Designation: A568/A568M – 09

Standard Specification for Steel, Sheet, Carbon, Structural, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for[1]

This standard is issued under the fixed designation A568/A568M; 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 the general requirements for steel sheet in coils and cut lengths. It applies to the following specifications that describe carbon steel, structural steel, and high-strength, low-alloy steel (HSLA) furnished as hot-rolled sheet and cold-rolled sheet: Specifications A414/A414M, A424, A606, A659/A659M, A794, A1008/A1008M, A1011/A1011M, and A1039/A1039M.

1.2 This specification is not applicable to hot-rolled heavy-thickness carbon sheet coils (Specification A635/A635M).

1.3 In case of any conflict in requirements, the requirements of the individual material specification shall prevail over those of this general specification.

1.4 For the purposes of determining conformance with this and the appropriate product specification 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 E29.

1.5 Annex A1 lists permissible variations in dimensions and mass (see Note 1) in SI [metric] units. The values listed are not exact conversions of the values listed in the inch-pound tables, but instead are rounded or rationalized values. Conformance to Annex A1 is mandatory when the "M" specification is used.

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

1.6 The values stated in either SI units or inch-pound units are to be regarded separately as standard. 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 the standard.

1.7 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:*[2]

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A414/A414M Specification for Steel, Sheet, Carbon, for Pressure Vessels

A424 Specification for Steel, Sheet, for Porcelain Enameling

A606 Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, with Improved Atmospheric Corrosion Resistance

A635/A635M Specification for Steel, Sheet and Strip, Heavy-Thickness Coils, Hot-Rolled, Alloy, Carbon, Structural, High-Strength Low-Alloy, and High-Strength Low-Alloy with Improved Formability, General Requirements for

A659/A659M Specification for Commercial Steel (CS), Sheet and Strip, Carbon (0.16 Maximum to 0.25 Maximum Percent), Hot-Rolled

A700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Shipment

A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A794 Specification for Commercial Steel (CS), Sheet, Carbon (0.16 % Maximum to 0.25 % Maximum), Cold-Rolled

A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

A1008/A1008M Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Bake Hardenable

A1011/A1011M Specification for Steel, Sheet and Strip,

[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 May 1, 2009. Published May 2009. Originally approved in 1966. Last previous edition approved in 2007 as A568/A568M – 07a. DOI: 10.1520/A0568_A0568M-09.

[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.**

Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength

A1030/A1030M Practice for Measuring Flatness Characteristics of Steel Sheet Products

A1039/A1039M Specification for Steel, Sheet, Hot Rolled, Carbon, Commercial, Structural, and High-Strength Low-Alloy, Produced by Twin-Roll Casting Process

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

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

E59 Practice for Sampling Steel and Iron for Determination of Chemical Composition[3]

E290 Test Methods for Bend Testing of Material for Ductility

2.2 *Military Standards:*[4]

MIL-STD-129 Marking for Shipment and Storage

2.3 *Federal Standards:*[4]

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

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *Steel Types*:

3.1.2 *carbon steel*—designation for steel when no minimum content is specified or required for aluminum, chromium, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any element added to obtain a desired alloying effect; when the specified minimum for copper does not exceed 0.40 %; or when the maximum content specified for any of the following elements does not exceed the percentages noted: manganese 1.65, silicon 0.60, or copper 0.60.

3.1.2.1 *Discussion*—In all carbon steels small quantities of certain residual elements unavoidably retained from raw materials are sometimes found which are not specified or required, such as copper, nickel, molybdenum, chromium, etc. These elements are considered as incidental and are not normally determined or reported.

3.1.3 *high-strength, low-alloy steel*—specific group of steels in which higher strength, and in some cases additional resistance to atmospheric corrosion or improved formability, are obtained by moderate amounts of one or more alloying elements.

3.1.4 *Product Types*:

3.1.5 *hot-rolled sheet*—manufactured by hot rolling slabs in a continuous mill to the required thickness and can be supplied in coils or cut lengths as specified.

