation in 2 in. [50 mm], min, % | 21[B] |

[A] See the Orientation subsection inthe Tension Tests section of Specification A 6/A 6M.

[B] For wide flange shapes over 426 lb/ft [634 kg/m], the 80 ksi [550 MPa] maximum tensile strength does not apply and a minimum elongation in 2 in. [50 mm] of 19 % applies.

[C] Yield point 32 ksi [220 MPa] for plates over 8 in. [200 mm] in thickness.

[D] Elongation not required to be determined for floor plate.

[E] For plates wider than 24 in. [600 mm], the elongation requirement is reduced two percentage points. See the Elongation Requirement Adjustments subsection under the Tension Tests section of Specification A 6/A 6M.

## 9. Keywords

9.1 bars; bolted construction; bridges; buildings; carbon; plates; riveted construction; shapes; steel; structural steel; welded construction

## SUPPLEMENTARY REQUIREMENTS

These requirements shall not apply unless specified in the order.

Standardized supplementary requirements for use at the option of the purchaser are listed in Specification A 6/A 6M. Those that are considered suitable for use with this specification are listed by title:

S5. Charpy V-Notch Impact Test.

S30. Charpy V-Notch Impact Test for Structural Shapes: Alternate Core Location

In addition, the following optional supplementary requirement is also suitable for use with this specification:

### S97. Limitation on Rimmed or Capped Steel

S97.1 The steel shall be other than rimmed or capped.

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Designation: A 830/A 830M – 02

# Standard Specification for Plates, Carbon Steel, Structural Quality, Furnished to Chemical Composition Requirements[1]

This standard is issued under the fixed designation A 830/A 830M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers structural quality carbon steel plates furnished to chemical composition requirements.

1.2 The plates are available in several standard steel grades and non-standard grades.

1.3 The plates are usually furnished in the as-rolled (hot-rolled) condition.

1.4 Supplementary requirements are provided for additional requirements that may be specified on the order.

1.5 When the steel is to be welded, it is presupposed that a welding procedure suitable for the grade of steel and intended use or service will be utilized. See Appendix X3 of Specification A 6/A 6M for information on weldability.

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling[2]

## 3. Ordering Information

3.1 In addition to the information required by Specification A 6/A 6M, the order shall include the following, if applicable:

3.1.1 Silicon requirements (see 5.3 and Supplementary Requirement S96), and

3.1.2 Limitation on rimmed or capped steel (see 4.3 and Supplementary Requirement S97).

## 4. Materials and Manufacture

4.1 Steel specified to a maximum carbon content of 0.39 % or lower on heat analysis may be made to any deoxidation practice unless otherwise specified on the order.

4.2 Steel specified to a maximum carbon content of 0.40 % or higher on heat analysis shall be killed unless otherwise specified on the order.

4.3 If rimmed or capped steel is not acceptable, Supplementary Requirement S97 shall be specified on the order.

## 5. Chemical Composition

5.1 The heat analysis shall conform to the requirements for the applicable grade listed in Table 1, unless otherwise specified as permitted in 5.2.

5.2 The chemical requirements for heat analysis may be specified in accordance with the ranges and limits listed in Table 2. In such instances, the heat analysis shall conform to the requirements specified on the order.

5.3 When silicon is required, the range on heat analysis shall be from 0.15 to 0.40 % unless otherwise specified on the order (see Supplementary Requirement S96).

## 6. General Requirements

6.1 Material furnished under this specification shall conform to the requirements of the current edition of Specification A 6/A 6M, for the ordered material, unless a conflict exists in which case this specification shall prevail.

## 7. Keywords

7.1 carbon; chemical composition; non-standard grades; plates; standard grades; steel; structural steel

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.02 on Structural Steel for Bridges, Buildings, Rolling Stock, and Ships.

Current edition approved Dec 10, 2002. Published June 2003. Originally published in 1984. Last previous edition approved in 2000 as A 830/A 830M – 00.

[2] *Annual Book of ASTM Standards,* Vol 01.04.

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**TABLE 1 Carbon Plate Compositions, Standard Steels[A]**

| Grade | | Chemical Composition Limits, % | | | |
|---|---|---|---|---|---|
| UNS | Number | Carbon | Manganese | Phosphorous, max | Sulfur, max |
| G10060 | 1006 | 0.08 max | 0.45 max | 0.035 | 0.04 |
| G10080 | 1008 | 0.10 max | 0.50 max | 0.035 | 0.04 |
| G10090 | 1009 | 0.15 max | 0.60 max | 0.035 | 0.04 |
| G10100 | 1010 | 0.08 to 0.13 | 0.30 to 0.60 | 0.035 | 0.04 |
| G10120 | 1012 | 0.10 to 0.15 | 0.30 to 0.60 | 0.035 | 0.04 |
| G10150 | 1015 | 0.13 to 0.18 | 0.30 to 0.60 | 0.035 | 0.04 |
| G10160 | 1016 | 0.13 to 0.18 | 0.60 to 0.90 | 0.035 | 0.04 |
| G10170 | 1017 | 0.15 to 0.20 | 0.30 to 0.60 | 0.035 | 0.04 |
| G10180 | 1018 | 0.15 to 0.20 | 0.60 to 0.90 | 0.035 | 0.04 |
| G10190 | 1019 | 0.15 to 0.20 | 0.70 to 1.00 | 0.035 | 0.04 |
| G10200 | 1020 | 0.18 to 0.23 | 0.30 to 0.60 | 0.035 | 0.04 |
| G10210 | 1021 | 0.18 to 0.23 | 0.60 to 0.90 | 0.035 | 0.04 |
| G10220 | 1022 | 0.18 to 0.23 | 0.70 to 1.00 | 0.035 | 0.04 |
| G10230 | 1023 | 0.20 to 0.25 | 0.30 to 0.60 | 0.035 | 0.04 |
| G10250 | 1025 | 0.22 to 0.28 | 0.30 to 0.60 | 0.035 | 0.04 |
| G10260 | 1026 | 0.22 to 0.28 | 0.60 to 0.90 | 0.035 | 0.04 |
| G10300 | 1030 | 0.28 to 0.34 | 0.60 to 0.90 | 0.035 | 0.04 |
| G10330 | 1033 | 0.30 to 0.36 | 0.70 to 1.00 | 0.035 | 0.04 |
| G10350 | 1035 | 0.32 to 0.38 | 0.60 to 0.90 | 0.035 | 0.04 |
| G10370 | 1037 | 0.32 to 0.38 | 0.70 to 1.00 | 0.035 | 0.04 |
| G10380 | 1038 | 0.35 to 0.42 | 0.60 to 0.90 | 0.035 | 0.04 |
| G10390 | 1039 | 0.37 to 0.44 | 0.70 to 1.00 | 0.035 | 0.04 |
| G10400 | 1040 | 0.37 to 0.44 | 0.60 to 0.90 | 0.035 | 0.04 |
| G10420 | 1042 | 0.40 to 0.47 | 0.60 to 0.90 | 0.035 | 0.04 |
| G10430 | 1043 | 0.40 to 0.47 | 0.70 to 1.00 | 0.035 | 0.04 |
| G10450 | 1045 | 0.43 to 0.50 | 0.60 to 0.90 | 0.035 | 0.04 |
| G10460 | 1046 | 0.43 to 0.50 | 0.70 to 1.00 | 0.035 | 0.04 |
| G10490 | 1049 | 0.46 to 0.53 | 0.60 to 0.90 | 0.035 | 0.04 |
| G10500 | 1050 | 0.48 to 0.55 | 0.60 to 0.90 | 0.035 | 0.04 |
| G10550 | 1055 | 0.50 to 0.60 | 0.60 to 0.90 | 0.035 | 0.04 |
| G10600 | 1060 | 0.55 to 0.65 | 0.60 to 0.90 | 0.035 | 0.04 |
| G10640 | 1064 | 0.60 to 0.70 | 0.50 to 0.80 | 0.035 | 0.04 |
| G10650 | 1065 | 0.60 to 0.70 | 0.60 to 0.90 | 0.035 | 0.04 |
| G10700 | 1070 | 0.65 to 0.75 | 0.60 to 0.90 | 0.035 | 0.04 |
| G10740 | 1074 | 0.70 to 0.80 | 0.50 to 0.80 | 0.035 | 0.04 |
| G10780 | 1078 | 0.72 to 0.85 | 0.30 to 0.60 | 0.035 | 0.04 |
| G10800 | 1080 | 0.75 to 0.88 | 0.60 to 0.90 | 0.035 | 0.04 |
| G10840 | 1084 | 0.80 to 0.93 | 0.60 to 0.90 | 0.035 | 0.04 |
| G10850 | 1085 | 0.80 to 0.93 | 0.70 to 1.00 | 0.035 | 0.04 |
| G10860 | 1086 | 0.80 to 0.93 | 0.30 to 0.50 | 0.035 | 0.04 |
| G10900 | 1090 | 0.85 to 0.98 | 0.60 to 0.90 | 0.035 | 0.04 |
| G10950 | 1095 | 0.90 to 1.03 | 0.30 to 0.50 | 0.035 | 0.04 |
| G15240 | 1524 | 0.19 to 0.25 | 1.30 to 1.65 | 0.035 | 0.04 |
| G15270 | 1527 | 0.22 to 0.29 | 1.20 to 1.55 | 0.035 | 0.04 |
| G15360 | 1536 | 0.30 to 0.37 | 1.20 to 1.55 | 0.035 | 0.04 |
| G15410 | 1541 | 0.36 to 0.44 | 1.30 to 1.65 | 0.035 | 0.04 |
| G15480 | 1548 | 0.44 to 0.52 | 1.05 to 1.40 | 0.035 | 0.04 |
| G15520 | 1552 | 0.47 to 0.55 | 1.20 to 1.55 | 0.035 | 0.04 |

[A] Grades with a specified maximum carbon content of 0.40 % or higher on heat analysis shall have a silicon content from 0.15 to 0.40 % on heat analysis, unless otherwise specified on the order.

**TABLE 2 Heat Analysis Ranges for Carbon Steel Plates**

NOTE 1—*Carbon*—When the maximum manganese limit exceeds 1.00 %, add 0.01 to the carbon range shown in Column 3.
NOTE 2—*Boron*—Boron steels can be expected to have 0.0005 % minimum boron content.
NOTE 3—*Lead*—Carbon steels can be produced with a lead range from 0.15 to 0.35. A heat analysis for lead is not determinable, since lead is added to the stream while each ingot is poured.

| Element | Chemical Ranges, % | |
|---|---|---|
| | When Maximum of Specified Element is | Range |
| Carbon | To 0.15, incl | 0.05 |
| | Over 0.15 to 0.30, incl | 0.06 |
| | Over 0.30 to 0.40, incl | 0.07 |
| | Over 0.40 to 0.60, incl | 0.08 |
| | Over 0.60 to 0.80, incl | 0.11 |
| | Over 0.80 | 0.14 |
| Manganese | To 0.50, incl | 0.20 |
| | Over 0.50 to 1.15, incl | 0.30 |
| | Over 1.15 to 1.65, incl | 0.35 |
| Phosphorus | To 0.08, incl | 0.03 |
| Sulfur | To 0.08, incl | 0.03 |
| | Over 0.08 to 0.15, incl | 0.05 |
| | Over 0.15 to 0.23, incl | 0.07 |
| | Over 0.23 to 0.33, incl | 0.10 |
| Silicon | To 0.15, incl | 0.08 |
| | Over 0.15 to 0.30, incl | 0.15 |
| | Over 0.30 to 0.60, incl | 0.30 |
| Copper | When copper is required, 0.20 % minimum is commonly specified. | |

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order or contract. Standardized supplementary requirements for use at the option of the purchaser are listed in Specification A 6/A 6M. Those that are considered suitable for use with this specification are listed by title:

S1. Vacuum Treatment,
S2. Product Analysis, and
S8. Ultrasonic Examination.

## ADDITIONAL SUPPLEMENTARY REQUIREMENTS

In addition, the following special supplementary requirements are also suitable for use with this specification.

### S96. Silicon Requirement

S96.1 When a silicon content, or limitation, of other than from 0.15 to 0.40 % on heat analysis is required, the specific requirements shall be as specified on the order.

### S97. Limitation on Rimmed or Capped Steel

S97.1 The steel shall be other than rimmed or capped.

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Designation: A 204/A 204M – 93 (Reapproved 1999)

An American National Standard

# Standard Specification for Pressure Vessel Plates, Alloy Steel, Molybdenum[1]

This standard is issued under the fixed designation A 204/A 204M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

## 1. Scope

1.1 This specification[2] covers molybdenum-alloy steel plates, intended particularly for welded boilers and other pressure vessels.

1.2 Material under this specification is available in three grades having different strength levels as follows:

| Grade | Tensile Strength, ksi [MPa] |
|---|---|
| A | 65–85 [450–585] |
| B | 70–90 [485–620] |
| C | 75–95 [515–655] |

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements; however, current practice normally limits the maximum thickness of plates furnished under this specification as follows:

| Grade | Maximum Thickness, in. [mm] |
|---|---|
| A | 6 [150] |
| B | 6 [150] |
| C | 4 [100] |

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

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels[3]

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates[3]

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates[3]

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications[3]

## 3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

## 4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed.

## 5. Heat Treatment

5.1 Plates 1½in. [40 mm] and under in thickness are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved or both.

5.2 Plates over 1½in. [40 mm] in thickness shall be normalized.

## 6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.11 on Steel Plates for Boilers and Pressure Vessels.

Current edition approved June 15, 1993. Published August 1993. Originally published as A204 – 37 T. Last previous edition A204/A 204M– 90.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-204/SA 204M in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol. 01.04.

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Steel, in Specification A 20/A 20M.

## 7. Mechanical Requirements

7.1 *Tension Test Requirements*—The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

**TABLE 1 Chemical Requirements**

| Element | Composition, % | | |
|---|---|---|---|
| | Grade A | Grade B | Grade C |
| Carbon, max[A]: | | | |
| Up to 1 in. [25 mm] incl, in thickness | 0.18 | 0.20 | 0.23 |
| Over 1 in. to 2 in. [50 mm] incl, in thickness | 0.21 | 0.23 | 0.26 |
| Over 2 in. to 4 in. [100 mm] incl, in thickness | 0.23 | 0.25 | 0.28 |
| Over 4 in. [100 mm] in thickness | 0.25 | 0.27 | 0.28 |
| Manganese, max: | | | |
| Heat analysis | 0.90 | 0.90 | 0.90 |
| Product analysis | 0.98 | 0.98 | 0.98 |
| Phosphorous, max[A] | 0.035 | 0.035 | 0.035 |
| Sulfur, max[A] | 0.035 | 0.035 | 0.035 |
| Silicon: | | | |
| Heat analysis | 0.15–0.40 | 0.15–0.40 | 0.15–0.40 |
| Product analysis | 0.13–0.45 | 0.13–0.45 | 0.13–0.45 |
| Molybdenum: | | | |
| Heat analysis | 0.45–0.60 | 0.45–0.60 | 0.45–0.60 |
| Product analysis | 0.41–0.64 | 0.41–0.64 | 0.41–0.64 |

[A]Applies to both heat and product analyses.

**TABLE 2 Tensile Requirements**

| | Grade A | | Grade B | | Grade C | |
|---|---|---|---|---|---|---|
| | ksi | [MPa] | ksi | [MPa] | ksi | [MPa] |
| Tensile strength | 65–85 | [450–585] | 70–90 | [485–620] | 75–95 | [515–655] |
| Yield strength, min[A] | 37 | [255] | 40 | [275] | 43 | [295] |
| Elongation in 8 in. [200 mm], min, %[B] | 19 | | 17 | | 16 | |
| Elongation in 2 in. [50 mm], min, %[B] | 23 | | 21 | | 20 | |

[A]Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.

[B]See Specification A 20/A 20M for elongation adjustment.

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Those which are considered suitable for use with this specification are listed in this section by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.



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Designation: A 302/A 302M – 03

# Standard Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel[1]

This standard is issued under the fixed designation A 302/A 302M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

## 1. Scope*

1.1 This specification[2] covers manganese-molybdenum and manganese-molybdenum-nickel alloy steel plates intended particularly for welded boilers and other pressure vessels.

1.2 Plates under this specification are available in four grades having different strength levels as follows:

| Grade | Tensile Strength, ksi [MPa] | Type |
|---|---|---|
| A | 75–95 [515–655] | Mn-Mo |
| B | 80–100 [550–690] | Mn-Mo |
| C | 80–100 [550–690] | Mn-Mo-Ni |
| D | 80–100 [550–690] | Mn-Mo-Ni |

1.3 The maximum thickness of plates is limited only by the capacity of the chemical composition to meet the specified mechanical property requirements. The minimum thickness is limited to 0.25 in. [6.5 mm].

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

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels[3]

## 3. General Requirements and Ordering Information

3.1 Plates supplied to this product specification shall conform to Specification A 20/A 20M, which outlines the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, and so forth.

3.2 Specification A 20/A 20M also establishes the rules for ordering information that should be complied with when purchasing plates to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available where additional control, testing, or examination is required to meet end use requirements.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1—For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plates from coil are described in Specification A 20/A 20M.

3.6 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

## 4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine grain size requirement of Specification A 20/A 20M.

## 5. Heat Treatment

5.1 Plates 2 in. [50 mm] and under in thickness are normally supplied in the as-rolled condition. Plates may be ordered normalized or stress relieved, or both.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.11 on Steel Plates for Boilers and Pressure Vessels.

Current edition approved Sept. 10, 2003. Published October 2003. Originally approved in 1947. Last previous edition approved in 1997 as A 302/A 302M – 97$^{\epsilon 1}$.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-302/SA-302M in Section II of that Code.

[3] *Annual Book of ASTM Standards,* Vol 01.04.

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

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5.2 Plates over 2 in. [50 mm] in thickness shall be normalized.

5.3 When normalizing plates 4 in. [100 mm] or over in thickness, the cooling rate may be accelerated by air blasting or liquid quenching to obtain mechanical properties comparable to those developed by normalizing plates in the lesser thicknesses.

5.4 If approved by the purchaser, for plates less than 4 in. [100 mm] in thickness, cooling rates faster than those obtained by cooling in air are permissible for improvement of toughness, provided the plates are subsequently tempered in the temperature range from 1100 to 1300 °F [595 to 705 °C].

