



Designation: A6/A6M – 22

Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling¹

This standard is issued under the fixed designation A6/A6M; 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 U.S. Department of Defense.

1. Scope*

1.1 This general requirements specification² 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
A36/A36M	Carbon Structural Steel
A131/A131M	Structural Steel for Ships
A242/A242M	High-Strength Low-Alloy Structural Steel
A283/A283M	Low and Intermediate Tensile Strength Carbon Steel Plates
A328/A328M	Steel Sheet Piling
A514/A514M	High-Yield-Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Welding
A529/A529M	High-Strength Carbon-Manganese Steel of Structural Quality
A572/A572M	High-Strength Low-Alloy Columbium-Vanadium Structural Steel
A573/A573M	Structural Carbon Steel Plates
A588/A588M	High-Strength Low-Alloy Structural Steel, up to 50 ksi [345 MPa] Minimum Yield Point, with Atmospheric Corrosion Resistance
A633/A633M	Normalized High-Strength Low-Alloy Structural Steel Plates
A656/A656M	Hot-Rolled Structural Steel, High-Strength Low-Alloy Plate with Improved Formability
A690/A690M	High-Strength Low-Alloy Nickel, Copper, Phosphorus Steel H-Piles and Sheet Piling with Atmospheric Corrosion Resistance for Use in Marine Environments
A709/A709M	Structural Steel for Bridges
A710/A710M	Precipitation-Strengthened Low-Carbon Nickel-Copper-Chromium-Molybdenum-Columbium (Niobium) Alloy Structural Steel Plates
A769/A769M	Carbon and High-Strength Electric Resistance Forge-Welded Steel Structural Shapes
A786/A786M	Hot-Rolled Carbon, Low-Alloy, High-Strength Low-Alloy, and Alloy Steel Floor Plates

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.

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.

A827/A827M	Plates, Carbon Steel, for Forging and Similar Applications
A829/A829M	Alloy Structural Steel Plates
A830/A830M	Plates, Carbon Steel, Structural Quality, Furnished to Chemical Composition Requirements
A857/A857M	Steel Sheet Piling, Cold Formed, Light Gage
A871/A871M	High-Strength Low-Alloy Structural Steel Plate With Atmospheric Corrosion Resistance
A913/A913M	High-Strength Low-Alloy Steel Shapes of Structural Quality, Produced by Quenching and Self-Tempering Process (QST)
A945/A945M	High-Strength Low-Alloy Structural Steel Plate with Low Carbon and Restricted Sulfur for Improved Weldability, Formability, and Toughness
A950/A950M	Fusion-Bonded Epoxy-Coated Structural Steel H-Piles and Sheet Piling
A992/A992M	Structural Steel Shapes
A1043/A1043M	Structural Steel with Low Yield to Tensile Ratio for Use in Buildings
A1066/A1066M	High-Strength Low-Alloy Structural Steel Plate Produced by Thermo-Mechanical Controlled Process (TMCP)

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

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

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 E29.

1.12 The text of this general requirements 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.

1.13 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 may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with this specification.

1.14 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.

1.15 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.16 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:³

- A131/A131M Specification for Structural Steel for Ships
- A370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A673/A673M Specification for Sampling Procedure for Impact Testing of Structural Steel
- A700 Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment
- A751 Test Methods and Practices for Chemical Analysis of Steel Products
- A829/A829M Specification for Alloy Structural Steel Plates
- A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E112 Test Methods for Determining Average Grain Size

E208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels

2.2 American Welding Society Standards:⁴

A5.1/A5.1M Mild Steel Covered Arc-Welding Electrodes

A5.5/A5.5M Low-Alloy Steel Covered Arc-Welding Electrodes

A5.17/A5.17M Specification For Carbon Steel Electrodes And Fluxes For Submerged Arc Welding

A5.18/A5.18M Specification For Carbon Steel Electrodes And Rods For Gas Shielded Arc Welding

A5.20/A5.20M Carbon Steel Electrodes For Flux Cored Arc Welding

A5.23/A5.23M Low Alloy Steel Electrodes And Fluxes For Submerged Arc Welding

A5.28/A5.28M Specification For Low-Alloy Steel Electrodes And Rods For Gas Shielded Arc Welding

A5.29/A5.29M Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding

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

2.3 U.S. Military Standards:⁵

MIL-STD-129 Marking for Shipment and Storage

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

2.4 U.S. Federal Standard:⁵

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

2.5 American Society of Mechanical Engineers Code:⁶

ASME Boiler and Pressure Vessel Code, Section IX

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/ft² [47.10 kg/m²] or heavier.

(2) Over 48 in. [1200 mm] in width and 7.350 lb/ft² [35.32 kg/m²] 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

⁴ Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126, <http://www.aws.org>.