(1) Hot-rolled carbon steel sheet is commonly classified by size as follows:

Coils and Cut Lengths

Width, in.	Thickness, in.
All Widths[A]	0.027 to 0.230, excl

[A] Hot-rolled sheet in coils and cut lengths less than 12 in. in width must have cut edges. Hot-rolled material with mill edges 12 in. and less in width is considered hot-rolled strip.

Coils and Cut Lengths

Width, mm	Thickness, mm
All Widths[A]	0.7 to 6.0, excl

[A] Hot-rolled sheet in coils and cut lengths less than 300 mm. in width must have cut edges. Hot-rolled material with mill edges 300 mm and less in width is considered hot-rolled strip.

(2) Hot-rolled high-strength low-alloy steel sheet is commonly classified by size as follows:

Coils and Cut Lengths

Width, in.	Thickness, in.
All Widths[A]	0.031 to 0.230, excl

[A] Hot-rolled sheet in coils and cut lengths less than 12 in. in width must have cut edges. Hot-rolled material with mill edges 12 in. and less in width is considered hot-rolled strip.

Coils and Cut Lengths

Width, in.	Thickness, mm
All Widths[A]	0.8 to 6.0, excl

[A] Hot-rolled sheet in coils and cut lengths less than 300 mm in width must have cut edges. Hot-rolled material with mill edges 300 mm and less in width is considered hot-rolled strip.

NOTE 2—The changes in width limits with the publication of A568/A568M – 06a result in a change in tensile testing direction for material from 0.180 in. [4.5 mm] to 0.230 in. exclusive [6.0 mm exclusive] over 48 in. [1200 mm] wide. Material formerly tested in the transverse direction will be tested in the longitudinal direction. This is expected to result in some changes in reported properties. The purchaser is advised to discuss this change with the supplier.

3.1.6 *cold-rolled sheet*—manufactured from hot-rolled descaled coils by cold reducing to the desired thickness, generally followed by annealing to recrystallize the grain structure. If the sheet is not annealed after cold reduction it is known as full hard with a hardness of 84 HRB minimum and can be used for certain applications where ductility and flatness are not required.

(1) Cold-rolled carbon sheet is commonly classified by size as follows:

Width, in.	Thickness, in.
All Widths[A,B]	Through 0.142
Width, mm	Thickness, mm
All Widths[A,B]	Through 4.0

[A] Cold-rolled sheet coils and cut lengths, slit from wider coils with cut edge (only) and in thicknesses through 0.142 in. [4.0 mm] carbon 0.25 % maximum by cast analysis.

[B] When no special edge or finish (other than matte, commercial bright, or luster finish) or single strand rolling of widths, or both under 24 in. [600 mm] is not specified or required.

(2) Cold-rolled high-strength low-alloy sheet is commonly classified by size as follows:

Width, in.	Thickness, in.
Through 12[A]	0.019 through 0.082
Over 12[B]	0.020 and over
Width, mm	Thickness, mm
To 300, incl[A]	0.5 to 2.0, incl
Over 300[B]	0.5 and Over

[A] Cold-rolled sheet coils and cut lengths, slit from wider coils with cut edge (only) and in thicknesses 0.019 in. [0.5 mm] through 0.082 in. [2.0 mm] carbon 0.25 % maximum by cast analysis.

[B] When no special edge or finish (other than matte, commercial bright, or luster finish) or single strand rolling of widths, or both under 24 in. [600 mm] is not specified or required.

3.1.6.1 *Discussion*—Steel products are available in various thickness, width, and length combinations depending upon

[3] Withdrawn. The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://www.dodssp.daps.mil.

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 for 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 requirements specification 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.

3.1.7 *retests*, *n*—additional test, or tests, made from the original material when the original test did not meet the appropriate acceptance criteria required by a product specification and the failure was mechanical in natures as described in Section 11.

3.1.8 *resample*, *n*—additional test or tests made when the test on the original sample did not meet the appropriate acceptance criteria required by the product specification, but possibly requiring that the material in question have an appropriate amount discarded prior to securing the new sample or samples.