## 6. Chemical Composition

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

**TABLE 1 Chemical Requirements**

| Elements | Composition, % | | | |
|---|---|---|---|---|
| | Grade A | Grade B | Grade C | Grade D |
| Carbon, max[A]: | | | | |
| Up to 1 in. [25 mm], incl, in thickness | 0.20 | 0.20 | 0.20 | 0.20 |
| Over 1 to 2 in. [50 mm], incl | 0.23 | 0.23 | 0.23 | 0.23 |
| Over 2 in. [50 mm] in thickness | 0.25 | 0.25 | 0.25 | 0.25 |
| Manganese: | | | | |
| Heat analysis | 0.95–1.30 | 1.15–1.50 | 1.15–1.50 | 1.15–1.50 |
| Product analysis | 0.87–1.41 | 1.07–1.62 | 1.07–1.62 | 1.07–1.62 |
| Phosphorus, max[A] | 0.035 | 0.035 | 0.035 | 0.035 |
| Sulfur, max[A] | 0.035 | 0.035 | 0.035 | 0.035 |
| Silicon: | | | | |
| Heat analysis | 0.15–0.40 | 0.15–0.40 | 0.15–0.40 | 0.15–0.40 |
| Product analysis | 0.13–0.45 | 0.13–0.45 | 0.13–0.45 | 0.13–0.45 |
| Molybdenum: | | | | |
| Heat analysis | 0.45–0.60 | 0.45–0.60 | 0.45–0.60 | 0.45–0.60 |
| Product analysis | 0.41–0.64 | 0.41–0.64 | 0.41–0.64 | 0.41–0.64 |
| Nickel: | | | | |
| Heat analysis | ... | ... | 0.40–0.70 | 0.70–1.00 |
| Product analysis | ... | ... | 0.37–0.73 | 0.67–1.03 |

[A]Applies to both heat and product analyses.

## 7. Mechanical Properties

7.1 *Tension Test Requirements*—The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

7.1.1 For accelerated cooled plates with a nominal thickness of ¾ in. [20 mm] or less, the 1½-in. [40-mm] wide rectangular specimen may be used for the tension test, and the elongation may be determined in a 2-in. [50-mm] gage length that includes the fracture and that shows the greatest elongation.

## 8. Keywords

8.1 alloy steel plate; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessel applications

**TABLE 2 Tensile Requirements**

| | Grade A | Grade B | Grade C | Grade D |
|---|---|---|---|---|
| Tensile strength, ksi [MPa] | 75–95 [515–655] | 80–100 [550–690] | 80–100 [550–690] | 80–100 [550–690] |
| Yield strength, min, ksi [MPa] | 45 [310] | 50 [345] | 50 [345] | 50 [345] |
| Elongation in 8 in. [200 mm], min, %[A] | 15 | 15 | 17 | 17 |
| Elongation in 2 in. [50 mm], min, %[A] | 19 | 18 | 20 | 20 |

[A]See Specification A 20/A 20M for elongation adjustment.

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Those that are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,
S2. Product Analysis,
S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,
S4.1 Additional Tension Test,
S5. Charpy V-Notch Impact Test,
S6. Drop Weight Test,
S7. High-Temperature Tension Test,
S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,
S9. Magnetic Particle Examination,
S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,
S12. Ultrasonic Examination in accordance with Specification A 578/A 578M, and
S17. Vacuum Carbon-Deoxidized Steel.

## SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 302/A 302M – 97$^{\epsilon 1}$) that may impact the use of this standard.

*(1)* 3.5 and Note 1 were added to be consistent with the terminology and requirements of Specification A 20/A 20M.

*(2)* 3.3 was revised to be more general.

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Designation: A 387/A 387M – 99ε1

Used in USDOE-NE Standards

# Standard Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum[1]

This standard is issued under the fixed designation A 387/A 387M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε[1] NOTE—Editorial changes were made throughout in June 2001.

## 1. Scope

1.1 This specification[2] covers chromium-molybdenum alloy steel plates intended primarily for welded boilers and pressure vessels designed for elevated temperature service.

1.2 Plates are available under this specification in several grades having different alloy contents as follows:

| Grade | Nominal Chromium Content, % | Nominal Molybdenum Content, % |
|---|---|---|
| 2 | 0.50 | 0.50 |
| 12 | 1.00 | 0.50 |
| 11 | 1.25 | 0.50 |
| 22, 22L | 2.25 | 1.00 |
| 21, 21L | 3.00 | 1.00 |
| 5 | 5.00 | 0.50 |
| 9 | 9.00 | 1.00 |
| 91 | 9.00 | 1.00 |
| 911 | 9.00 | 1.00 |

1.3 Each grade except Grades 21L, 22L, 91 and 911 is available in two classes of tensile strength levels as defined in the Tensile Requirements tables, depending on heat treatment. In the annealed condition all grades are available only as Class 1. Grades 21L and 22L are available only as Class 1. Grade 91 and 911 are available only as Class 2.

1.4 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements.

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

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels[3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[4]

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates[3]

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates[3]

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications[3]

## 3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and weight, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M. If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.11 on Steel Plates for Boilers and Pressure Vessels.

Current edition approved March 10, 1999. Published June 1999. Originally published as A 387 – 55 T. Last previous edition A 387/A 387M – 98.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-387/SA-387M in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.04.

[4] *Annual Book of ASTM Standards*, Vol 01.01.

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## 4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed.

## 5. Heat Treatment

5.1 Except for Grades 91 and 911, all plates shall be thermally treated either by annealing, normalizing- and -tempering, or, when permitted by the purchaser, accelerated cooling from the austenitizing temperature by air blasting or liquid quenching, followed by tempering. Minimum tempering temperatures shall be as follows:

| Grade | Temperature, °F [°C] |
|---|---|
| 2, 12, and 11 | 1150 [620] |
| 22, 22L, 21, 21L, and 9 | 1250 [675] |
| 5 | 1300 [705] |

5.1.1 Grades 91 and 911 plates shall be normalized at 1900 to 2000°F [1040 to 1095°C] and shall be tempered at not less than 1350°F [730°C].

5.2 Grade 5, 9, 21, 21L, 22, 22L, 91 and 911 plates ordered without the heat treatment required by 5.1 shall be furnished in either the stress-relieved or the annealed condition.

5.3 For plates ordered without the heat treatment required by 5.1, heat treatment of the plates to conform to 5.1 and to Table 2 or Table 3, as applicable, shall be the responsibility of the purchaser.

## 6. Chemical Requirements

6.1 The steel shall conform to the requirements as to chemical composition shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M for grades other than Grade 11.

## 7. Metallurgical Structure

7.1 *Austenitic Grain Size*—Grade 2 material shall have a coarse austenitic grain size.

## 8. Mechanical Requirements

8.1 *Tension Test Requirements*:

8.1.1 The material as represented by the tension test specimens shall conform to the applicable requirements of Table 2 or Table 3, as specified on the order.

8.1.2 Adjustment of the percentage elongation requirements is permitted in accordance with Specification A 20/A 20M for plates up to ¾ in. [20 mm] inclusive, in thickness when an 8-in. [200-mm] gage length is used.

## 9. Marking

9.1 In addition to the marking required in Specification A 20/A 20M, each plate shall be legibly stamped or stenciled, depending upon the ordered thickness, with the letter *A* for annealed, *N* for normalized and tempered, and *Q* for accelerated cooled and tempered, as applicable.

**TABLE 2 Tensile Requirements for Class 1 Plates**

| | Grades 2 and 12 | Grade 11 | Grades 22, 21, 5, 9, 21L, 22L |
|---|---|---|---|
| Tensile strength, ksi [MPa] | 55 to 80 [380 to 550] | 60 to 85 [415 to 585] | 60 to 85 [415 to 585] |
| Yield strength, min, ksi [MPa] | 33 | 35 | 30 |
| Elongation in 8 in. [200 mm], min, %[A] | 18 | 19 | ... |
| Elongation in 2 in. [50 mm], min, %[A] | 22 | 22 | 18 |
| Reduction of area, min, % | ... | ... | 45[B]<br>40[C] |

[A] See Specification A 20/A 20M, elongation adjustments.
[B] Measured on round test specimens.
[C] Measured on flat specimen.



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**TABLE 3 Tensile Requirements for Class 2 Plates[A]**

| | Grade 2 | Grade 11 | Grade 12 | Grades 22, 21, 5, 9 | Grade 91 | Grade 911 |
|---|---|---|---|---|---|---|
| Tensile strength, ksi [MPa] | 70 to 90 [485 to 620] | 75 to 100 [515 to 690] | 65 to 85 [450 to 585] | 75 to 100 [515 to 690] | 85 to 110 [585 to 760] | 90 to 120 [620 to 840] |
| Yield strength, min, ksi [MPa]/(0.2 % offset) | 45 [310] | 45 [310] | 40 [275] | 45 [310] | 60 [415] | 64 [440] |
| Elongation in 8 in. [200 mm], min, %[B] | 18 | 18 | 19 | ... | ... | ... |
| Elongation in 2 in. [50 mm], min, %[B] | 22 | 22 | 22 | 18 | 18 | 18 |
| Reduction of area, min, % | ... | ... | ... | 45[C]<br>40[D] | ... | ... |

[A] Not applicable to annealed material.
[B] See Specification A 20/A 20M, elongation adjustments.
[C] Measured on round test specimens.
[D] Measured on flat specimen.



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**TABLE 1 Chemical Requirements**

| Element | Composition, % | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grade 2 | Grade 12 | Grade 11 | Grade 22 | Grade 22L | Grade 21 | Grade 21L | Grade 5 | Grade 9 | Grade 91 | Grade 911 |
| Carbon: | | | | | | | | | | | |
| Heat analysis | 0.05–0.21 | 0.05–0.17 | 0.05–0.17 | 0.05–0.15[A] | 0.10 max | 0.05–0.15[A] | 0.10 max | 0.15 max | 0.15 max | 0.08–0.12 | 0.09–0.13 |
| Product analysis | 0.04–0.21 | 0.04–0.17 | 0.04–0.17 | 0.04–0.15[A] | 0.12 max | 0.04–0.15[A] | 0.12 max | 0.15 max | 0.15 max | 0.06–0.15 | 0.08–0.14 |
| Manganese: | | | | | | | | | | | |
| Heat analysis | 0.55–0.80 | 0.40–0.65 | 0.40–0.65 | 0.30–0.60 | 0.30–0.60 | 0.30–0.60 | 0.30–0.60 | 0.30–0.60 | 0.30–0.60 | 0.30–0.60 | 0.30–0.60 |
| Product analysis | 0.50–0.88 | 0.35–0.73 | 0.35–0.73 | 0.25–0.66 | 0.25–0.66 | 0.25–0.66 | 0.25–0.66 | 0.25–0.66 | 0.25–0.66 | 0.25–0.66 | 0.25–0.66 |
| Phosphorus, max: | | | | | | | | | | | |
| Heat analysis | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.030 | 0.020 | 0.020 |
| Product analysis | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.030 | 0.025 | 0.025 |
| Sulfur, max: | | | | | | | | | | | |
| Heat analysis | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.030 | 0.030 | 0.010 | 0.010 |
| Product analysis | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.030 | 0.030 | 0.012 | 0.012 |
| Silicon: | | | | | | | | | | | |
| Heat analysis | 0.15–0.40 | 0.15–0.40 | 0.50–0.80 | 0.50 max | 0.50 max | 0.50 max | 0.50 max | 0.50 max | 1.00 max | 0.20–0.50 | 0.10–0.50 |
| Product analysis | 0.13–0.45 | 0.13–0.45 | 0.44–0.86 | 0.50 max | 0.50 max | 0.50 max | 0.50 max | 0.55 max | 1.05 max | 0.18–0.56 | 0.08–0.56 |
| Chromium: | | | | | | | | | | | |
| Heat analysis | 0.50–0.80 | 0.80–1.15 | 1.00–1.50 | 2.00–2.50 | 2.00–2.50 | 2.75–3.25 | 2.75–3.25 | 4.00–6.00 | 8.00–10.00 | 8.00–9.50 | 8.50–10.50 |
| Product analysis | 0.46–0.85 | 0.74–1.21 | 0.94–1.56 | 1.88–2.62 | 1.88–2.62 | 2.63–3.37 | 2.63–3.37 | 3.90–6.10 | 7.90–10.10 | 7.90–9.60 | 8.40–10.70 |
| Molybdenum: | | | | | | | | | | | |
| Heat analysis | 0.45–0.60 | 0.45–0.60 | 0.45–0.65 | 0.90–1.10 | 0.90–1.10 | 0.90–1.10 | 0.90–1.10 | 0.45–0.65 | 0.90–1.10 | 0.85–1.05 | 0.90–1.10 |
| Product analysis | 0.40–0.65 | 0.40–0.65 | 0.40–0.70 | 0.85–1.15 | 0.85–1.15 | 0.85–1.15 | 0.85–1.15 | 0.40–0.70 | 0.85–1.15 | 0.80–1.10 | 0.85–1.15 |
| Nickel, max: | | | | | | | | | | | |
| Heat analysis | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0.40 | 0.40 |
| Product analysis | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0.43 | 0.43 |
| Vanadium: | | | | | | | | | | | |
| Heat analysis | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0.18–0.25 | 0.18–0.25 |
| Product analysis | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0.16–0.27 | 0.16–0.27 |
| Columbium: | | | | | | | | | | | |
| Heat analysis | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0.06–0.10 | 0.060–0.10 |
| Product analysis | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0.05–0.11 | 0.05–0.11 |
| Boron: | | | | | | | | | | | |
| Heat analysis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0.0003–0.006 |
| Product analysis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0.0002–0.007 |
| Nitrogen: | | | | | | | | | | | |
| Heat analysis | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0.030–0.070 | 0.04–0.09 |
| Product analysis | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0.025–0.080 | 0.035–0.095 |
| Aluminum, max: | | | | | | | | | | | |
| Heat analysis | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0.04 | 0.04 |
| Product analysis | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0.05 | 0.05 |
| Tungsten: | | | | | | | | | | | |
| Heat analysis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0.90–1.10 |
| Product analysis | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0.85–1.15 |

[A] The carbon content for plates over 5 in. [125 mm] in thickness is 0.17 max on product analysis.

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

## ADDITIONAL SUPPLEMENTARY REQUIREMENTS

In addition, the following supplementary requirements are suitable for this application. S62 and S63 are applicable for Grades 22 and 21 only.

### S60. Restricted Carbon

S60.1 The maximum carbon content of Grade 5 shall be 0.10 %.

### S62. Temper Embrittlement Factor

S62.1 The composition of the steel, based on heat analysis, shall be restricted in accordance with the following equations:

$$J = (Si + Mn) \times (P + Sn) \times 10^4 \leq 150 \quad \text{(Si, Mn, P and Sn in wt \%)}$$

$$Cu \leq 0.20\%$$

$$Ni \leq 0.30\%$$

S62.1.1 Lower values of J, Cu, and Ni can be specified by agreement between purchaser and the supplier.

S62.1.2 When so specified by the purchaser, the maximum value of J shall not exceed 100.

S62.1.3 The values of J shall be reported.

S62.1.4 If the plates are repaired by welding, the composition of the weld deposit shall be restricted in accordance with the following equations:

$$X = (10P + 5Sb + 4Sn + As)/100 \leq 15 \quad \text{(P, Sb, Sn and As in ppm)}$$

$$Cu \leq 0.20\%$$

$$Ni \leq 0.30\%$$

S62.1.5 The values of X shall be reported.

### S63. Impact Properties After Step Cooling

S63.1 The Charpy V-notch impact properties shall be determined as follows:

S63.1.1 A sufficient amount of Charpy V-notch test specimens shall be taken from the same location from a plate from each heat of steel to construct two transition temperature curves.

S63.1.2 The test specimens for one transition temperature curve shall be given the minimum post weld heat treatment (PWHT) cycle specified by the purchaser.

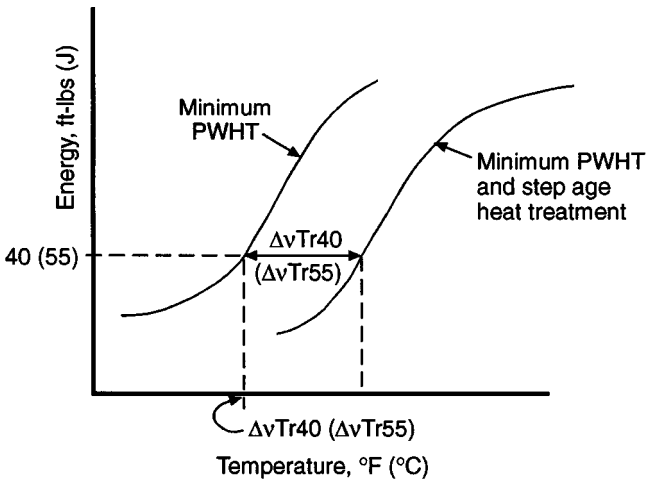


**FIG. S1.1 Transition Temperature Curves Before and After Step Cool Heat Treatment**

S63.2 The test specimens for the other transition temperature curve shall be given the PWHT cycle specified in S63.1.2 plus the following step cooling heat treatment:

Hold at 1100°F (593°C) for 1 h, then cool at 10°F (5.6°C)/h to 1000°F (538°C).

Hold at 1000°F (538°C) for 15 h, then cool at 10°F (5.6°C)/h to 975°F (524°C).

Hold at 975°F (524°C) for 24 h, then cool at 10°F (5.6°C)/h to 925°F (496°C).

Hold at 925°F (496°C) for 60 h, then cool at 5°F (2.8°C)/h to 875°F (468°C).

Hold at 875°F (468°C) for 100 h, then cool at 50°F



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(27.8°C)/h to 600°F (315°C).

Cool in still air.

S63.3 Test the Charpy V-notch test specimens in accordance with Test Methods and Definitions A 370 to determine the 40 ft-lbs (55 J) transition temperature from each transition temperature curve using a set of three test specimens at each test temperature. The test temperatures shall include tests on the upper and lower shelves and a minimum of four intermediate temperatures.

S63.4 The following requirements shall be met.

$$vTr40 + 2.5\Delta vTr40 \leq 50°F$$

$$vTr55 + 2.5\Delta vTr55 \leq 10°C$$

where:

vTr40 (vTr55) = the 40 ft-lbs (55 J) transition temperature of the material subjected to the minimum PWHT specified by the purchaser.

ΔvTr40 (ΔvTr55) = the shift of the 40 ft-lbs (55 J) transition temperature the of the step cooled material. (The 40 ft-lbs (55 J) transition temperature the of the step cooled material minus that of the material subjected to the minimum PWHT only).

S63.5 The 40 ft-lbs (55 J) transition temperatures for the two material conditions shall be reported.

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**Designation: A 514/A514M – 00a**

# Standard Specification for High-Yield-Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Welding[1]

This standard is issued under the fixed designation A 514/A514M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

## 1. Scope

1.1 This specification covers quenched and tempered alloy steel plates of structural quality in thicknesses of 6 in. [150 mm] and under intended primarily for use in welded bridges and other structures.

NOTE 1—All grades are not available in a maximum thickness of 6 in. [150 mm]. See Table 1 for thicknesses available in each grade.