⁵ Available from DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, <http://quicksearch.dla.mil>.

⁶ Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, <http://www.asme.org>.

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 – 15, 18, and 19 and the applicable product specification).

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 16 $\frac{2}{3}$ %.

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 16 $\frac{2}{3}$ %.

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 $\frac{13}{64}$ 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 semi-circular.

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 for other than stainless steel that is intended to produce a killed steel that is capable of meeting the requirements for fine austenite grain size when and if the as-rolled or as-forged product is reheated to a temperature at or above the transformation temperature, Ac₃.

3.1.18.1 *Discussion*—When stated as a requirement, fine

grain practice 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. Austenite grain refining elements include, but are not limited to, aluminum, columbium (niobium), titanium, and vanadium. A fine grain practice requirement (1) does not specify a minimum austenite grain refining element addition; (2) does not require prior austenite grain size testing; (3) does not require meeting any prior austenite grain size test result; and (4) does not apply to, nor in any way control, the prior austenite grain size or the ferrite grain size of the steel in the as-rolled or as-forged condition. The prior austenite grain size and the ferrite grain size of as-rolled or as-forged steel products are controlled by the manufacturing process and may be assisted by suitable chemistry. The appropriate manufacturing process controls needed to meet the mechanical property requirements of the specification in the as-rolled or as-forged condition are neither defined nor implied by the inclusion of a fine grain practice requirement.

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 [A941](#) 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 [5.4](#) 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 a basic-oxygen or electric-arc furnace, possibly followed by additional 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 killed.

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

5.3.1 *Strand Cast:*

5.3.1.1 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.

5.3.1.2 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.

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

5.5 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.

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

6. Heat Treatment

6.1 Where the 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 the manufacturer or processor 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 Terminology **A751**.

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 (niobium); 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**). Boron shall be reported if intentionally added.

NOTE 3—For steels that do not have intentional boron additions for hardenability, the boron content will not normally exceed 0.0008 %.

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 **A751**. 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 **A751** shall be used.

7.4 *Grade Substitution*—Alloy steel grades that meet the chemical requirements of Table 1 of Specification **A829/A829M** 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 **E112** and at least 70 % of the grains in the area examined shall meet the specified grain size requirement.

8.1.1 *Discussion—Austenitic Grain Size*—All requirements for austenitic grain size control in Section 8, Metallurgical Structure, refer to a size of austenite grains that form when and if the structural product is reheated to a temperature at or above the transformation temperature, A_{c3} , after the product has experienced the complete rolling operation and has cooled to ambient temperature. The requirements for austenitic grain size control in Section 8, including the results of the referenced testing methods, do not measure or control the prior austenitic grain size or the ferritic grain size of the structural product in the as-rolled condition.

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 4—Such austenitic grain size numbers may be achieved with lower contents of austenitic grain refining elements 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 5—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.

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 1/8 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 A131/A131M 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 3/8 in. [10 mm] in thickness; (2) 1/16 in. [2 mm], for material 3/8 to 2 in. [10 to 50 mm] inclusive in thickness; or (3) 1/8 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 1 1/4 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 1/2 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).

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
Phosphorus	to 0.04 incl	...	0.010 ^B
	over 0.04 to 0.15 incl	...	...
Sulfur	to 0.06 incl	...	0.010 ^B
	over 0.06	...	...
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 10.00 incl	0.10	0.10
	over 10.00 to 15.00 incl	0.15	0.15
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 (Niobium) ^D	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 %.

^D Columbium and niobium are interchangeable names for the same element.

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
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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

9.4.2 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 Specifications A5.1/A5.1M, A5.5/A5.5M, A5.17/A5.17M, A5.18/A5.18M, A5.20/A5.20M, A5.23/A5.23M, A5.28/A5.28M, or A5.29/A5.29M, 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 AWS D1.1/D1.1M or ASME Boiler and Pressure Vessel Code, 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 AWS D1.1/D1.1M or ASME Boiler and Pressure Vessel Code, Section IX, with the following exceptions or clarifications:

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

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

(3) An AWS D1.1/D1.1M prequalified complete joint penetration groove weld WPS is acceptable.

(4) Any material not listed in the prequalified base metal-filler metal combinations of AWS D1.1/D1.1M 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 AWS D1.1/D1.1M.

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 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 ¼ 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 **A370**.

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 **E29**.

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 $1T$ from any as-heat treated edge where T is the thickness of the plate and shall be at least $\frac{1}{2}$ in. [12.5 mm] from flame cut or heat-affected-zone surfaces.

11.1.1.2 A steel thermal buffer pad, $1T$ by $1T$ by at least $3T$, 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 $3T$ by $3T$ 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 $\frac{2}{3}$ 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**). Test specimens for sheet piling, when several locations are possible, shall be taken from the web or flange section with the greatest thickness. If the geometry of the section with the greatest thickness does not allow for sufficient available flat space from which to obtain a test specimen, the alternate location may be used.