3.1.9 *steel manufacturer*, *n*—the organization that directly controls or is responsible for the melting and refining of steel and the conversion of that steel into semifinished steel products known as slabs either through continuous casting, conventional or compact methods, or ingot casting and subsequent conversion of the ingots to slabs, and for one or more additional operations such as testing, marking, loading for shipment, and certification.

3.1.10 *coil processor*—the organization that directly controls or is responsible for operations involved in processing the coil such as leveling, cutting to length, testing, inspection, blanking, slitting, pickling, cold rolling (cold reduction), heat treating, temper rolling, coating, packaging, marking, loading for shipment, and certification.

3.1.10.1 *Discussion*—The processing operations need not be controlled by the organization that hot rolls the slab into a coil. If only one organization controls or is responsible for (or both) the hot rolling and processing operations, that organization is termed the manufacturer. If more than one organization controls or is responsible for (or both) hot rolling and processing operations, the organization that controls and is responsible for the hot rolling is termed the hot roll manufacturer and the organization or organizations controlling and responsible for the processing operations is/are termed the processor or processors. Likewise, one organization may be the manufacturer of the hot roll coil and another the manufacturer of the cold roll coil. In such case, the organization responsible for the conversion of the hot roll coil to a cold roll coil and other processing operations will also be termed the cold roll manufacturer and organizations performing additional processing operations to the cold roll coil will be termed the coil processor or coil processors.

3.1.11 *hot roll manufacturer*, *n*—the organization that directly controls or is responsible for the conversion of steel slabs, by hot rolling into coils, and for one or more additional operations such as leveling, cutting to length, testing, inspection, blanking, slitting, pickling, cold rolling, heat treating, coating, packaging, marking, loading for shipment, and certification.

3.1.12 *cold roll manufacturer*, *n*—the organization that directly controls or is responsible for the conversion of hot roll coils into cold roll coils, and for one or more additional operations such as pickling, annealing, temper rolling, slitting, cutting to length, testing, inspection, blanking, coating, packaging, marking, loading for shipment, and certification.

3.2 Refer to Terminology A941 for additional definitions of terms used in this standard.

4. Materials and Manufacture

4.1 Unless otherwise specified, hot-rolled material shall be furnished hot-rolled, not annealed, not pickled.

4.2 Coil breaks, stretcher strains, and fluting can occur during the user's processing of hot-rolled or hot-rolled pickled sheet. When any of these features are detrimental to the application, the manufacturer shall be notified at time of ordering in order to properly process the sheet.

4.3 Cold-rolled carbon steel sheet is available as discussed in 10.2, 10.3, and in Table 1.

4.4 Unless specified as a full-hard product, cold-rolled sheet is annealed after being cold reduced to thickness. The annealed, cold-rolled sheet can be used as annealed last (dead soft) for unexposed end-use applications. When cold-rolled sheet is used for unexposed applications and coil breaks are a hazard in uncoiling, it may be necessary to further process the material. In this case the manufacturer should be consulted. After annealing, cold-rolled sheet is generally given a light skin pass to impart shape or may be given a heavier skin pass or temper pass to prevent the phenomenon known as stretcher straining or fluting, when formed. Temper passing also provides a required surface texture.

4.5 *Temper Rolling*:

4.5.1 Unless otherwise specified, cold-rolled sheet for exposed applications shall be temper rolled and is usually specified and furnished in the strain free condition as shipped. See Appendix X1, Effect of Aging of Cold-Rolled Carbon Steel Sheet on Drawing and Forming.

4.5.2 Cold-rolled sheet for unexposed applications may be specified and furnished "annealed last" or "temper rolled." "Annealed last" is normally produced without temper rolling but may be lightly temper rolled during oiling or rewinding. Unexposed temper-rolled material may be specified strain-free or nonfluting. Where specific hardness range or limit or a specified surface texture is required, the application is considered as exposed.