1.2 When the steel is to be welded, it is presupposed that a welding procedure suitable for the grade of steel and intended use or service will be utilized. See Appendix X 3 of Specification A 6/A 6M for information on weldability.

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

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling[2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]

E 112 Test Methods for Determining the Average Grain Size[4]

## 3. General Requirements for Delivery

3.1 Material furnished under this specification shall conform to the requirements of the current edition of Specification A 6/A 6M, for the ordered material, unless a conflict exists in which case this specification shall prevail.

## 4. Materials and Manufacture

4.1 The requirements for fine austenitic grain size in Specification A 6/A 6M shall be met.

## 5. Heat Treatment

5.1 The material shall be heat treated by the manufacturer to conform to the tensile and hardness requirements of Table 2 by heating to not less than 1650°F [900°C], quenching in water or oil and tempering at not less than 1150°F [620°C]. The heat-treating temperatures shall be reported on the test certificates.

## 6. Chemical Composition

6.1 The heat analysis shall conform to the requirements prescribed in Table 1.

6.2 The steel shall conform on product analysis to the requirements as prescribed in Table 1, subject to the product analysis tolerances in Specification A 6/A 6M.

## 7. Mechanical Properties

7.1 *Tension Test*—The material as represented by the tension test specimens shall conform to the tensile properties prescribed in Table 2.

7.2 *Hardness Test*—For plates ⅜ in. [10 mm] and under in thickness, a Brinell hardness test may be used instead of tension testing each plate, in which case a tension test shall be made from a corner of each of two plates per lot. A lot shall consist of plates from the same heat and thickness, same prior condition and scheduled heat treatment and shall not exceed 15 tons [15 Mg] in weight [mass]. A Brinell hardness test shall be made on each plate not tension tested and shall meet the requirements shown in Table 2.

## 8. Number of Tests

8.1 Except as described in 7.2, one tension test shall be taken from a corner of each plate as heat treated. Plates wider than 24 in. [600 mm] shall be tested in the transverse direction and are subject to the modifications for elongation and reduction of area contained in Footnote C of Table 2.

## 9. Retest

9.1 Plates subjected to Brinell hardness tests and which fail

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.02 on Structural Steel for Bridges, Buildings, Rolling Stock, and Ships.

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[2] *Annual Book of ASTM Standards*, Vol 01.04.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

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**TABLE 1 Chemical Requirements (Heat Analysis)**

NOTE 1—Where "..." appears in this table, there is no requirement.

| | Grade A, % | Grade B, % | Grade C, % | Grade E, % | Grade F, % | Grade H, % | Grade J, % |
|---|---|---|---|---|---|---|---|
| Maximum Thickness, in. [mm] | 1¼[32] | 1¼[32] | 1¼[32] | 6 [150] | 2½[65] | 2 [50] | 1¼[32] |
| Carbon | 0.15–0.21 | 0.12–0.21 | 0.10–0.20 | 0.12–0.20 | 0.10–0.20 | 0.12–0.21 | 0.12–0.21 |
| Manganese | 0.80–1.10 | 0.70–1.00 | 1.10–1.50 | 0.40–0.70 | 0.60–1.00 | 0.95–1.30 | 0.45–0.70 |
| Phosphorus, max | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 |
| Sulfur, max | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 |
| Silicon | 0.40–0.80 | 0.20–0.35 | 0.15–0.30 | 0.20–0.40 | 0.15–0.35 | 0.20–0.35 | 0.20–0.35 |
| Nickel | ... | ... | ... | ... | 0.70–1.00 | 0.30–0.70 | ... |
| Chromium | 0.50–0.80 | 0.40–0.65 | ... | 1.40–2.00 | 0.40–0.65 | 0.40–0.65 | ... |
| Molybdenum | 0.18–0.28 | 0.15–0.25 | 0.15–0.30 | 0.40–0.60 | 0.40–0.60 | 0.20–0.30 | 0.50–0.65 |
| Vanadium | ... | 0.03–0.08 | ... | [A] | 0.03–0.08 | 0.03–0.08 | ... |
| Titanium | ... | 0.01–0.03 | ... | 0.01–0.10 | ... | ... | ... |
| Zirconium | 0.05–0.15[B] | ... | ... | ... | ... | ... | ... |
| Copper | ... | ... | ... | ... | 0.15–0.50 | ... | ... |
| Boron | 0.0025 max | 0.0005–0.005 | 0.001–0.005 | 0.001–0.005 | 0.0005–0.006 | 0.0005–0.005 | 0.001–0.005 |
| Columbium, max | ... | ... | ... | ... | ... | ... | ... |

[A]May be substituted for part or all of titanium content on a one for one basis.
[B]Zirconium may be replaced by cerium. When cerium is added, the cerium/sulfur ratio should be approximately 1.5 to 1, based upon heat analysis.

| | Grade K, % | Grade M, % | Grade P, % | Grade Q, % | Grade R, % | Grade S, % | Grade T, % |
|---|---|---|---|---|---|---|---|
| Maximum Thickness, in. [mm] | 2 [50] | 2 [50] | 6 [150] | 6 [150] | 2½ [65] | 2½ [65] | 2 [50] |
| Carbon | 0.10–0.20 | 0.12–0.21 | 0.12–0.21 | 0.14–0.21 | 0.15–0.20 | 0.11–0.21 | 0.08–0.14 |
| Manganese | 1.10–1.50 | 0.45–0.70 | 0.45–0.70 | 0.95–1.30 | 0.85–1.15 | 1.10–1.50 | 1.20–1.50 |
| Phosphorus, max | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 |
| Sulfur, max | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.020 | 0.010 |
| Silicon | 0.15–0.30 | 0.20–0.35 | 0.20–0.35 | 0.15–0.35 | 0.20–0.35 | 0.15–0.45 | 0.40–0.60 |
| Nickel | . . . | 1.20–1.50 | 1.20–1.50 | 1.20–1.50 | 0.90–1.10 | ... | ... |
| Chromium | . . . | ... | 0.85–1.20 | 1.00–1.50 | 0.35–0.65 | ... | ... |
| Molybdenum | 0.45–0.55 | 0.45–0.60 | 0.45–0.60 | 0.40–0.60 | 0.15–0.25 | 0.10–0.60 | 0.45–0.60 |
| Vanadium, max | . . . | ... | ... | 0.03–0.08 | 0.03–0.08 | 0.06 | 0.03–0.08 |
| Titanium | . . . | ... | ... | ... | ... | [A] | ... |
| Zirconium | . . . | ... | ... | ... | ... | ... | ... |
| Copper | . . . | ... | ... | ... | ... | ... | ... |
| Boron | 0.001–0.005 | 0.001–0.005 | 0.001–0.005 | ... | ... | 0.001–0.005 | 0.001–0.005 |
| Columbium, max | . . . | ... | ... | ... | ... | 0.06 | . . . |

[A]Titanium may be present in levels up to 0.06 % to protect the boron additions.

**TABLE 2 Tensile and Hardness Requirements**

NOTE 1— See the Orientation and Preparation subsections in the Tension Tests section of Specification A 6/A 6M.
NOTE 2—Where "..'' appears in this table there is no requirement.

| Thickness, in. [mm] | Ultimate Tensile Strength, ksi [MPa] | Yield Strength[A] min, ksi [MPa] | Elongation in 2 in. [50 mm],[BCD] min, % | Reduction of Area[BC], min, % | Brinell Hardness[E] Number |
|---|---|---|---|---|---|
| To ¾ [20], incl | 110 to 130 [760 to 895] | 100 [690] | 18 | 40[F] | 235 to 293 |
| Over ¾ to 2½ [20 to 65], incl | 110 to 130 [760 to 895] | 100 [690] | 18 | 40[F], 50[G] | ... |
| Over 2½ to 6 [65 to 150], incl | 100 to 130 [690 to 895] | 90 [620] | 16 | 50[G] | ... |

[A]Measured at 0.2 % offset or 0.5 % extension under load as described in the Determination of Tensile Properties section of Test Methods and Definitions A 370.
[B]Elongation and reduction of area not required to be determined for floor plates.
[C]For plates tested in the transverse direction, the elongation requirement is reduced by two percentage points and the reduction of area minimum requirement is reduced by five percentage points. See elongation requirement adjustments in the Tension Tests section of Specification A 6/A 6M.
[D]When measured on the Fig. 3 (Test Methods and Definitions A 370) 1½-in. [40-mm] wide specimen, the elongation is determined in a 2-in. [50-mm] gage length that includes the fracture and shows the greatest elongation.
[E]See Section 8 of this specification.
[F]When measured on the Fig. 3 (Test Methods and Definitions A 370) 1½-in. [40-mm] wide specimen.
[G]When measured on the Fig. 4 (Test Methods and Definitions A 370) ½-in. [12.5-mm] round specimen.

to meet the hardness requirements, at the manufacturer's option, may be subjected to tension testing and shall be accepted if the results conform to the requirements of Table 2.

9.2 The manufacturer may reheat-treat plates that fail to meet the mechanical property requirements of this specification. All mechanical property tests shall be repeated when material is resubmitted for inspection.

## 10. Test Specimens

10.1 When possible, all test specimens shall be cut from the plate in its heat-treated condition as shipped. If it is necessary to prepare test specimens from separate pieces, these pieces shall be full thickness, and all pieces shall be similarly and simultaneously heat treated with the material. All such separate

pieces shall be of such size that the prepared test specimens are free of any variation in properties due to edge effects.

10.2 The purchaser shall specify on the purchase order any additional thermal treatments which shall be given to the test specimens in addition to the heat treatment specified in Section 5. (This is intended to simulate thermal treatments which subsequently may be done by the fabricator.)

## 11. Keywords

11.1 alloy; bridges; high-yield-strength; plates; quenched; steel; structural steel; tempered; welded construction

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Designation: A 515/A 515M – 01

# Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service[1]

This standard is issued under the fixed designation A 515/A 515M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

## 1. Scope

1.1 This specification[2] covers carbon-silicon steel plates primarily for intermediate- and higher-temperature service in welded boilers and other pressure vessels.

1.2 Material under this specification is available in three grades having different strength levels as follows:

| Grade U.S. [SI] | Tensile Strength, ksi [MPa] |
|---|---|
| 60 [415] | 60–80 [415–550] |
| 65 [450] | 65–85 [450–585] |
| 70 [485] | 70–90 [485–620] |

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements; however, current practice normally limits the maximum thickness of plates furnished under this specification as follows:

| Grade U.S. [SI] | Maximum Thickness, in. [mm] |
|---|---|
| 60 [415] | 8 [200] |
| 65 [450] | 8 [200] |
| 70 [485] | 8 [200] |

1.4 For plates produced from coil, the additional requirements, including additional testing requirements and the reporting of additional test results, of Specification A 20/A 20M apply.

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

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels[3]

## 3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 Coiled product is excluded from qualification to this specification until it is decoiled, leveled, and cut to length. Plate produced from coil means plate that has been cut to individual lengths from a coiled product and is furnished without heat treatment. The processor decoils, levels, cuts to length, and marks the product. Except as allowed by Section 6 in Specification A 20/A 20M, the processor is responsible for performing and certifying all tests, examinations, repairs, inspections, and operations not intended to affect the properties of the material. For plate produced from coils, the results of the tests performed shall be reported for each qualifying coil. See Note 1.

NOTE 1—Additional requirements regarding plate produced from coil are described in Specification A 20/A 20M.

3.6 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.11 on Steel Plates for Boilers and Pressure Vessels.

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[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-515/SA-515M in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.04.

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## 4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and made to a coarse austenitic grain size practice.

## 5. Heat Treatment

5.1 Plates 2 in. [50 mm] and under in thickness are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

5.2 Plates over 2 in. [50 mm] in thickness shall be normalized.

## 6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

## 7. Mechanical Requirements

7.1 *Tension Test Requirements*—The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

**TABLE 1 Chemical Requirements**

| Elements | Composition, % | | |
|---|---|---|---|
| | Grade 60[Grade 415] | Grade 65[Grade 450] | Grade 70[Grade 485] |
| Carbon, max[A]: | | | |
| 1 in. [25 mm] and under | 0.24 | 0.28 | 0.31 |
| Over 1 to 2 in. [25 to 50 mm], incl | 0.27 | 0.31 | 0.33 |
| Over 2 to 4 in. [50 to 100 mm], incl | 0.29 | 0.33 | 0.35 |
| Over 4 to 8 in. [100 to 200 mm], incl | 0.31 | 0.33 | 0.35 |
| Over 8 in. [200 mm] | 0.31 | 0.33 | 0.35 |
| Manganese, max: | | | |
| Heat analysis | 0.90 | 0.90 | 1.20 |
| Product analysis | 0.98 | 0.98 | 1.30 |
| Phosphorus, max[A] | 0.035 | 0.035 | 0.035 |
| Sulfur, max[A] | 0.035 | 0.035 | 0.035 |
| Silicon: | | | |
| Heat analysis | 0.15–0.40 | 0.15–0.40 | 0.15–0.40 |
| Product analysis | 0.13–0.45 | 0.13–0.45 | 0.13–0.45 |

[A]Applies to both heat and product analyses.

**TABLE 2 Tensile Requirements**

| | Grade | | |
|---|---|---|---|
| | 60 [415] | 65 [450] | 70 [485] |
| Tensile strength, ksi [MPa] | 60–80 [415–550] | 65–85 [450–585] | 70–90 [485–620] |
| Yield strength, min, ksi [MPa] | 32 [220] | 35 [240] | 38 [260] |
| Elongation in 8 in. [200 mm], min, %[A] | 21 | 19 | 17 |
| Elongation in 2 in. [50 mm], min, %[A] | 25 | 23 | 21 |

[A]See Specification A 20/A20M for elongation adjustment.

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Those which are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop-Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.



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## ADDITIONAL SUPPLEMENTARY REQUIREMENTS

Also listed below is an additional optional supplementary requirement suitable for this specification:

### S61. Austenitic Grain Size

S61.1 The material shall have a carburized austenitic grain size of 1 to 5.

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Designation: A 517/A 517M – 93 (Reapproved 1999)

# Standard Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered[1]

This standard is issued under the fixed designation A 517/A 517M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

## 1. Scope

1.1 This specification[2] covers high-strength quenched and tempered alloy steel plates intended for use in fusion welded boilers and other pressure vessels.

1.2 This specification includes a number of grades as manufactured by different producers, but all having the same mechanical properties and general characteristics.

1.3 The maximum thickness of plates furnished under this specification shall be as follows:

| Grade | Thickness |
|---|---|
| A, B, C, J | 1.25 in. [32 mm] |
| H, K, M, S, T | 2 in. [50 mm] |
| P | 4 in. [100 mm] |
| F | 2.50 in. [65 mm] |
| E, Q | 6 in. [150 mm] |

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

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels[3]

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates[3]

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates[3]

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications[3]

## 3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information which should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

## 4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

## 5. Heat Treatment

5.1 All plates shall be heat treated by the material manufacturer by heating to not less than 1650°F [900°C], quenching in water or oil and tempering at not less than 1150°F [620°C] for not less than ½ h.

## 6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M for grades other than Grade A.

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[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.11 on Steel Plates for Boilers and Pressure Vessels.

Current edition approved June 15, 1993. Published August 1993. Originally published as A 517 – 64. Last previous edition A 517/A 517M – 90.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-517/SA-517M in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.04.

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**TABLE 1 Chemical Requirements**