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 **A370** 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 **A370**.

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:

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 3/8 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
3/8 to 2 in. [10 to 50 mm], incl	Less than 3/8 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
	3/8 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 1—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.

11.4.4.1 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 3/4 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 A370 for either the 1 1/2-in. [40-mm] wide test specimen or the 1/2-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 1 1/2-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 A370, shall be subject to the limitation that adequate testing machine capacity is available.

11.5.1.3 For plates over 3/4 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 A370 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 3/4 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 A370 for either the 1 1/2-in. [40-mm] wide test specimen or the 1/2-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 1 1/2-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 **A370**, shall be subject to the limitation that adequate testing machine capacity is available.

11.5.2.3 For shapes over $\frac{3}{4}$ 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 **A370** 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 **A370**.

11.5.3.2 Except as provided in **11.5.3.5**, test specimens for bars $\frac{3}{4}$ in. [20 mm] and under in thickness shall conform to the requirements shown in Fig. 3 of Test Methods and Definitions **A370** for either the $\frac{1}{2}$ -in. [40-mm] wide test specimen or the $\frac{1}{2}$ -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 $\frac{3}{4}$ in. [20 mm] in thickness or diameter shall conform either to the requirements for the $\frac{1}{2}$ -in. [40-mm] or $\frac{1}{2}$ -in. [12.5-mm] wide test specimen shown in Fig. 3 of Test Methods and Definitions **A370**, or to the requirements for the 0.500-in. [12.5-mm] diameter test specimen shown in Fig. 4 of Test Methods and Definitions **A370**.

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 $\frac{3}{4}$ 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 **A370** 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 – 11.7 inclusive and Section 13 apply only for tests conducted at the place of manufacture prior to shipment.

NOTE 6—Compliance to this specification 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 this specification 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 this specification 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 to 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 to 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.

NOTE 7—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, zeos). Addition of such sections to **Annex A2** will be considered by Subcommittee A01.02 when and if a need for such listing is shown.

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 be within $\pm 2.5\%$ of the theoretical or specified amounts except for shapes with a nominal weight of less than 100 lb/ft [149 kg/m], in which the variation shall be within -2.5% to $+3.0\%$ of the theoretical cross-sectional area or the specified nominal weight [mass].

12.4 *Sheet Piling*—The weight [mass] of each steel sheet pile shall be within $\pm 2.5\%$ of 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.

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

12.6 *Conversion of Permitted Variations from Fractions of an Inch to Decimals*—Permitted variations in dimensions for products covered by this specification are generally given as

fractions of an inch and these remain the official permitted variations, where so stated. If the material is to be measured by equipment reporting dimensions as decimals, conversion of permitted variations from fractions of an inch to decimals shall be made to three decimal places; using the rounding method prescribed in Practice E29.

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 $\frac{3}{4}$ 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 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.

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 8—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 (niobium) 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.

14.1.3.2 Yield to tensile ratio when such a requirement is contained in the product specification.

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).

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. 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.

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.

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, 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 shall meet the requirements of the applicable product specification and shall conform to any existing EDI agreement 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 9—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 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 two 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 $\frac{3}{8}$ in. [10 mm] (or $\frac{5}{16}$ 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 – 18.4 inclusive, the manufacturer or processor shall have the option of using bar coding as a supplementary identification method.

NOTE 10—Bar coding should be consistent with AIAG Standards.⁷

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 – 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.

⁷ Available from Automotive Industry Action Group (AIAG), 26200 Lahser Rd., Suite 200, Southfield, MI 48033, <http://www.aiag.org>.

19. Packaging, Marking, and Loading for Shipment

19.1 Packaging, marking, and loading for shipment shall be in accordance with Practices **A700**.

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

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. When so specified, these permitted variations may be taken all over, in which case the sum of these permitted variations applies.

NOTE 3—Thickness to be measured at $\frac{3}{8}$ to $\frac{3}{4}$ in. from the longitudinal edge.

NOTE 4—For thicknesses measured at any location other than that specified in Note 4, the permitted variations over specified thickness shall be $1\frac{3}{4}$ 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 $\frac{1}{4}$, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	...	...	...
$\frac{1}{4}$ to $\frac{5}{16}$, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	...	...	...
$\frac{5}{16}$ to $\frac{3}{8}$, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	...	...
$\frac{3}{8}$ to $\frac{7}{16}$, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.06	...
$\frac{7}{16}$ to $\frac{1}{2}$, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.06	...
$\frac{1}{2}$ to $\frac{5}{8}$, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.07	...
$\frac{5}{8}$ to $\frac{3}{4}$, excl	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.07	0.07
$\frac{3}{4}$ 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	...