| Elements | Composition, % | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grade A | Grade B | Grade C | Grade E | Grade F | Grade H | Grade J | Grade K | Grade M | Grade P | Grade Q | Grade S | Grade T |
| Carbon: | | | | | | | | | | | | | |
| Heat analysis | 0.15 | 0.15 | 0.10 | 0.12 | 0.10 | 0.12 | 0.12 | 0.10 | 0.12 | 0.12 | 0.14 | 0.10 | 0.08 |
| | –0.21 | –0.21 | –0.20 | –0.20 | –0.20 | –0.21 | –0.21 | –0.20 | –0.21 | –0.21 | –0.21 | –0.20 | –0.14 |
| Product analysis | 0.13 | 0.13 | 0.08 | 0.10 | 0.08 | 0.10 | 0.10 | 0.08 | 0.10 | 0.10 | 0.12 | 0.10 | 0.06 |
| | –0.23 | –0.23 | –0.22 | –0.22 | –0.22 | –0.23 | –0.23 | –0.22 | –0.23 | –0.23 | –0.23 | –0.22 | –0.16 |
| Manganese: | | | | | | | | | | | | | |
| Heat analysis | 0.80 | 0.70 | 1.10 | 0.40 | 0.60 | 0.95 | 0.45 | 1.10 | 0.45 | 0.45 | 0.95 | 1.10 | 1.20 |
| | –1.10 | –1.00 | –1.50 | –0.70 | –1.00 | –1.30 | –0.70 | –1.50 | –0.70 | –0.70 | –1.30 | –1.50 | –1.50 |
| Product analysis | 0.74 | 0.64 | 1.02 | 0.35 | 0.55 | 0.87 | 0.40 | 1.02 | 0.40 | 0.40 | 0.87 | 1.02 | 1.12 |
| | –1.20 | –1.10 | –1.62 | –0.78 | –1.10 | –1.41 | –0.78 | –1.62 | –0.78 | –0.78 | –1.41 | –1.62 | –1.60 |
| Phosphorus, max[A] | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 |
| Sulfur, max[A] | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 | 0.010 |
| Silicon: | | | | | | | | | | | | | |
| Heat analysis | 0.40 | 0.15 | 0.15 | 0.10 | 0.15 | 0.15 | 0.20 | 0.15 | 0.20 | 0.20 | 0.15 | 0.15 | 0.40 |
| | –0.80 | –0.35 | –0.30 | –0.40 | –0.35 | –0.35 | –0.35 | –0.30 | –0.35 | –0.35 | –0.35 | –0.40 | –0.60 |
| Product analysis | 0.34 | 0.13 | 0.13 | 0.08 | 0.13 | 0.13 | 0.18 | 0.13 | 0.18 | 0.18 | 0.13 | 0.13 | 0.34 |
| | –0.86 | –0.37 | –0.32 | –0.45 | –0.37 | –0.37 | –0.37 | –0.32 | –0.37 | –0.37 | –0.37 | –0.45 | –0.66 |
| Nickel: | | | | | | | | | | | | | |
| Heat analysis | . . . | . . . | . . . | . . . | 0.70 | 0.30 | . . . | . . . | 1.20 | 1.20 | 1.20 | . . . | . . . |
| | | | | | –1.00 | –0.70 | | | –1.50 | –1.50 | –1.50 | | |
| Product analysis | . . . | . . . | . . . | . . . | 0.67 | 0.27 | . . . | . . . | 1.15 | 1.15 | 1.15 | . . . | . . . |
| | | | | | –1.03 | –0.73 | | | –1.55 | –1.55 | –1.55 | | |
| Chromium: | | | | | | | | | | | | | |
| Heat analysis | 0.50 | 0.40 | . . . | 1.40 | 0.40 | 0.40 | . . . | . . . | . . . | 0.85 | 1.00 | . . . | . . . |
| | –0.80 | –0.65 | | –2.00 | –0.65 | –0.65 | | | | –1.20 | –1.50 | | |
| Product analysis | 0.46 | 0.36 | . . . | 1.34 | 0.36 | 0.36 | . . . | . . . | . . . | 0.79 | 0.94 | . . . | . . . |
| | –0.84 | –0.69 | | –2.06 | –0.69 | –0.69 | | | | –1.26 | –1.56 | | |
| Molybdenum: | | | | | | | | | | | | | |
| Heat analysis | 0.18 | 0.15 | 0.20 | 0.40 | 0.40 | 0.20 | 0.50 | 0.45 | 0.45 | 0.45 | 0.40 | 0.10 | 0.45 |
| | –0.28 | –0.25 | –0.30 | –0.60 | –0.60 | –0.30 | –0.65 | –0.55 | –0.60 | –0.60 | –0.60 | –0.35 | –0.60 |
| Product analysis | 0.15 | 0.12 | 0.17 | 0.36 | 0.36 | 0.17 | 0.46 | 0.42 | 0.41 | 0.41 | 0.36 | 0.10 | 0.41 |
| | –0.31 | –0.28 | –0.33 | –0.64 | –0.64 | –0.33 | –0.69 | –0.50 | –0.64 | –0.64 | –0.64 | –0.38 | –0.64 |
| Boron | 0.0025 | 0.0005 | 0.001 | 0.001 | 0.0005 | 0.0005 | 0.001 | 0.001 | 0.001 | 0.001 | . . . | . . . | 0.001 |
| | max | –0.005 | –0.005 | –0.005 | –0.006 | min | –0.005 | –0.005 | –0.005 | –0.005 | | | –0.005 |
| Vanadium: | | | | | | | | | | | | | |
| Heat analysis | . . . | 0.03 | . . . | [B] | 0.03 | 0.03 | . . . | . . . | . . . | . . . | 0.03 | . . . | 0.03 |
| | | –0.08 | | | –0.08 | –0.08 | | | | | –0.08 | | –0.08 |
| Product analysis | . . . | 0.02 | . . . | . . . | 0.02 | 0.02 | . . . | . . . | . . . | . . . | 0.02 | . . . | 0.02 |
| | | –0.09 | | | –0.09 | –0.09 | | | | | –0.09 | | –0.09 |
| Titanium: | | | | | | | | | | | | | |
| Heat analysis | . . . | 0.01 | . . . | 0.01 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 0.06 | . . . |
| | | –0.03 | | –0.10 | | | | | | | | | |
| Product analysis | . . . | 0.01 | . . . | 0.005 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 0.07 | . . . |
| | | –0.04 | | –0.11 | | | | | | | | | |
| Zirconium: | | | | | | | | | | | | | |
| Heat analysis | 0.05[C] | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . |
| | –0.15 | | | | | | | | | | | | |
| Product analysis | 0.04 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . |
| | –0.16 | | | | | | | | | | | | |
| Copper: | | | | | | | | | | | | | |
| Heat analysis | . . . | . . . | . . . | . . . | 0.15 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . |
| | | | | | –0.50 | | | | | | | | |
| Product analysis | . . . | . . . | . . . | . . . | 0.12 | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . |
| | | | | | –0.53 | | | | | | | | |
| Columbium, max | | | | | | | | | | | | | |
| Heat analysis | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 0.06 | . . . |
| Product analysis | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | 0.07 | . . . |

[A] Applied to both heat and product analyses.
[B] May be substituted for part or all of titanium content on a one for one basis.
[C] Zirconium may be replaced by cerium. When cerium is added, the cerium/sulfur ration should be approximately 1.5 to 1, based on heat analysis.

## 7. Mechanical Requirements

7.1 *Tension Tests*:

7.1.1 *Requirements*—The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

7.1.2 *Test Methods*:

7.1.2.1 The yield strength may be determined by the 0.2 % offset method or by the total extension under load of 0.5 % method.

7.1.2.2 For material ¾ in. [20 mm] and under in thickness, the test specimen shall be the 1½ -in. [40-mm] wide rectangular-test specimen.

**TABLE 2 Tensile Requirements**

| | 2.50 in. [65 mm] and Under | Over 2.50 to 6 in. [65 to 150 mm] |
|---|---|---|
| Tensile strength, ksi [MPa] | 115–135 [795–930] | 105–135 [725 to 930] |
| Yield strength, min, ksi [MPa] | 100 [690] | 90 [620] |
| Elongation in 2 in. [50 mm], min, %[A] | 16 | 14 |
| Reduction of area, min, %: | | |
| Rectangular specimens | 35 | . . . |
| Round specimens | 45 | 45 |

[A] See Specification A 20/A 20M for elongation adjustment.

7.1.2.3 For material over ¾ in. [20 mm], either the full thickness rectangular-test specimen or the ½ -in. [12.5-mm] round-test specimen may be used.

7.1.2.4 When the 1½ -in. [40-mm] wide rectangular-test specimen is used, the elongation is measured in a 2-in. or [50-mm] gage length which includes the fracture.

7.2 *Impact Properties Requirements*:

7.2.1 Transverse Charpy V-notch impact test specimens shall have a lateral expansion opposite the notch of not less than 0.015 in. [0.38 mm].

7.2.2 The test temperature shall be agreed upon between the manufacturer and the purchaser, but shall not be higher than 32°F [0°C].

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

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Designation: A 612/A612M – 03

# Standard Specification for Pressure Vessel Plates, Carbon Steel, High Strength, for Moderate and Lower Temperature Service[1]

This standard is issued under the fixed designation A 612/A612M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope*

1.1 This specification[2] covers killed carbon-manganese-silicon steel plates intended for welded pressure vessels in service at moderate and lower temperatures.

1.2 The maximum thickness of plates supplied under this specification is 1 in. [25 mm].

1.3 For plates produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results, of Specification A 20/A 20M apply.

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

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels[3]

A 435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates[3]

A 577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates[3]

A 578/A578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications[3]

## 3. General Requirements and Ordering Information

3.1 Plates supplied to this product specification shall conform to Specification A 20/A 20M, which outlines the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, and so forth.

3.2 Specification A 20/A 20M also establishes the rules for ordering information that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available where additional control, testing, or examination is required to meet end use requirements.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1—For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plates from coil are described in Specification A 20/A 20M.

3.6 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

## 4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.11 on Steel Plates for Boilers and Pressure Vessels.

Current edition approved Sept. 10, 2003. Published October 2003. Originally approved in 1970. Last previous edition approved in 2001 as A 612/A 612M – 01.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-612/SA-612M in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.04.

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

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**TABLE 1 Chemical Requirements**

| Elements | Composition, % |
|---|---|
| Carbon, max: | |
| Heat analysis | 0.25 |
| Product analysis | 0.29 |
| Manganese | |
| Heat analysis | 1.00–1.50 |
| Product analysis | 0.92–1.62 |
| Phosphorus, max[A] | 0.035 |
| Sulfur, max[A] | 0.025 |
| Silicon | |
| Heat analysis | 0.15–0.50 |
| Product analysis | 0.13–0.55 |
| Copper, max:[B] | |
| Heat analysis | 0.35 |
| Product analysis | 0.38 |
| Nickel, max:[B] | |
| Heat analysis | 0.25 |
| Product analysis | 0.28 |
| Chromium, max:[B] | |
| Heat analysis | 0.25 |
| Product analysis | 0.29 |
| Molybdenum, max:[B] | |
| Heat analysis | 0.08 |
| Product analysis | 0.09 |
| Vanadium, max:[B] | |
| Heat analysis | 0.08 |
| Product analysis | 0.09 |

[A] Applies to both heat and product analyses.
[B] When analysis shows that the amount of an element is 0.02 % or lower, the value may be reported as ≤0.02 %.

## 5. Heat Treatment

5.1 Plates are normally supplied in the as-rolled condition. Plates may be ordered normalized or stress relieved, or both.

## 6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition given in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

## 7. Mechanical Properties

7.1 *Tension Test* —The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

**TABLE 2 Tensile Requirements**

| | Thickness | |
|---|---|---|
| | 0.5 in [12.5 mm] and Under | Over 0.5 in. to 1 in. [Over 12.5 to 25 mm] |
| Tensile strength, ksi [MPa] | 83–105 [570–725] | 81–101 [560–695] |
| Yield strength, min,[A] ksi [MPa] | 50 [345] | 50 [345] |
| Elongation in 8 in. [200 mm], min, %[B] | 16 | 16 |
| Elongation in 2 in. [50 mm], min, %[B] | 22 | 22 |

[A] Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.

[B] See Specification A 20/A 20M for elongation adjustments.

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Those that are considered suitable for use with this specification are listed by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M, and

S17. Vacuum Carbon-Deoxidized Steel.

## SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 612/A 612M – 01) that may impact the use of this standard.

*(1)* 1.3, 3.6, and Note 1 were revised to be consistent with the terminology and requirements of Specification A 20/A 20M.

*(2)* 3.3 was revised to be more general.

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Designation: A 841/A 841M – 03a

# Standard Specification for Steel Plates for Pressure Vessels, Produced by Thermo-Mechanical Control Process (TMCP)[1]

This standard is issued under the fixed designation A 841/A 841M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope*

1.1 This specification[2] covers steel plates produced by the thermo-mechanical control process (TMCP). The plates are intended primarily for use in welded pressure vessels.

1.2 The TMCP method consists of rolling-reduction and cooling rate controls that result in mechanical properties in the finished plate that are equivalent to those attained using conventional rolling and heat treating processes, which entail reheating after rolling. A description of the TMCP method is given in Appendix X1.

1.3 Due to the inherent characteristics of the TMCP method, the plates cannot be formed at elevated temperatures without sustaining significant losses in strength and toughness. The plates may be formed and post-weld heat-treated at temperatures not exceeding 1200°F [650°C], providing the requirements of 6.1 are met.

1.4 The maximum permitted nominal thickness of plates furnished to this specification is 4 in. [100 mm] for Grades A, B, and C; and 1.5 in. [40 mm] for Grades D[3], E, and F.

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

## 2. Referenced Documents

2.1 *ASTM Standards:* [4]

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

## 3. General Requirements and Ordering Information

3.1 Plates supplied to this product specification shall conform to Specification A 20/A 20M, which outlines the testing and retesting methods and procedures, permissible variations in dimensions, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for ordering information that should be complied with when purchasing plates to this specification.

3.2.1 If the plates are to be subjected to warm forming or post-weld heat treatment, the order must indicate the temperatures and times-at-temperature that will be utilized in such operations. (See 6.1 and Specification A 20/A 20M, Supplementary Requirement S3.)

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Additional or special impact testing, and

3.3.4 Nondestructive examination.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.11 on Steel Plates for Boilers and Pressure Vessels.

Current edition approved April 10, 2003. Published June 2003. Originally approved in 1985. Last previous edition approved in 2001 as A 841/A 841M – 01.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-841/SA-841M in Section II of that Code.

[3] ExxonMobil Upstream Research Company has patents pending concerning the use of chemistry ranges in ASTM A 841 Grade D, in combination with specific TMCP routes and/or specific microstructural features. Interested parties are invited to submit information regarding identification of alternatives to these patented items to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

[4] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

## 4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

4.2 The plates shall be produced by the thermo-mechanical control process.

## 5. Chemical Composition

5.1 The chemical composition on heat analysis shall conform to the requirements given in Table 1, except as otherwise provided in Supplementary Requirement S17 of Specification A 20/A 20M when that requirement is involved.

5.2 If a product analysis is made on a sample taken from the standard location (see Specification A 20/A 20M), the results of the analysis shall not deviate from the limits for the heat analysis by more than the values given in Table 2.

## 6. Mechanical Requirements

6.1 If the plates are to be subjected to warm forming or post-weld heat treatment, the test coupons shall be subjected to heat treatment to simulate such fabrication operations. (See 3.2.1 and Specification A 20/A 20M, Supplementary Requirement S3.)

6.2 *Tension Test Requirements*—The plates as represented by the tension-test specimens shall conform to the requirements given in Table 3.

6.2.1 *Number and Location of Test Coupons*—Two tension tests shall be made from each plate-as-rolled. One test coupon shall be taken from a corner of the plate on each end.

6.3 *Notch Toughness Test Requirements*:

6.3.1 Longitudinal Charpy V-notch tests shall be made in accordance with Specification A 20/A 20M.

6.3.2 For Grades A, B and C, unless the test temperature and absorbed energy requirements are specified in the purchase order, the tests shall be conducted at –40°F [–40°C] and the average absorbed energy for each set of three full size specimens shall be 15 ft·lb [20J] or more.

6.3.3 For Grade D, unless the test temperature and the lateral expansion requirements are specified in the purchase

**TABLE 1 Chemical Requirements**

| Element | Composition % | | | | | |
|---|---|---|---|---|---|---|
| | Grade A | Grade B | Grade C | Grade D | Grade E | Grade F |
| Carbon, max | 0.20 | 0.15 | 0.10 | 0.09 | 0.07 | 0.10[A] |
| Manganese | | | | | | |
| t ≤ 1.5 in. [40 mm] | 0.70–1.35[B] | 0.70–1.35[B] | 0.70–1.60 | 1.00–2.00 | 0.70–1.60 | 1.10–1.70[A] |
| t > 1.5 in. [40 mm] | 1.00–1.60 | 1.00–1.60 | 1.00–1.60 | [C] | [C] | [C] |
| Phosphorus, max | 0.030 | 0.030 | 0.030 | 0.010 | 0.015 | 0.020 |
| Sulfur, max | 0.030 | 0.025 | 0.015 | 0.005 | 0.005 | 0.008 |
| Silicon | 0.15–0.50 | 0.15–0.50 | 0.15–0.50 | 0.05–0.25 | 0.05–0.30 | 0.10–0.45 |
| Copper, max | 0.35 | 0.35 | 0.35 | 0.50 | 0.35 | 0.40 |
| Nickel | 0.25 max | 0.60 max | 0.25 max | 1.0–5.0 | 0.60 max | 0.85 max |
| Chromium, max | 0.25 | 0.25 | 0.25 | 0.30 | 0.30 | 0.30 |
| Molybdenum, max | 0.08 | 0.30 | 0.08 | 0.40 | 0.30 | 0.50 |
| Columbium, max | 0.03 | 0.03 | 0.06 | 0.05 | 0.08 | 0.10 |
| Vanadium, max | 0.06 | 0.06 | 0.06 | 0.02 | 0.06 | 0.09 |
| Titanium | [D] | [D] | 0.006–0.02 | 0.006–0.03 | [D] | [E] |
| Boron | ... | ... | ... | 0.0005–0.002 | 0.0007 max | 0.0007 max |
| Aluminum, min | 0.020 total or | 0.020 total or | ... | ... | 0.020 total or | 0.020 total or |
| | 0.015 acid soluble[D] | 0.015 acid soluble[D] | | | 0.015 acid soluble[D] | 0.015 acid soluble[E] |

[A] For each reduction of 0.01 percentage point below the specified maximum for carbon, an increase of 0.06 percentage points above the specified maximum for manganese is permitted, up to a maximum of 1.85 %.

[B] Manganese may exceed 1.35 % on heat analysis, up to a maximum of 1.60 %, provided that the carbon equivalent on heat analysis does not exceed 0.47 %, or the value specified in Supplementary Requirement S77 when that requirement is invoked, when based on the following formula:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15\ \%$$

When this option is exercised, the manganese content on product analysis shall not exceed the heat analysis content by more than 0.12 percentage points.

[C] Not applicable.

[D] By agreement, the steel may be produced with titanium, in which case the minimum aluminum content shall not apply. When this option is exercised, the titanium content, by heat analysis, shall be 0.006 % to 0.02 %, and the actual titanium content shall be reported on the test report.

[E] By agreement, the steel may be produced with titanium, in which case the minimum aluminum content shall not apply. When this option is exercised, the titanium content, by heat analysis, shall be 0.006 % to 0.03 %, and the actual titanium content shall be reported on the test report.

**TABLE 2 Product Analysis Tolerances**

| Element | Specified Limit, % | Tolerances, % | |
|---|---|---|---|
| | | Under Minimum Limit | Over Maximum Limit |
| Carbon | to 0.15, incl | 0.02 | 0.03 |
| | over 0.15 | 0.03 | 0.04 |
| Manganese | to 0.60, incl | 0.05 | 0.06 |
| | over 0.60 to 0.90, incl | 0.06 | 0.08 |
| | over 0.90 to 1.20, incl | 0.08 | 0.10 |
| | over 1.20 to 1.35, incl | 0.09 | 0.11 |
| | over 1.35 to 1.65, incl | 0.09 | 0.12 |
| | over 1.65 | 0.11 | 0.14 |
| Phosphorus | to 0.020, incl | ... | 0.005 |
| | over 0.020 | ... | 0.010 |
| Sulfur | to 0.020, incl | ... | 0.005 |
| | over 0.020 | ... | 0.010 |
| Silicon | to 0.30, incl | 0.02 | 0.03 |
| | over 0.30 to 0.40, incl | 0.05 | 0.05 |
| | over 0.40 | 0.06 | 0.06 |
| Nickel | to 1.00, incl | 0.03 | 0.03 |
| | over 1.0 to 2.0, incl | 0.05 | 0.05 |
| | over 2.0 to 3.8, incl | 0.07 | 0.07 |
| | over 3.8 | 0.08 | 0.08 |
| Chromium | to 0.90, incl | 0.04 | 0.04 |
| Molybdenum | to 0.20, incl | 0.01 | 0.01 |
| | over 0.20 | 0.03 | 0.03 |
| Copper | to 1.00, incl | 0.03 | 0.03 |
| Vanadium | to 0.10, incl | 0.01 | 0.01 |
| Columbium | to 0.10, incl | 0.01 | 0.01 |
| Aluminum | to 0.15, incl | 0.005 | 0.01 |
| Titanium | to 0.010, incl | 0.002 | 0.01 |
| | over 0.010 | 0.01 | 0.01 |
| Boron | any | [A] | [A] |

[A] Product analysis is not applicable for this element.

order, the tests shall be conducted at –40°F [–40°C] and the lateral expansion for each specimen shall be 0.015 in. [0.4 mm] or more.

6.3.4 For Grades E and F, unless the test temperature and absorbed energy requirements are specified in the purchase order, the tests shall be conducted at –40°F [–40°C] and the average absorbed energy for each set of three full size specimens shall be 20 ft·lb [27 J] or more.

## 7. Marking

7.1 In addition to the marking required in Specification A 20/A 20M, each plate shall be legibly stamped with the letters “TMC” following the stamped specification designation.

## 8. Keywords

8.1 pressure containing parts; pressure vessel steel; steel plates; steel plates for pressure vessel applications

**TABLE 3 Tensile Requirements**

| | Grades A, B, and C | | Grade D | Grade E | | Grade F | | |
|---|---|---|---|---|---|---|---|---|
| | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 | Class 6 | Class 7 | Class 8 |
| Yield strength, min, ksi [MPa] | | | | | | | | |
| to 1.5 in. [40 mm] incl | 50 [345] | 60 [415] | 100 [690] | 70 [485] | 75 [515] | 70 [485] | 75 [515] | 80 [550] |
| over 1.5 in. [40 mm] to 2.5 in. [to 65 mm] | 50 [345] | 60 [415] | [A] | [A] | [A] | [A] | [A] | [A] |
| over 2.5 in. [over 65 mm] | 45 [310] | 55 [380] | [A] | [A] | [A] | [A] | [A] | [A] |
| Tensile strength, ksi [MPa] | | | | | | | | |
| to 1.5 in. [40 mm] incl | 70–90 [480–620] | 80–100 [550–690] | 145–170 [1000–1170] | 84–104 [580–715] | 88–108 [605–745] | 82–102 [565–705] | 86–106 [590–730] | 90–110 [620–760] |
| over 1.5 in. [40 mm] to 2.5 in. [to 65 mm] | 70–90 [480–620] | 80–100 [550–690] | [A] | [A] | [A] | [A] | [A] | [A] |
| over 2.5 in. [over 65 mm] | 65–85 [450–585] | 75–95 [515–655] | [A] | [A] | [A] | [A] | [A] | [A] |
| Elongation in 2 in. [50 mm], min, %[B] | | | | | | | | |
| to 1.5 in. [40 mm] incl | 22 | 22 | 13 | 20 | 19 | 20 | 19 | 18 |
| over 1.5 in. [40 mm] to 2.5 in. [to 65 mm] | 22 | 22 | [A] | [A] | [A] | [A] | [A] | [A] |
| over 2.5 in. [over 65 mm] | 22 | 22 | [A] | [A] | [A] | [A] | [A] | [A] |
| Elongation in 8 in. [200 mm], min, %[B] | | | | | | | | |
| to 1.5 in. [40 mm] incl | 18 | ... | ... | 16 | 15 | 16 | 15 | 14 |
| over 1.5 in. [40 mm] to 2.5 in. [to 65 mm] | 18 | .... | [A] | [A] | [A] | [A] | [A] | [A] |
| over 2.5 in. [over 65 mm] | 18 | ... | [A] | [A] | [A] | [A] | [A] | [A] |

[A] Not applicable.
[B] See Specification A 20/A 20M for elongation requirement adjustments.

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Several of those that are considered suitable for use with this specification are listed in this section by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S10. Charpy V-Notch Test Curve,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S13. NDT Temperature Determination,

S17. Vacuum Carbon-Deoxidized Steel,

S18. Unspecified Elements, and

S19. Restricted Chemical Requirements.

## ADDITIONAL SUPPLEMENTARY REQUIREMENTS

Also listed are additional supplementary requirements suitable for use with this specification.

### S77. Carbon Equivalent Limit

S77.1 The carbon equivalent, on heat analysis, shall not exceed the limits listed in this section when based on the following equation:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Cu + Ni)/15\ \%$$

| | |
|---|---|
| [Grade A] | |
| t = 2 in. [50 mm] and under in thickness | 0.40% |
| t > 2 in. [50 mm] in thickness | 0.45% |
| [Grade B] | |
| t = 2 in. [50 mm] and under in thickness | 0.45% |
| t > 2 in. [50 mm] in thickness | 0.50% |

### S78. Low Sulfur Treatment

S78.1 Restricted sulfur content shall be specified on the order. In the absence of such a specification the maximum sulfur furnished under this supplementary requirement shall be 0.003 % on heat analysis.

NOTE 1—The low sulfur treatment is for the purpose of enhancing the HIC (Hydrogen Induced Cracking) and SSC (Sulfide Stress Cracking) resistance.

### S79. Carbon Equivalent Limit

S79.1 The carbon equivalent, on heat analysis, shall not exceed 0.27 %, or a lower value as specified in the purchase order, when based on the following equation:

$$P_{CM} = C + \frac{Si}{30} + \frac{Mn + Cu + Cr}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B\ \%$$

## APPENDIX

**(Nonmandatory Information)**

### X1. THERMO-MECHANICAL CONTROLED PROCESSING (TMCP)

X1.1 *Introduction*—The Thermo-Mechanical Controled Processing, commonly referred to as "TMCP," has evolved from the "controlled rolling" (CR) processes, which have been known and used for a number of years. TMCP produces fine-grained steel by a combination of chemical composition and integrated controls of manufacturing processes from slab reheating to post-rolling cooling, thereby achieving the specified mechanical properties in the required plate thicknesses. TMCP requires accurate control of both the steel temperature and rolling reductions, and does not involve coiling after the post- cooling.

X1.2 *Outline of TMCP*—As shown in Fig. X1.1, TMCP may incorporate three processes, as follows:

X1.2.1 *Thermo-Mechanical Rolling (TMR)*—Steels of fine grain size are produced by rolling in the recrystallization and the nonrecrystallization regions of austenite, and sometimes in the dual-phase temperature region of austenite and ferrite. Generally, a high proportion of the rolling reduction is performed close to, or below, the temperature at which austenite begins to transform to ferrite during cooling (Ar3) and may involve rolling in the lower portion of the temperature range of the intercritical dual-phase region.

X1.2.2 *Accelerated Cooling (AC)*—Steels meeting the specified requirements are produced by controlled cooling (accelerated cooling and air cooling) through the dual-phase temperature region immediately after final controlled rolling (CR) or TMR operation.

X1.2.3 *Direct Quenched and Tempered (DQT)*—Steels meeting the specified requirements are produced by promoting grain refinement and increasing hardness through direct quenching immediately after final controlled rolling (CR) or TMR operations. Subsequent to direct quenching the plates are tempered.

X1.3 The selection, from the above, of the method to be used is made by the plate producer depending upon the chemical composition, the plate thickness, and the required properties.

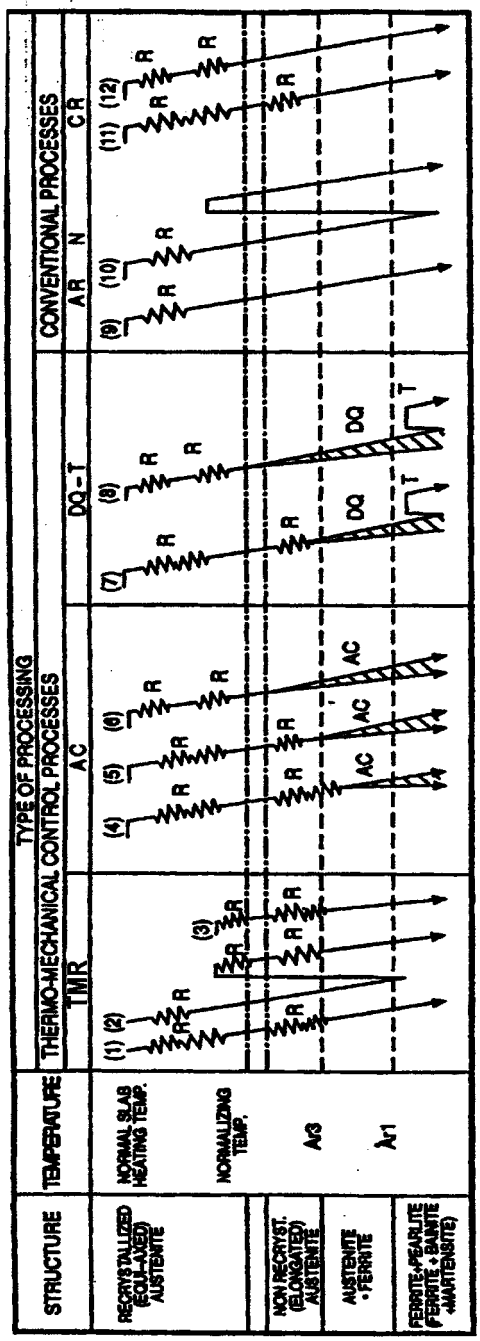


FIG. X1.1 Schematic Diagrams of Thermo-Mechanical Control and Conventional Process of Steel Plate

## SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 841/A 841M - 03) that may impact the use of this standard.

*(1)* Revised Appendix X1.

Committee A01 has identified the location of selected changes to this standard since the last issue (A 841/A 841M - 01) that may impact the use of this standard.

*(1)* Added new Grades E and F. Grade E is available as Class 4 or 5. Grade F is available as Class 6, 7, or 8.

*(2)* Deleted S.14 Bend Test.

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Designation: A 852/A 852M – 03

# Standard Specification for Quenched and Tempered Low-Alloy Structural Steel Plate with 70 ksi [485 MPa] Minimum Yield Strength to 4 in. [100 mm] Thick[1]

This standard is issued under the fixed designation A 852/A 852M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope*

1.1 This specification covers quenched and tempered high-strength low-alloy structural steel plates for welded, riveted, or bolted construction. It is intended primarily for use in welded bridges and buildings where savings in weight, added durability, and good notch toughness are important. The atmospheric corrosion resistance of this steel in most environments is substantially better than that of carbon structural steels with or without copper addition (see Note 1). When properly exposed to the atmosphere, this steel can be used bare (unpainted) for many applications. Welding technique is of fundamental importance, and it is presupposed that the welding procedure will be suitable for the steel and the intended service. This specification is limited to material up to 4 in. [100 mm], inclusive, in thickness. See Appendix X3 of Specification A 6/A 6M for information on weldability.

NOTE 1—For methods of estimating the atmospheric corrosion resistance of low-alloy steels, see Guide G 101.

1.2 Plates produced under this specification are impact tested at a temperature not higher than 50°F [10°C].

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

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling[2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]

A 673/A 673M Specification for Sampling Procedure for Impact Testing of Structural Steel[2]

G 101 Guide for Estimating the Atmospheric Corrosion Resistance of Low-Alloy Steels[4]

## 3. General Requirements for Delivery

3.1 Material furnished under this specification shall conform to the requirements of the current edition of Specification A 6/A 6M, for the ordered material, unless a conflict exists in which case this specification shall prevail.

## 4. Materials and Manufacture

4.1 The steel shall be made to fine grain practice, and the fine austenitic grain size requirements of Specification A 6/A 6M shall be met.

## 5. Heat Treatment

5.1 The material shall be heat treated by the manufacturer by heating to a temperature that produces an austenitic structure, but not less than 1650°F [900°C], holding a sufficient time to attain uniform heat throughout the material, quenching in a suitable medium, and tempering at not less than 1100°F [593°C]. Heat treating temperatures shall be reported on the test certificates.

## 6. Chemical Composition

6.1 The heat analysis shall conform to the requirement prescribed in Table 1.

6.2 When product analysis is required, the steel shall conform on product analysis to the requirements prescribed in Table 1, subject to the product analysis tolerances in Specification A 6/A 6M.

6.3 The atmospheric corrosion-resistance index calculated on the basis of the heat analysis of the steel, as described in Guide G 101–Predictive Method Based on the Data of Larabee and Coburn, shall be 6.0 or higher.

NOTE 2—The user is cautioned that the Guide G 101 (Predictive Method Based on the Data of Larabee and Coburn) for calculation of an atmospheric corrosion-resistance index has only been verified for the

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.02 on Structural Steel for Bridges, Buildings, Rolling Stock, and Ships.

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[2] *Annual Book of ASTM Standards,* Vol 01.04.

[3] *Annual Book of ASTM Standards,* Vol 01.03.

[4] *Annual Book of ASTM Standards,* Vol 03.02.

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

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**TABLE 1 Chemical Composition Requirements**

| Element | Composition, % |
|---|---|
| Carbon[A] | 0.19 max |
| Manganese[A] | 0.80–1.35 |
| Phosphorus | 0.035 max |
| Sulfur | 0.04 max |
| Silicon | 0.20–0.65 |
| Nickel | 0.50 max |
| Chromium | 0.40–0.70 |
| Copper | 0.20–0.40 |
| Vanadium | 0.02–0.10 |

[A]For each reduction of 0.01 percentage point below the specified maximum for carbon, an increase of 0.06 percentage point above the specified maximum for manganese is permitted, up to a maximum of 1.50 %.

composition limits stated in that guide.

6.4 When required, the manufacturer shall supply evidence of corrosion resistance satisfactory to the purchaser.

## 7. Tensile Test Requirements

7.1 *Tension Tests*—The material as represented by the test specimens shall conform to the requirements specified in Table 2.

7.2 *Number of Tests*—One tension test shall be taken from a corner of each plate as heat treated. Plates wider than 24 in. [610 mm] shall be tested in the transverse direction and are subject to the modifications for elongation contained in Footnote C of Table 2.

**TABLE 2 Tensile Requirements[A]**

| | |
|---|---|
| Yield strength, min, ksi [MPa][B] | 70 [485] |
| Tensile strength, range, ksi [MPa] | 90–110 [620–760] |
| Elongation in 2 in. [50 mm], min, %[C,D] | 19 |

[A] See Specimen Orientation under the Tension Tests section of Specification A 6/A 6M.

[B]Measured at 0.2 % offset or 0.5 % extension underload.

[C]For thicknesses of ¾ in. [19 mm] and under, measured on 1½ -in. [40-mm] wide full thickness rectangular specimen as shown in Fig. 3 of Test Methods A 370, the elongation is measured in a 2-in. [50 mm] gage length that includes the fracture and shows the greatest elongation.

[D]For plates wider than 24 in. [600 mm], the elongation requirement is reduced two percentage points. See Elongation Requirement Adjustments in the Tension Tests section of Specification A 6/A 6M.

## 8. Impact Test Requirements

8.1 Longitudinal Charpy V-notch impact tests shall be made in accordance with Test Frequency H of Specification A 673/A 673M. By agreement, Charpy V-notch impact tests may be made in accordance with Test Frequency P of Specification A 673/A 673M.

8.2 The tests results shall meet an average minimum value of 20 ft·lbf [27 J] at 50°F [10°C]. By agreement, a test temperature lower than 50°F [10°C] or an energy level greater than 20 ft·lbf, or both, may be specified.

## 9. Retest

9.1 The manufacturer may reheat treat plates that fail to meet the mechanical property requirements of this specification. All mechanical property tests shall be repeated when material is reheat treated.

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order or contract. Standardized supplementary requirements for use at the option of the purchaser are listed in Specification A 6/A 6M. Those that are considered suitable for use with this specification are listed by title.

S1. Vacuum Treatment,
S2. Product Analysis,
S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,
S6. Drop Weight Test, and
S8. Ultrasonic Examination.

## SUMMARY OF CHANGES

Committee A01 has identified the location of the following changes to this standard since A 852/A 852M – 01 that may impact the use of this standard.

*(1)* Table 1 has been revised.

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Designation: A 871/A 871M – 03

# Standard Specification for High-Strength Low-Alloy Structural Steel Plate With Atmospheric Corrosion Resistance[1]

This standard is issued under the fixed designation A 871/A 871M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope*

1.1 This specification covers high-strength low-alloy steel plate intended for use in tubular structures and poles or in other suitable applications. Two grades, 60 and 65, may be provided as-rolled, normalized or quenched and tempered as required to meet the specified mechanical requirements.

1.2 The atmospheric corrosion resistance of this steel in most environments is substantially better than that of carbon structural steels with or without copper addition (see Note 1). When properly exposed to the atmosphere, this steel can be used bare (unpainted) for many applications.

NOTE 1—For methods of estimating the atmospheric corrosion resistance of low-alloy steels, see Guide G 101.

1.3 When the steel is to be welded, it is presupposed that welding procedures suitable for the grade of steel and intended use or service will be utilized. See Appendix X3 of Specification A 6/A 6M for information on weldability.

1.4 Supplementary requirements in accordance with Specification A 6/A 6M are available, but shall apply only when specified by the purchaser at time of ordering.

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

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling[2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]

A 673/A 673M Specification for Sampling Procedure for Impact Testing of Structural Steel[2]

G 101 Guide for Estimating Atmospheric Corrosion Resistance of Low-Alloy Steels[4]

## 3. General Requirements for Delivery

3.1 Material furnished under this specification shall conform to the requirements of the current edition of Specification A 6/A 6M, for the ordered material, unless a conflict exists in which case this specification shall prevail.

## 4. Materials and Manufacture

4.1 The steel shall be made to fine grain practice.

## 5. Heat Treatment

5.1 Grade 65 in thicknesses of 3⁄16 to 3⁄4 in. [5 to 20 mm] and Grade 60 in thicknesses of 3⁄16 to 1 3⁄8 in. [5 to 35 mm] are normally furnished in the as-rolled condition. The manufacturer has the option to heat treat this material to meet the mechanical requirements of Section 7. Quenched and tempered material shall be heat treated by heating to not less than 1650°F [900°C], holding a sufficient time to attain uniform heat throughout the material, quenching in a suitable medium, and tempering at not less than 1100°F [595°C]. Heat treating temperatures shall be reported on the test certificates.

5.2 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical requirements. The individual manufacturer shall be contacted to determine the actual maximum thickness for each grade and heat treatment method.

## 6. Chemical Requirements

6.1 The heat analysis shall conform to the chemical requirements of Table 1.

6.2 The steel shall conform on product analysis to the chemical requirements of Table 1, subject to the product analysis tolerances in Specification A 6/A 6M.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.02 on Structural Steel for Bridges, Buildings, Rolling Stock, and Ships.

Current edition approved April 10, 2003. Published June 2003. Originally approved in 1987. Last previous edition approved in 2001 as A 871/A 871M – 01.

[2] *Annual Book of ASTM Standards,* Vol 01.04.

[3] *Annual Book of ASTM Standards,* Vol 01.03.

[4] *Annual Book of ASTM Standards,* Vol 03.02.

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

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**TABLE 1 Chemical Requirements (Heat Analysis)**

| Element | Composition, % | | | |
|---|---|---|---|---|
| | Type I | Type II | Type III | Type IV |
| Carbon[A] | 0.19 max | 0.20 max | 0.15 max | 0.17 max |
| Manganese[A] | 0.80–1.35 | 0.75–1.35 | 0.80–1.35 | 0.50–1.20 |
| Phosphorus | 0.04 max | 0.04 max | 0.04 max | 0.04 max |
| Sulfur | 0.05 max | 0.05 max | 0.05 max | 0.05 max |
| Silicon | 0.30–0.65 | 0.15–0.50 | 0.15–0.40 | 0.25–0.50 |
| Nickel | 0.40 max | 0.50 max | 0.25–0.50 | 0.40 max |
| Chromium | 0.40–0.70 | 0.40–0.70 | 0.30–0.50 | 0.40–0.70 |
| Molybdenum | . . . | . . . | . . . | 0.10 max |
| Copper | 0.25–0.40 | 0.20–0.40 | 0.20–0.50 | 0.30–0.50 |
| Vanadium | 0.02–0.10 | 0.01–0.10 | 0.01–0.10 | . . . |
| Columbium | . . . | . . . | . . . | 0.005–0.05[B] |

[A] For each reduction of 0.01 percentage point below the specified maximum for carbon, an increase of 0.06 percentage point above the specified maximum for manganese is permitted, up to a maximum of 1.50 %.

[B] For plates under ½ in. [13 mm] in thickness, the minimum columbium is waived.

6.3 The atmospheric corrosion-resistance index, calculated on the basis of the heat analysis for the steel, as described in Guide G 101—Predictive Method Based on the Data of Larabee and Coburn, shall be 6.0 or higher.

NOTE 2—The user is cautioned that the Guide G 101 (Predictive Method Based on the Data of Larabee and Coburn) for calculation of an atmospheric corrosion-resistance index has only been verified for the composition limits stated in that guide.

6.4 When required, the manufacturer shall supply evidence of corrosion resistance satisfactory to the purchaser.

## 7. Mechanical Requirements

7.1 *Tension Tests*:

7.1.1 The steel as represented by the tension test specimens shall conform to the tensile requirements of Table 2.

7.1.2 For adjustments in Table 2 percentage elongation requirements for material thickness under 0.312 in. [8 mm] and over 3.5 in. [90 mm], see Specification A 6/A 6M.

7.2 *Charpy V-Notch Impact Tests*:

**TABLE 2 Tensile Requirements[A]**

| Grade | Yield Strength[B] min. ksi [MPa] | Tensile Strength min. ksi [MPa] | Minimum Elongation, %[C] | |
|---|---|---|---|---|
| | | | In 8 in. [200 mm] | In 2 in. [50 mm] |
| 60 | 60 [415] | 75 [520] | 16 | 18 |
| 65 | 65 [450] | 80 [550] | 15 | 17 |

[A] For plates wider than 24 in. [600 mm], the test specimen is taken in the transverse direction. See 11.2 of Specification A 6/A 6M.

[B] Measured at 0.2 % offset or 0.5 % extension under load as described in Section 13 on yield strength of Test Methods A 370.

[C] For plates wider than 24 in. [600 mm], the elongation requirement is reduced three percentage points.

7.2.1 The steel, as represented by the Charpy V-Notch test, shall conform to the impact test requirements of Table 3.

7.2.2 If more stringent impact requirements are required, they shall be negotiated between the purchaser and the manufacturer.

## 8. Test Specimens and Number of Tests

8.1 The purchaser shall indicate on the purchase order the frequency of Charpy V-Notch Impact Testing, as provided for in Specification A 673/A 673M. If the purchase order does not specify the frequency, "H" testing frequency shall be supplied.

## 9. Keywords

9.1 as-rolled; atmospheric corrosion resistance; high-strength; low-alloy; normalized; plate; poles; quenched; steel; structural steel; tempered; tubular structures

**TABLE 3 Charpy V-Notch Impact Test Requirements**

| Plate Thickness in [mm] | Absorbed Energy ft-lb [J] | Temperature °F [°C] |
|---|---|---|
| Up to ½ [12] incl | 15 [20] | 0 [−18] |
| Over ½ [12] | 15 [20] | − 20 [−29] |

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order or contract. Standardized supplementary requirements for use at the option of the purchaser are listed in Specification A 6/A 6 M.

## SUMMARY OF CHANGES

Committee A01 has identified the location of the following changes to this standard since A 871/A 871M – 01 that may impact the use of this standard.

*(1)* Table 1 has been revised

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Designation: A 131/A 131M – 01

# Standard Specification for Structural Steel for Ships[1]

This standard is issued under the fixed designation A 131/A 131M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers structural steel plates, shapes, bars, and rivets intended primarily for use in ship construction.

1.2 Material under this specification is available in the following categories:

1.2.1 *Ordinary Strength*—Grades A, B, D, CS, and E with a specified minimum yield point of 34 ksi [235 MPa], and

1.2.2 *Higher Strength*—Grades AH, DH, EH, and FH with specified minimum yield points of either 46 ksi [315 MPa], 51 ksi [350 MPa], or 57 ksi [390 MPa].

1.3 Shapes and bars are normally available as Grades A, AH32, or AH36. Other grades may be furnished by agreement between the purchaser and the manufacturer.

1.4 When the steel is to be welded, it is presupposed that a welding procedure suitable for the grade of steel and intended use or service will be utilized. See Appendix X3 of Specification A 6/A 6M for information on weldability.

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

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 6/A6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling[2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]

E 112 Test Methods for Determining Average Grain Size[4]

## 3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *control rolling, n*—a steel treatment that consists of final rolling within the range used for normalizing heat treatments so that the austenite completely recrystallizes.

3.1.2 *thermo-mechanical controlled processing, n*—a steel treatment that consists of strict control of the steel temperature and the rolling reduction. A high proportion of the rolling reduction is to be carried out close to or below the $Ar_3$ transformation temperature and may involve rolling towards the lower end of the temperature range of the intercritical duplex phase region thus permitting little if any recrystallization of the austenite. The process may involve accelerated cooling on completion of rolling.

## 4. Ordering Information

4.1 Specification A 6/A 6M establishes the rules for the ordering information that should be complied with when purchasing material to this specification.

4.2 Additional ordering considerations specific to this specification are:

4.2.1 Cold flanging, if applicable, and

4.2.2 Condition (control rolled or thermo-mechanical control processed).

## 5. Materials and Manufacture

5.1 Except for Grade A steel up to and including ½ in. [12.5 mm] in thickness, rimmed steels shall not be applied.

5.2 Except for Grades A and B steel, semi-killed steels shall not be applied.

5.3 Except as permitted in 5.3.1, Grades D, CS, E, AH32, AH36, AH40, DH32, DH36, DH40, EH32, EH36, EH40, FH32, FH36, and FH40 shall be made using a fine grain practice. For ordinary strength grades, aluminum shall be used to obtain grain refinement. For high strength grades, aluminum, vanadium, or columbium (niobium) may be used for grain refinement.

5.3.1 Grade D material 1.0 in. [25 mm] and under in thickness, at the option of the manufacturer, may be killed and exempt from the fine austenitic grain size requirement of 7.1, but such material shall be subject to the toughness requirement of 8.2.1.

5.4 Plates in all thicknesses ordered to Grade CS shall be normalized. Plates in all thicknesses ordered to Grade E shall be normalized, or thermo-mechanical control processed. Plates over 1⅜ in. [35 mm] in thickness ordered to Grade D shall be normalized, control rolled, or thermo-mechanical control processed. See Table 1.

5.5 Plates in all thicknesses ordered to Grades EH32 and

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.02 on Structural Steel for Bridges, Buildings, Rolling Stock, and Ships.

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[2] *Annual Book of ASTM Standards*, Vol 01.04.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

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**TABLE 1 Condition of Supply and Frequency of Impact Tests Ordinary Strength Hull Structural Steel**

| Grade | Deoxidation | Products[A] | Condition of Supply[B] (Impact Test Lot Size[C], in Tons [Mg]) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Thickness, in inches [mm] | | | | |
| | | exceeding:→ not exceeding:→ | 0.25 [6.4] 0.5 [12.5] | 0.5 [12.5] 1.0 [25] | 1.0 [25] 1.375 [35] | 1.375 [35] 2.0 [50] | 2.0 [50] 4.0 [100] |
| A | Rimmed | All | AR (–) | | | | |
| | Semi-Killed | All | | | | | |
| | Killed | P | AR (–) | | | | N (–)[D] TM (–) CR (50 [45]) AR (50 [45]) |
| | | S | | | | | |
| B | Semi-Killed | All | | | | | |
| | Killed | P | AR (–) | | AR (50 [45]) | | N (50 [45]) TM (50 [45]) CR (25 [23]) AR (25 [23]) |
| | | S | | | | | |
| D | Killed | P | AR (50) N (50) | | | | |
| | | S | | | | | |
| D | Killed & Fine Grain | P | AR (50 [45]) N (50 [45]) | | | N (50 [45]) TM (50 [45]) CR (50 [45]) | N (50 [45]) TM (50 [45]) CR (25 [23]) |
| | | S | | | | | |
| E | Killed & Fine Grain | P | N (P) TM (P) | | | | N (P) TM (P) |
| | | S | N (25 [23]) TM (25 [23]) CR (15 [14]) | | | | |
| CS | Killed & Fine Grain | P | N (–) | | | | N (P) |
| | | S | N (–) | | | | |

[A]Products: P = plate S = shapes and bars
[B]Conditions of Supply: AR = as-rolled N = normalized CR = control rolled TM = thermo-mechanical controlled processing
[C]Frequency of Impact Test: (Impact Test Lot Size in Tons from Each Heat) (–) = no impact test required (P) = each plate as-rolled
[D]Impact tests for Grade A are not required when material is produced using a fine grain practice and normalized.

EH36 shall be normalized, or thermo-mechanical control processed. Plates in all thicknesses ordered to Grade EH40, FH32, FH36, and FH40 shall be normalized, thermo-mechanical control processed, or quenched and tempered. Plates ordered to Grades AH32, AH36, AH40, DH32, DH36, and DH40 shall be normalized, control rolled, or thermo-mechanical control processed when so specified. See Table 2.

5.6 In the case of shapes, the thicknesses referred to are those of the flange. Heat treatment and rolling requirements for shapes and bars are shown in Tables 1 and 2.

## 6. Chemical Requirements

6.1 The heat analysis shall conform to the requirements for chemical composition prescribed in Tables 3 and 4.

6.1.1 When specified, the steel shall conform on product analysis to the requirements prescribed in Tables 3 and 4, subject to the product analysis tolerances in Specification A 6/A 6M.

6.2 For thermo-mechanical control process steel, the carbon equivalent shall be determined from the heat analysis and shall

**TABLE 2 Condition of Supply and Frequency of Impact Tests Higher Strength Hull Structural Steel**

| Grade | Deoxidation | Grain Refining Element | Products[C] | Condition of Supply[A] (Impact Test Lot Size[B], in Tons [Mg]) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Thickness, in inches (mm) | | | | | |
| | | | | Exceeding:→ not exceeding:→ | 0.25 [6.4] 0.5 [12.5] | 0.5 [12.5] 0.80 [20] | 0.80 [20] 1.0 [25] | 1.0 [25] 1.375 [35] | 1.375 [35] 2.0 [50] | 2.0 [50] 4.0 [100] |
| AH36 AH32 | Killed & Fine Grain Practice | Nb V | P | | AR (50 [45]) | N (50 [45]) TM (50 [45]) CR (50 [45]) | | | | N (50 [45]) TM (50 [45]) CR (25 [23]) |
| | | | S | | AR (50 [45]) | N (50 [45]) TM (50 [45]) CR (50 [45]) AR (25 [23]) | | | | |
| | | Al | P | | AR (50 [45]) | | AR (25 [23]) | N (50 [45]) TM (50 [45]) CR (50 [45]) | | N (50 [45]) TM (50 [45]) CR (25 [23]) |
| | | Al + Ti | S | | AR (50 [45]) | | N (50 [45]) TM (50 [45]) CR (50 [45]) AR (25 [23]) | | | |
| DH32 DH36 | | Nb | P | | AR (50 [45]) | N (50 [45]) TM (50 [45]) CR (50 [45]) | | | | N (50 [45]) TM (50 [45]) CR (25 [23] |
| | | V | S | | AR (50 [45]) | N (50 [45]) TM (50 [45]) CR (50 [45]) | | | | |
| | | Al | P | | AR (50 [45]) | | AR (25 [23]) | N (50 [45]) TM (50 [45]) CR (50 [45]) | | N (50 [45]) TM (50 [45]) CR (25 [23] |
| | | Al + Ti | S | | AR (50 [45]) | | AR (25 [23]) | N (50 [45]) TM (50 [45]) CR (50 [45]) | | |
| EH32 EH36 | | Any | P | | N (P) TM (P) | | | | | N (P) TM (P) |
| | | | S | | N (25 [23]) TM (25 [23]) CR (15 [14]) | | | | | |
| FH32 FH36 | | Any | P | | N (P) TM (P) QT (P) | | | | | |
| | | | S | | N (25 [23]) TM (25 [23]) QT (25 [23]) | | | | | |
| AH40 | | Any | All | | AR (50 [45]) | N (50 [45]) TM (50 [45]) CR (50 [45]) | | | | |
| DH40 | | Any | All | | N (50 [45]) TM (50 [45]) CR (50 [45]) | | | | | |
| EH40 | | Any | P | | N (P) TM (P) QT (P) | | | | | |
| | | | S | | N (25 [23]) TM (25 [23]) CR (25 [23]) | | | | | |
| FH40 | | Any | P | | N (P) TM (P) QT (P) | | | | | |
| | | | S | | N (25 [23]) TM (25) CR (25 [23]) | | | | | |

[A]Conditions of Supply: AR = as-rolled TM = thermo-mechanical controlled processing CR = controlled QT = quenched and tempered N = normalized
[B]Frequency of Impact Test: (Impact Test Lot Size in Tons from Each Heat) (–) = no impact test required (P) = each plate as-rolled
[C]Products: P = plate S = shapes and bars



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**TABLE 3 Chemical Requirements Ordinary Strength Hull Structural Steel**

| Grade | A | B | D | E | CS |
|---|---|---|---|---|---|
| Deoxidation | Killed or Semi-Killed[A] t ≤ 2.0 in.. [50 mm] Killed t > 2.0 in. [50 mm] | Killed or Semi-Killed t ≤ 2.0 in.. [50 mm] Killed t > 2.0 in. [50 mm] | Killed t ≤ 1.0 in.. [25 mm] Killed and Fine Grain t > 1.0 in. [25 mm][B] | Killed and Fine Grain[B] | Killed and Fine Grain[B] |
| | Chemical composition (ladle analysis), % max, unless specified otherwise[C] | | | | |
| C | 0.21[D] | 0.21 | 0.21 | 0.18 | 0.16 |
| $Mn_{min}$ | 2.5 × C | 0.80[E] | 0.60 | 0.70 | 1.00 |
| Si | 0.50 | 0.35 | 0.10–0.35[F] | 0.10–0.35[F] | 0.10–0.35[F] |
| P | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 |
| S | 0.035 | 0.035 | 0.035 | 0.035 | 0.035 |
| Ni | See Footnote[G] | See Footnote[G] | See Footnote[G] | See Footnote[G] | See Footnote[G] |
| Cr | See Footnote[G] | See Footnote[G] | See Footnote[G] | See Footnote[G] | See Footnote[G] |
| Mo | See Footnote[G] | See Footnote[G] | See Footnote[G] | See Footnote[G] | See Footnote[G] |
| Cu | See Footnote[G] | See Footnote[G] | See Footnote[G] | See Footnote[G] | See Footnote[G] |
| C + Mn/6 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |

[A] For Grade A, rimmed steel shapes and bars may be accepted up to and including 0.5 in. [12.5 mm].
[B] Grade D steel over 1.0 in. [25 mm], Grade E steel and Grade CS steel are to contain at least one of the grain refining elements in sufficient amount to meet the fine grain practice requirements (see Section 7).
[C] Intentionally added elements are to be determined and reported.
[D] A maximum carbon content of 0.23 % is acceptable for Grade A shapes and bars.
[E] For Grade B steel of cold flanging quality or where fully killed, the lower limit of manganese may be reduced to 0.60 %.
[F] Where the content of soluble aluminum is not less than 0.015 %, the minimum required silicon content does not apply.
[G] The contents of nickel, chromium, molybdenum and copper are to be determined and reported. When the amount does not exceed 0.02 %, these elements may be reported as ≤0.02 %.

**TABLE 4 Chemical Requirements Higher-Strength Hull Structural Steel**

| Grades | AH/DH/EH 32, AH/DH/EH 36 and AH/DH/EH 40 | FH 32/36/40 |
|---|---|---|
| Deoxidation | Killed, Fine Grain Practice[A] | Killed, Fine Grain Practice[A] |
| | Chemical composition[B] (ladle analysis), % max, unless specified in range | |
| C | 0.18 | 0.16 |
| Mn | 0.90–1.60[C] | 0.90–1.60 |
| Si | 0.10–0.50[D] | 0.10–0.50[D] |
| P | 0.035 | 0.025 |
| S | 0.035 | 0.025 |
| Al (acid soluble), min[E,F] | 0.015 | 0.015 |
| Nb[F,G] | 0.02–0.05 | 0.02–0.05 |
| V[F,G] | 0.05–0.10 | 0.05–0.10 |
| Ti | 0.02 | 0.02 |
| Cu[H] | 0.35 | 0.35 |
| Cr[H] | 0.20 | 0.20 |
| Ni[H] | 0.40 | 0.40 |
| Mo[H] | 0.08 | 0.08 |
| N | ... | 0.009 0.012 (if Al present) |

[A] *The steel is to contain at least one of the grain refining elements in sufficient amount to meet the fine grain practice requirement (see Section 7).*
[B] The contents of any other element intentionally added is to be determined and reported.
[C] Grade AH 0.5 in. [12.5 mm] and under in thickness may have a minimum manganese content of 0.70 %.
[D] Where the content of soluble aluminum is not less than 0.015 %, the minimum required silicon content does not apply.
[E] The total aluminum content may be used instead of acid soluble content, in accordance with 7.1.
[F] The indicated amount of aluminum, niobium, and vanadium applies when any such element is used singly. When used in combination, the minimum content in 7.2.2 and 7.2.3, as appropriate, will apply.
[G] These elements need not be reported on the mill sheet unless intentionally added.
[H] These elements may be reported as ≤0.02 % where the amount present does not exceed 0.02 %.

conform to the requirements in Table 5.

## 7. Metallurgical Structure

7.1 The steel grades indicated in Section 5 shall be made to fine grain practice, and the requirements for fine austenitic grain size in Specification A 6/A 6M shall be met.

7.2 Where the use of fine grain practice using columbium, vanadium, or combinations is permitted under Section 5, the following limits shall be applied:

7.2.1 Minimum columbium (niobium) content of 0.020 % or minimum vanadium content of 0.050 % for each heat, or

7.2.2 When vanadium and aluminum are used in combination, minimum vanadium content of 0.030 % and minimum

**TABLE 5 Carbon Equivalent for Higher-Strength Hull Structural Steel Produced by TMCP**

| Grade | Carbon Equivalent[A], max, % | |
|---|---|---|
| | $t \le 2.0$ in. [50 mm] | $t > 2.0$ in. [50 mm] $t \le 4.0$ in. [100 mm] |
| AH32, DH32, EH32 | 0.36 | 0.38 |
| FH32 | 0.36 | |
| AH36, DH36, EH36 | 0.38 | 0.40 |
| FH36 | 0.38 | |
| AH40, DH40, EH40, FH40 | 0.40 | |

[A] The following carbon equivalent formula shall be used to calculate the carbon equivalent, $C_{eq}$:

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} (\%)$$



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acid-soluble aluminum content of 0.010 %, or minimum total aluminum content of 0.015 %.

7.2.3 When columbium (niobium) and aluminum are used in combination, minimum columbium (niobium) content of 0.010 % and minimum acid-soluble aluminum content of 0.010 %, or minimum total aluminum content of 0.015 %.

## 8. Mechanical Requirements

8.1 *Tension Test*:

8.1.1 Except as specified in the following paragraphs, the material as represented by the test specimens shall conform to the tensile requirements prescribed in Table 6.

8.1.1.1 Shapes less than 1 in.$^2$ [645 mm$^2$] in cross section, and bars, other than flats, less than ½ in. [12.5 mm] in thickness or diameter need not be subjected to tension tests by the manufacturer, but chemistry consistent with the required tensile properties must be applied.

8.1.1.2 The elongation requirement of Table 6 does not apply to material ordered as floor plates with a raised pattern. However, for floor plates over ½in. [12.5 mm] in thickness, test specimens shall be bent cold with the raised pattern on the inside of the specimen through an angle of 180° without cracking when subjected to a bend test in which the inside diameter is three times plate thickness. Sampling for bend testing shall be as specified for the tension tests in 8.1.2.

8.1.2 One tension test shall be made from each of two different plates, shapes, or bars from each heat of structural steel and steel for cold flanging unless the finished material from a heat is less than 50 tons [45 Mg], when one tension test will be sufficient. If, however, material from one heat differs ⅜ in. [10 mm] or more in thickness or diameter, one tension test shall be made from both the thickest and the thinnest material rolled, regardless of the weight represented.

8.1.3 Two tension tests shall be made from each heat of rivet steel.

8.1.4 For quenched and tempered steel, including Grades EH40, FH32, FH36, and FH40, one tension test shall be made on each plate as quenched and tempered.

8.2 *Toughness Tests*:

8.2.1 Charpy V-notch tests shall be made on Grade A material over 2 in. [50 mm] in thickness, on Grade B material over 1 in. [25 mm] in thickness and on material over ¼in. [6.4 mm] in thickness of Grades D, E, AH32, AH36, AH40, DH32, DH36, DH40, EH32, EH36, EH40, FH32, FH36, and FH40, as required by Tables 1 and 2. The frequency of Charpy V-notch impact tests shall be as required in Tables 1 and 2. The test results shall conform to the requirements of Table 7.

8.2.2 For Grades EH32, EH36, EH40, FH32, FH36, and FH40 plate material, one set of three impact specimens shall be made from each plate-as-rolled.

8.2.3 For Grade A, B, D, AH32, AH36, AH40, DH32, DH36, and DH40 plate material, and for all shape material, and all bar material, one set of three impact specimens shall be made from the thickest material in each test lot size of each heat, as required by Tables 1 and 2. When heat testing is called for, a set of three specimens shall be tested for each test lot size indicated in Tables 1 and 2, of the same type of product produced on the same mill from each heat of steel. The set of impact specimens shall be taken from different as-rolled or heat-treated pieces of the heaviest gage produced. An as-rolled piece refers to the product rolled from a slab, billet, bloom, or directly from an ingot. Where the maximum thickness or diameter of various sections differs by ⅜in. [10 mm] or more, one set of impacts shall be made from both the thickest and the thinnest material rolled regardless of the weight represented.

8.2.4 The specimens for plates shall be taken from a corner of the material and the specimens from shapes shall be taken from the end of a shape at a point one third the distance from the outer edge of the flange or leg to the web or heel of the shape. Specimens for bars shall be in accordance with Specification A 6/A 6M.

8.2.5 The largest size specimens possible for the material thickness are to be machined. For plates, flats, and bars, the specimens are to be located with its edge within 0.08 in. [2 mm] from the surface except that where the thickness exceeds 1.57 in. [40 mm], the longitudinal axis of the specimen is to be located at a point midway between the surface and the center of the thickness. The length of the notch is to be perpendicular to the original rolled surface.

8.2.6 Unless a specific orientation is called for on the purchase order, the longitudinal axis of the specimens may be parallel or transverse to the final direction of rolling of the material at the option of the steel manufacturer.

8.2.7 The impact test shall be made in accordance with the Charpy Impact Testing section in Test Methods and Definitions A 370.

8.2.8 Each impact test shall constitute the average value of

**TABLE 6 Tensile Requirements Ordinary Strength and Higher-Strength Hull Structural Steel**

| Grade | Tensile Strength, ksi [MPa] | Yield Point, min, ksi [MPa] | Elongation, min, %,[A,B] in 8 in. [200 mm] | Elongation, min, %,[B,C] in 2 in. [50 mm] |
|---|---|---|---|---|
| Ordinary strength: | | | | |
| A, B, D, E, CS | 58 to 75 [400 to 520][D] | 34 [235] | 21 | 24 |
| Rivet steel and steel for cold flanging | 55 to 65 [380 to 450] | 30 [205] | 23 | 26 |
| Higher strength: | | | | |
| AH32, DH32, EH32, FH32 | 64 to 85 [440 to 590] | 46 [315] | 19 | 22 |
| AH36, DH36, EH36, FH36 | 71 to 90 [490 to 620] | 51 [355] | 19 | 22 |
| AH40, DH40, EH40, FH40 | 74 to 94 [510 to 650] | 57 [390] | 19 | 22 |

[A] For nominal thickness or diameter under 5/16 in. [8 mm], a deduction from the specified percentage of elongation in 8 in. [200 mm] shall be made. See elongation requirement adjustments under the Tension Tests section of Specification A 6/A 6M for deduction values.

[B] Elongation is not required for floor plate.

[C] For nominal thickness or diameter over 3.5 in. [90 mm], a deduction from the specified percentage of elongation in 2 in. [50 mm] shall be made. See elongation requirement adjustments under the Tension Tests section of Specification A 6/A 6M for deduction values.

[D] For Grade A shapes and bars, the upper limit of tensile strength may be 80 ksi [550 MPa].



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**TABLE 7 Charpy V-Notch Impact Requirements Ordinary Strength and Higher-Strength Hull Structural Steel**

| Material Thickness | | Average Absorbed Energy[A], min, ft-lbf [J] | | | | | |
|---|---|---|---|---|---|---|---|
| | | ≤2.0 in. [50 mm] | | >2.0 in. [50 mm] ≤2.8 in. [70 mm] | | >2.8 in. [70 mm] ≤4.0 in. [100 mm] | |
| Grade[B,C] | Test Temperature,° F (°C) | Charpy V-notch Impact Specimen Orientation | | | | | |
| | | Longitudinal[D] | Transverse[D] | Longitudinal[D] | Transverse[D] | Longitudinal[D] | Transverse[D] |
| A | 68 [20] | ... | ... | 25 [34] | 17 [24] | 30 [41] | 20 [27] |
| B | 32 [0] | 20 [27] | 14 [20] | 25 [34] | 17 [24] | 30 [41] | 20 [27] |
| AH32 | | 25 [34] | 17 [24] | 28 [38] | 19 [26] | 34 [46] | 23 [31] |
| AH36 | | 25 [34] | 17 [24] | 30 [41] | 20 [27] | 37 [50] | 25 [34] |
| AH40 | | 30 [41] | 20 [27] | NA | NA | NA | NA |
| D | −4 [−20] | 20 [27] | 14 [20] | 25 [34] | 17 [24] | 30 [41] | 20 [27] |
| DH32 | | 25 [34] | 17 [24] | 28 [38] | 19 [26] | 34 [46] | 23 [31] |
| DH36 | | 25 [34] | 17 [24] | 30 [41] | 20 [27] | 37 [50] | 25 [34] |
| DH40 | | 30 [41] | 20 [27] | ... | ... | ... | ... |
| E | −40 [−40] | 20 [27] | 14 [20] | 25 [34] | 17 [24] | 30 [41] | 20 [27] |
| CS | | ... | ... | 25 [34] | 17 [24] | 30 [41] | 20 [27] |
| EH32 | | 25 [34] | 17 [24] | 28 [38] | 19 [26] | 34 [46] | 23 [31] |
| EH36 | | 25 [34] | 17 [24] | 30 [41] | 20 [27] | 37 [50] | 25 [34] |
| EH40 | | 30 [41] | 20 [27] | ... | ... | ... | ... |
| FH32 | −76 [−60] | 25 [34] | 17 [24] | | | | |
| FH36 | | 25 [34] | 17 [24] | ... | ... | ... | ... |
| FH40 | | 30 [41] | 20 [27] | | | | |

[A]The energy shown is minimum for full-sized (0.394 by 0.394-in. [10 × 10-mm]) specimen. For sub-sized specimens, the energy shall be reduced as follows:

| Specimen Size, in in. [mm] | 0.394× 0.295 [10× 7.5] | 0.394× 0.197 [10× 5.0] | 0.394× 0.098 [10× 2.5] |
|---|---|---|---|
| Required Energy | 5E/6 | 2E/3 | E/2 |

E—energy required for full-sized specimen

[B] Either direction is acceptable.

[C]Charpy V-notch impact test requirements for ordinary strength hull structural steel grades apply where such test is required by Table 5.

[D]Charpy V-notch impact test requirements for higher-strength hull structural steel grades apply where such test is required by Table 6.

three specimens taken from a single test location. The average value shall meet the specified minimum average with not more than one value below the specified minimum average but in no case below 70% of the specified minimum average.

8.2.8.1 When the results fail to meet the preceding requirements but 8.2.8.1 (*2*) and (*3*) are complied with, three additional specimens may be taken from the location as close to the initial specimens as possible and their test results added to those previously obtained to form a new average. The material represented may be accepted if for the six specimens 8.2.8.1 (*1*), (*2*), and (*3*) are met.

(*1*) The average is not less than the required minimum average.

(*2*) No more than two individual values are below the required minimum average.

(*3*) No more than one individual value is below 70% of the required minimum average.

8.2.8.2 If the required energy values are not obtained upon retest, the material may be heat treated at the option of the producer in the case of as-rolled material or reheat treated in the case of heat-treated material.

8.2.8.3 After heat treatment or reheat treatment, a set of three specimens shall be tested and evaluated in the same manner as for the original material.

8.2.8.4 If the impact test result fails to meet the requirement for the thickest product tested when heat testing, that material shall be rejected and the next thickest material may be tested to qualify the balance of the heat in accordance with 8.2.8. At the option of the producer, retests may be made on each piece of the rejected material, in which case each piece shall stand on the results of its own test. It shall also be the option of the producer to heat treat the product prior to retesting if desired.

8.3 *Rivet Steel and Rivets*:

8.3.1 For rivet steel a sulfur print requirement shall be met when other than killed or semi-killed steel is applied, in order to confirm that its core is free of concentrations of sulfur segregates and other nonmetallic substances.

8.3.2 Test specimens for rivet bars that have been cold drawn shall be normalized before testing.

8.3.3 Finished rivets are to be selected as sample specimens from each diameter and tested hot and cold by bending and crushing as follows: The shank must stand being doubled together cold, and the head being flattened hot to a diameter 2½ times the diameter of the shank, both without fracture. Bend test requirements for rivets are given in Table 8.

## 9. General Requirements for Delivery

9.1 Material furnished under this specification shall conform to the requirements of the current edition of Specification A 6/A 6M, for the ordered material, unless a conflict exists in which case this specification shall prevail.

## 10. Plate Conditioning

10.1 After removal of any imperfection preparatory to welding the thickness of the plate at any location must not be reduced by more than 20 % of the nominal thickness of the plate.

**TABLE 8 Bend Test Requirements for Rivet Steel**

| Thickness of Material, in. [mm] | Ratio of Bend Diameter to Thickness of Specimen |
|---|---|
| ¾ [20] and under | flat on itself |
| Over ¾ [20] to 1¼ [30], incl | 1 |
| Over 1¼ [30] | 2 |



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## 11. Test Reports

11.1 When test reports are required by the purchase order, the report shall show the results of each test required by Sections 7 and 8, except that the results of only one set of tests need be reported when the amount of material from a heat in a shipment is less than 10 tons [9 Mg] and when the thickness variations described in Section 8 are not exceeded.

11.2 The thickness of the product tested may not necessarily be the same as an individual ordered thickness since it is the heat that is tested rather than each ordered item.

## 12. Marking

12.1 In addition to the marking specified in Specification A 6/A 6M, material ordered to cold flanging quality shall be additionally marked with the letter **F**.

12.2 Plates produced to a normalized heat treatment condition shall be marked with the suffix **N** to indicate that the material has been normalized.

12.3 Plates produced to a control rolled condition shall be marked with the suffix **CR** to indicate that the material has been control rolled.

12.4 Plates produced to a thermo-mechanical control processed condition shall be marked with the suffix **TM** to indicate that the material has been thermo-mechanical control processed.

12.5 Plates produced to a quenched and tempered heat treatment condition shall be marked with the suffix **QT** to indicate that the material has been quenched and tempered.

## 13. Keywords

13.1 bars; higher strength; ordinary strength; plates; rivets; shapes; ship construction; steel; structural steel

## SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified in the order:

### S85. Product Chemical Analysis

S85.1 The chemical composition shall be determined for plates, shapes, or bars in accordance with 6.1.1. The number of pieces to be tested shall be stated on the order.

### S86. Orientation of Impact Specimens

S86.1 The orientation of the impact test specimens shall be as specifically stated on the order. (The purchaser shall state whether the tests are to be longitudinal or transverse.)

### S87. Heat-Treatment of Grade DH

S87.1 Grade DH aluminum-treated steel over ¾in. [19 mm] in thickness shall be normalized.

### S88. Additional Tension Tests

S88.1 At least one tension test shall be made from each 50 tons [45 Mg] or fraction thereof from each heat. If the material differs by 0.375 in. [10 mm] or more in nominal thickness or diameter, one tension test shall be made from both the thickest and thinnest material in each 50 tons.

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Designation: A 435/A 435M – 90 (Reapproved 2001)

# Standard Specification for Straight-Beam Ultrasonic Examination of Steel Plates[1]

This standard is issued under the fixed designation A 435/A 435M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification[2] covers the procedure and acceptance standards for straight-beam, pulse-echo, ultrasonic examination of rolled fully killed carbon and alloy steel plates, ½ in. [12.5 mm] and over in thickness. It was developed to assure delivery of steel plates free of gross internal discontinuities such as pipe, ruptures, or laminations and is to be used whenever the inquiry, contract, order, or specification states that the plates are to be subjected to ultrasonic examination.

1.2 Individuals performing examinations in accordance with this specification shall be qualified and certified in accordance with the requirements of the latest edition of ASNT SNT-TC-1A or an equivalent accepted standard. An equivalent standard is one which covers the qualification and certification of ultrasonic nondestructive examination candidates and which is acceptable to the purchaser.

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

## 2. Referenced Documents

2.1 *ASNT Standard:*

SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing[3]

## 3. Apparatus

3.1 The manufacturer shall furnish suitable ultrasonic equipment and qualified personnel necessary for performing the test. The equipment shall be of the pulse-echo straight beam type. The transducer is normally 1 to 1⅛ in. [25 to 30 mm] in diameter or 1 in. [25 mm] square; however, any transducer having a minimum active area of 0.7 in.$^2$ [450 mm$^2$] may be used. The test shall be performed by one of the following methods: direct contact, immersion, or liquid column coupling.

3.2 Other search units may be used for evaluating and pinpointing indications.

## 4. Test Conditions

4.1 Conduct the examination in an area free of operations that interfere with proper functioning of the equipment.

4.2 Clean and smooth the plate surface sufficiently to maintain a reference back reflection from the opposite side of the plate at least 50 % of the full scale during scanning.

4.3 The surface of plates inspected by this method may be expected to contain a residue of oil or rust or both. Any specified identification which is removed when grinding to achieve proper surface smoothness shall be restored.

## 5. Procedure

5.1 Ultrasonic examination shall be made on either major surface of the plate. Acceptance of defects in close proximity may require inspection from the second major surface. Plates ordered in the quenched and tempered condition shall be tested following heat treatment.

5.2 A nominal test frequency of 2¼ MHz is recommended. Thickness, grain size, or microstructure of the material and nature of the equipment or method may require a higher or lower test frequency. However, frequencies less than 1 MHz may be used only on agreement with the purchaser. A clear, easily interpreted trace pattern should be produced during the examination.

5.3 Conduct the examination with a test frequency and instrument adjustment that will produce a minimum 50 to a maximum 75 % of full scale reference back reflection from the opposite side of a sound area of the plate. While calibrating the instrument, sweep the crystal along the plate surface for a distance of at least 1*T* or 6 in. [150 mm], whichever is the greater, and note the position of the back reflection. A shift in location of the back reflection during calibration shall be cause for recalibration of the instrument.

5.4 Scanning shall be continuous along perpendicular grid lines on nominal 9-in. [225-mm] centers, or at the manufacturer's option, shall be continuous along parallel paths, transverse to the major plate axis, on nominal 4-in. [100-mm] centers, or shall be continuous along parallel paths parallel to the major plate axis, on 3-in. [75-mm] or smaller centers. A

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.11 on Steel Plates for Boilers and Pressure Vessels.

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[2] For ASME Boiler and Pressure Vessel Code applications, see related Specifications SA-435/SA-435M in Section II of that Code.

[3] Available from American Society for Nondestructive Testing, 1711 Arlingate Plaza, Columbus, OH 43228.

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suitable couplant such as water, soluble oil, or glycerin, shall be used.

5.5 Scanning lines shall be measured from the center or one corner of the plate. An additional path shall be scanned within 2 in. [50 mm] of all edges of the plate on the scanning surface.

5.6 Where grid scanning is performed and complete loss of back reflection accompanied by continuous indications is detected along a given grid line, the entire surface area of the squares adjacent to this indication shall be scanned continuously. Where parallel path scanning is performed and complete loss of back reflection accompanied by continuous indications is detected, the entire surface area of a 9 by 9-in. [225 by 225-mm] square centered on this indication shall be scanned continuously. The true boundaries where this condition exists shall be established in either method by the following technique: Move the transducer away from the center of the discontinuity until the heights of the back reflection and discontinuity indications are equal. Mark the plate at a point equivalent to the center of the transducer. Repeat the operation to establish the boundary.

## 6. Acceptance Standards

6.1 Any discontinuity indication causing a total loss of back reflection which cannot be contained within a circle, the diameter of which is 3 in. [75 mm] or one half of the plate thickness, whichever is greater, is unacceptable.

6.2 The manufacturer reserves the right to discuss rejectable ultrasonically tested plates with the purchaser with the object of possible repair of the ultrasonically indicated defect before rejection of the plate.

6.3 The purchaser's representative may witness the test.

## 7. Marking

7.1 Plates accepted in accordance with this specification shall be identified by stamping or stenciling UT 435 adjacent to marking required by the material specification.

## SUPPLEMENTARY REQUIREMENTS

The following shall apply only if specified in the order:

S1. Instead of the scanning procedure specified by 5.4 and 5.5, and as agreed upon between manufacturer and purchaser, 100 % of one major plate surface shall be scanned. Scanning shall be continuous along parallel paths, transverse or parallel to the major plate axis, with not less than 10 % overlap between each path.

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Designation: A 578/A578M – 96 (Reapproved 2001)

# Standard Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications[1]

This standard is issued under the fixed designation A 578/A578M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification[2] covers the procedure and acceptance standards for straight-beam, pulse-echo, ultrasonic examination of rolled carbon and alloy plain and clad steel plates, ⅜ in. [10 mm] in thickness and over, for special applications. The method will detect internal discontinuities parallel to the rolled surfaces. Three levels of acceptance standards are provided. Supplementary requirements are provided for examination of clad plate and for alternative procedures.

1.2 Individuals performing examinations in accordance with this specification shall be qualified and certified in accordance with the requirements of the latest edition of ASNT SNT-TC-1A or an equivalent accepted standard. An equivalent standard is one which covers the qualification and certification of ultrasonic nondestructive examination candidates and which is acceptable to the purchaser.

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

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

2.1 *ASTM Standards:*

A 263 Specification for Corrosion-Resisting Chromium Steel-Clad Plate, Sheet, and Strip[3]

A 264 Specification for Stainless Chromium-Nickel Steel-Clad Plate, Sheet, and Strip[3]

A 265 Specification for Nickel and Nickel-Base Alloy-Clad Steel Plate[3]

2.2 *ANSI Standard:*

B 46.1 Surface Texture[4]

2.3 *ASNT Standard:*

SNT-TC-1A[5]

## 3. Ordering Information

3.1 The inquiry and order shall indicate the following:

3.1.1 Acceptance level requirements (Sections 7, 8, and 9). Acceptance Level B shall apply unless otherwise agreed to by purchaser and manufacturer.

3.1.2 Any additions to the provisions of this specification as prescribed in 5.2, 13.1, and Section 10.

3.1.3 Supplementary requirements, if any.

## 4. Apparatus

4.1 The amplitude linearity shall be checked by positioning the transducer over the depth resolution notch in the IIW or similar block so that the signal from the notch is approximately 30 % of the screen height, and the signal from one of the back surfaces is approximately 60 % of the screen height (two times the height of the signal from the notch). A curve is then plotted showing the deviations from the above established 2:1 ratio that occurs as the amplitude of the signal from the notch is raised in increments of one scale division until the back reflection signal reaches full scale, and then is lowered in increments of one scale division until the notch signal reaches one scale division. At each increment the ratio of the two signals is determined. The ratios are plotted on the graph at the position corresponding to the larger signal. Between the limits of 20 and 80 % of the screen height, the ratio shall be within 10 % of 2:1. Instrument settings used during inspection shall not cause variation outside the 10 % limits established above.

4.2 The transducer shall be 1 or 1⅛ in. [25 or 30 mm] in diameter or 1 in. [25 mm] square.

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[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.11 on Steel Plates for Boilers and Pressure Vessels.

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[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-578/SA-578M in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

[4] Available from American National Standards Institute, 11 W. 42nd St., 13th floor, New York, NY 10036.

[5] Available from American Society for Nondestructive Testing, 1711 Arlingate Plaza, Columbus, OH 43228.

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4.3 Other search units may be used for evaluating and pinpointing indications.

## 5. Procedure

5.1 Perform the inspection in an area free of operations that interfere with proper performance of the test.

5.2 Unless otherwise specified, make the ultrasonic examination on either major surface of the plate.

5.3 The plate surface shall be sufficiently clean and smooth to maintain a first reflection from the opposite side of the plate at least 50 % of full scale during scanning. This may involve suitable means of scale removal at the manufacturer's option. Condition local rough surfaces by grinding. Restore any specified identification which is removed when grinding to achieve proper surface smoothness.

5.4 Perform the test by one of the following methods: direct contact, immersion, or liquid column coupling. Use a suitable couplant such as water, soluble oil, or glycerin. As a result of the test by this method, the surface of plates may be expected to have a residue of oil or rust or both.

5.5 A nominal test frequency of 2¼ MHz is recommended. When testing plates less than ¾ in. [20 mm] thick a frequency of 5 MHz may be necessary. Thickness, grain size or microstructure of the material and nature of the equipment or method may require a higher or lower test frequency. Use the transducers at their rated frequency. A clean, easily interpreted trace pattern should be produced during the examination.

5.6 *Scanning*:

5.6.1 Scanning shall be along continuous perpendicular grid lines on nominal 9-in. [225-mm] centers, or at the option of the manufacturer, shall be along continuous parallel paths, transverse to the major plate axis, on nominal 4-in. [100-mm] centers, or shall be along continuous parallel paths parallel to the major plate axis, on 3-in. [75-mm] or smaller centers. Measure the lines from the center or one corner of the plate with an additional path within 2 in. [50 mm] of all edges of the plate on the searching surface.

5.6.2 Conduct the general scanning with an instrument adjustment that will produce a first reflection from the opposite side of a sound area of the plate from 50 to 90 % of full scale. Minor sensitivity adjustments may be made to accommodate for surface roughness.

5.6.3 When a discontinuity condition is observed during general scanning adjust the instrument to produce a first reflection from the opposite side of a sound area of the plate of 75 ± 5 % of full scale. Maintain this instrument setting during evaluation of the discontinuity condition.

## 6. Recording

6.1 Record all discontinuities causing complete loss of back reflection.

6.2 For plates ¾ in. [20 mm] thick and over, record all indications with amplitudes equal to or greater than 50 % of the initial back reflection and accompanied by a 50 % loss of back reflection.

NOTE 1—Indications occurring midway between the initial pulse and the first back reflection may cause a second reflection at the location of the first back reflection. When this condition is observed it shall be investigated additionally by use of multiple back reflections.

6.3 Where grid scanning is performed and recordable conditions as in 6.1 and 6.2 are detected along a given grid line, the entire surface area of the squares adjacent to this indication shall be scanned. Where parallel path scanning is performed and recordable conditions as in 6.1 and 6.2 are detected, the entire surface area of a 9 by 9-in. [225 by 225-mm] square centered on this indication shall be scanned. The true boundaries where these conditions exist shall be established in either method by the following technique: Move the transducer away from the center of the discontinuity until the height of the back reflection and discontinuity indications are equal. Mark the plate at a point equivalent to the center of the transducer. Repeat the operation to establish the boundary.

## 7. Acceptance Standard—Level A

7.1 Any area where one or more discontinuities produce a continuous total loss of back reflection accompanied by continuous indications on the same plane that cannot be encompassed within a circle whose diameter is 3 in. [75 mm] or ½ of the plate thickness, whichever is greater, is unacceptable.

## 8. Acceptance Standards—Level B

8.1 Any area where one or more discontinuities produce a continuous total loss of back reflection accompanied by continuous indications on the same plane that cannot be encompassed within a circle whose diameter is 3 in. [75 mm] or ½ of the plate thickness, whichever is greater, is unacceptable.

8.2 In addition, two or more discontinuities smaller than described in 8.1 shall be unacceptable unless separated by a minimum distance equal to the greatest diameter of the larger discontinuity or unless they may be collectively encompassed by the circle described in 8.1.

## 9. Acceptance Standard—Level C

9.1 Any area where one or more discontinuities produce a continuous total loss of back reflection accompanied by continous indications on the same plane that cannot be encompassed within a 1-in. [25-mm] diameter circle is unacceptable.

## 10. Report

10.1 Unless otherwise agreed to by the purchaser and the manufacturer, the manufacturer shall report the following data:

10.1.1 All recordable indications listed in Section 6 on a sketch of the plate with sufficient data to relate the geometry and identity of the sketch to those of the plate.

10.1.2 Test parameters including: Make and model of instrument, test frequency, surface condition, transducer (type and frequency), and couplant.

10.1.3 Date of test.

## 11. Inspection

11.1 The inspector representing the purchaser shall have access at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the ultrasonic testing of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections shall be made at the place of manufacture prior to shipment, unless otherwise

specified, and shall be conducted without interfering unnecessarily with the manufacturer's operations.

### 12. Rehearing

12.1 The manufacturer reserves the right to discuss rejectable ultrasonically tested plate with the purchaser with the object of possible repair of the ultrasonically indicated defect before rejection of the plate.

### 13. Marking

13.1 Plates accepted according to this specification shall be identified by stenciling (stamping) "UT A 578—A" on one corner for Level A, "UT A 578—B" for Level B, and "UT A 578—C" for Level C. The supplement number shall be added for each supplementary requirement ordered.

### 14. Keywords

14.1 nondestructive testing; pressure containing parts; pressure vessel steels; steel plate for pressure vessel applications; steel plates; ultrasonic examinations

## SUPPLEMENTARY REQUIREMENTS

These supplementary requirements shall apply only when individually specified by the purchaser. When details of these requirements are not covered herein, they are subject to agreement between the manufacturer and the purchaser.

### S1. Scanning

S1.1 Scanning shall be continuous over 100 % of the plate surface.

### S2. Acceptance Standard

S2.1 Any recordable condition listed in Section 6 that (*1*) is continuous, (*2*) is on the same plane (within 5 % of the plate thickness), and (*3*) cannot be encompassed by a 3-in. [75-mm] diameter circle, is unacceptable. Two or more recordable conditions (see Section 5), that (*1*) are on the same plane (within 5 % of plate thickness), (*2*) individually can be encompassed by a 3-in. [75-mm] diameter circle, (*3*) are separated from each other by a distance less than the greatest dimension of the smaller indication, and (*4*) collectively cannot be encompassed by a 3-in. [75-mm] diameter circle, are unacceptable.

S2.2 An acceptance level more restrictive than Section 7 or 8 shall be used by agreement between the manufacturer and purchaser.

### S3. Procedure

S3.1 The manufacturer shall provide a written procedure in accordance with this specification.

### S4. Certification

S4.1 The manufacturer shall provide a written certification of the ultrasonic test operator's qualifications.

### S5. Surface Finish

S5.1 The surface finish of the plate shall be conditioned to a maximum 125 µin. [3 µm] AA (see ANSI B 46.1) prior to test.

### S6. Examination of Integrally Bonded Clad Plate, Acceptance Level S 6

S6.1 Examine the plate from the clad surface using procedures and techniques in accordance with this specification.

S6.2 Inspect the backing steel to Level B or, if specifically requested by customer, to Level A or Level C.

S6.3 The cladding shall be interpreted to be unbonded when there is complete loss of back reflection accompanied by an echo indication from the plane of the interface of the clad and backing steel.

S6.4 Unless otherwise specified, indications of unbond determined in accordance with S 6.3 that cannot be encompassed within a 3-in. [75-mm] diameter circle shall be weld repaired subject to the requirements and limitations for the repair of defects in cladding of the appropriate material specification.

S6.5 This supplementary requirement is applicable to Specifications A 263, A 264, and A 265.

### S7. Examination of Integrally Bonded Clad Plate, Acceptance Level S 7

S7.1 The plate shall be examined from the clad surface using procedures and techniques according to this specification except 100 % surface search is mandatory.

S7.2 Inspect the backing steel to Level B or, if specifically requested by customer, to Level A or Level C.

S7.3 The cladding shall be interpreted to be unbonded when there is complete loss of back reflection accompanied by an echo indication from the plane of the interface of the clad and backing steel.

S7.4 Unless otherwise specified, indications of unbond determined in accordance with S 7.3 that cannot be encompassed within a 1-in. [25-mm] diameter circle shall be weld repaired subject to the requirements and limitations for the repair of defects in cladding of the appropriate material specification. Additionally, prior approval must be obtained if the weld repaired surface exceeds 1.5 % of the cladding surface.

S7.5 This supplementary requirement is applicable to Specifications A 263, A 264, and A 265.

### S8. Ultrasonic Examination Using Flat Bottom Hole Calibration (for Plates 4 in. [100 mm] Thick and Greater)

S8.1 Use the following calibration and recording procedures

in place of 5.6.2, 5.6.3, and Section 6.

S8.2 The transducer shall be in accordance with 4.2.

S8.3 *Reference Reflectors*—The *T*/4, *T*/2, and 3*T*/4 deep flat bottom holes shall be used to calibrate the equipment. The flat bottom hole diameter shall be in accordance with Table S8.1. The holes may be drilled in the plate to be examined if they can be located without interfering with the use of the plate, in a prolongation of the plate to be examined, or in a reference block of the same nominal composition, and thermal treatment as the plate to be examined. The surface of the reference block shall be no better to the unaided eye than the plate surface to be examined. The reference block shall be of the same nominal thickness (within 75 to 125 % or 1 in. [25 mm] of the examined plate, whichever is less) and shall have acoustical properties similar to the examined plate. Acoustical similarity is presumed when, without a change in instrument setting, comparison of the back reflection signals between the reference block and the examined plate shows a variation of 25 % or less.

S8.4 *Calibration Procedure:*

S8.4.1 Couple and position the search unit for maximum amplitudes from the reflectors at *T*/4, *T*/2, and 3*T*/4. Set the instrument to produce a 75 ± 5 % of full scale indication from the reflector giving the highest amplitude.

S8.4.2 Without changing the instrument setting, couple and position the search unit over each of the holes and mark on the screen the maximum amplitude from each hole and each minimum remaining back reflection.

S8.4.3 Mark on the screen half the vertical distance from the sweep line to each maximum amplitude hole mark. Connect the maximum amplitude hole marks and extend the line through the thickness for the 100 % DAC (distance amplitude correction curve). Similarly connect and extend the half maximum amplitude marks for the 50 % DAC.

S8.5 *Recording:*

S8.5.1 Record all areas where the remaining back reflection is smaller than the highest of the minimum remaining back reflections found in S 8.4.2.

S8.5.2 Record all areas where indications exceed 50 % DAC.

S8.5.3 Where recordable conditions listed in S 8.5.1 and S 8.5.2 are detected along a given grid line, continuously scan the entire surface area of the squares adjacent to the condition and record the boundaries or extent of each recordable condition.

S8.6 Scanning shall be in accordance with 5.6.

S8.7 The acceptance levels of Section 7 or 8 shall apply as specified by the purchaser except that the recordable condition shall be as given in S 8.5.

**TABLE S8.1 Calibration Hole Diameter as a Function of Plate Thickness (S8)**

| Plate Thickness, in. [mm] | 4–6 [100–150] | >6–9 [>150–225] | >9–12 [>225–300] | >12–20 [>300–500] |
|---|---|---|---|---|
| Hole Diameter, in. [mm] | 5/8 [16] | 3/4 [19] | 7/8 [22] | 1 1/8 [29] |

## S9. Ultrasonic Examination of Electroslag Remelted (ESR) and Vacuum-Arc Remelted (VAR) Plates, from 1 to 16 in. [25 to 400 mm] in Thickness, Using Flat-Bottom Hole Calibration and Distance-Amplitude Corrections

S9.1 The material to be examined must have a surface finish of 200 µin. [5 µm] as maximum for plates up to 8 in. [200 mm] thick, inclusive, and 250 µin. [6 µm] as maximum for plates over 8 to 16 in. [200 to 400 mm] thick.

S9.2 Use the following procedures in place of 5.6.1, 5.6.2, 5.6.3, and Section 6.

S9.3 The transducer shall be in accordance with 4.2.

S9.4 *Reference Reflectors*—The *T*/4, *T*/2, and 3*T*/4 deep flat bottom holes shall be used to calibrate the equipment. The flat bottom hole diameter shall be in accordance with Table S9.1. The flat bottoms of the holes shall be within 1° of parallel to the examination surface. The holes may be drilled in the plate to be examined if they can be located without interfering with the use of the plate, in a prolongation of the plate to be examined, or in a reference block of the same nominal composition and thermal treatment as the plate to be examined. The surface of the reference block shall be no better to the unaided eye than the plate surface to be examined. The reference block shall be of the same nominal thickness (within 75 to 125 % or 1 in. [25 mm] of the examined plate, whichever is less) and shall have acoustical properties similar to the examined plate. Acoustical similarity is presumed when, without a change in instrument setting, comparison of the back reflection signals between the reference block and the examined plate shows a variation of 25 % or less.

**TABLE S9.1 Calibration Hole Diameter as a Function of Plate Thickness (S9)**

| Plate Thickness, in. [mm] | 1–4 [25–100] | >4–8 [>100–200] | >8–12 [>200–300] | >12–16 [>300–400] |
|---|---|---|---|---|
| Hole Diameter, in. [mm] | 1/8 [3] | 1/4 [6] | 3/8 [10] | 1/2 [13] |

S9.5 *Calibration Procedure:*

S9.5.1 Couple and position the search unit for maximum amplitudes from the reflectors at *T*/4, *T*/2, and 3*T*/4. Set the instrument to produce a 75 ± 5 % of full-scale indication from the reflector giving the highest amplitude.

S9.5.2 Without changing the instrument setting, couple and position the search unit over each of the holes and mark on the screen the maximum amplitude from each of the holes.

S9.5.3 Mark on the screen half the vertical distances from the sweep line to each maximum amplitude hole mark. Connect the maximum amplitude hole marks and extend the line through the thickness for the 100 % DAC (distance amplitude correction curve). Similarly connect and extend the half maximim amplitude marks for the 50 % DAC.

S9.6 *Scanning*—Scanning shall cover 100 % of one major plate surface, with the search unit being indexed between each pass such that there is at least 15 % overlap of adjoining passes in order to assure adequate coverage for locating discontinuities.

S9.7 *Recording*—Record all areas where the back reflection

drops below the 50 % DAC. If the drop in back reflection is not accompanied by other indications on the screen, recondition the surface in the area and reexamine ultrasonically. If the back reflection is still below 50 % DAC, the loss may be due to the metallurgical structure of the material being examined. The material shall be held for metallurgical review by the purchaser and manufacturer.

S9.8 *Acceptance Standards*—Any indication that exceeds the 100 % DAC shall be considered unacceptable. The manufacturer may reserve the right to discuss rejectable ultrasonically examined material with the purchaser, the object being the possible repair of the ultrasonically indicated defect before rejection of the plate.

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