NOTE 3—Skin-passed sheet is subject to an aging phenomenon (see Appendix X1). Unless special killed (nonaging) steel is specified, it is to the user's interest to fabricate the sheet as soon as possible, for optimum performance.

5. Chemical Composition

5.1 *Limits*:

TABLE 1 Cold-Rolled Sheet Steel Class Comparison

	Exposed	Unexposed
Major imperfections:		
Cut lengths	Mill rejects	Mill rejects
Coils	Purchaser accepts within the manufacturer's published standards (policy)	Purchaser accepts within the manufacturer's published standards (policy)
Minor imperfections:		
Cut lengths	Mill rejections repetitive imperfections. May contain random imperfections which the purchaser accepts within the manufacturer's published standards (policy)	Purchaser accepts all minor imperfections
Coils	Purchaser accepts within the manufacturer's published standards (policy)	Purchaser accepts all minor imperfections
Finish	Matte unless otherwise specified	Purchaser accepts all finishes
Special oils	May be specified	May not be specified
Thickness, width and length tolerance:		
Standard	Will be met	Will be met
Restricted	May be specified	May not be specified
Flatness tolerance:		
Standard	Will be met	Will be met (temper rolled) Not guaranteed—normally within twice standard (annealed last)
Restricted Squareness	May be specified	May not be specified
Coil wraps	Purchaser accepts within the manufacturer's published standards (policy)	Purchaser accepts all
Coil welds	Purchaser accepts within the manufacturer's published standards (policy)	Purchaser accepts within the manufacturer's published standards (policy)
Outside inspection	May be specified	May not be specified
Special testing	May be specified	May not be specified

5.1.1 The chemical composition shall be in accordance with the applicable product specification. However, if other compositions are required for carbon steel, they shall be prepared in accordance with Appendix X2.

5.1.2 Where the material is used for fabrication by welding, care must be exercised in selection of chemical composition or mechanical properties to assure compatibility with the welding process and its effect on altering the properties.

5.2 *Cast or Heat Analysis*:

5.2.1 An analysis of each cast or heat of steel shall be made by the steel manufacturer to determine the percentage of elements specified or restricted by the applicable specification.

5.2.2 When requested, cast or heat analysis for elements listed or required shall be reported to the purchaser or to his representative. The steel manufacturer, or the hot roll manufacturer, cold roll manufacturer, or processor, if different from the steel manufacturer, is responsible for providing this information to the purchaser or his representative as requested.

5.3 *Product, Check, or Verification Analysis*:

5.3.1 Non-killed steels such as capped or rimmed steels are not technologically suited to product analysis due to the nonuniform character of their chemical composition and therefore, the tolerances in Table 2 do not apply. Product analysis is appropriate on these types of steel only when misapplication is apparent or for copper when copper steel is specified.

5.3.2 For steels other than non-killed (capped or rimmed), product analysis may be made by the purchaser. The chemical analysis shall not vary from the limits specified by more than the amounts in Table 2. The several determinations of any element in a cast shall not vary both above and below the specified range.

5.4 *Sampling for Product Analysis*:

5.4.1 To indicate adequately the representative composition of a cast by product analysis, it is general practice to select samples to represent the steel, as fairly as possible, from a minimum number of pieces as follows: 3 pieces for lots up to 15 tons incl, and 6 pieces for lots over 15 tons (see Practice E59).

5.4.2 When the steel is subject to tension test requirements, samples for product analysis may be taken either by drilling entirely through the used tension test specimens themselves, or as covered in 5.4.3.

TABLE 2 Tolerances for Product Analysis

Element	Limit, or Maximum of Specified Element, %	Tolerance: Under Minimum Limit	Tolerance: 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 0.80 incl	0.03	0.05
	over 0.80	0.03	0.06
Manganese	to 0.60 incl	0.03	0.03
	over 0.60 to 1.15 incl	0.04	0.04
	over 1.15 to 1.65 incl	0.05	0.05
Phosphorus		. . .[A]	0.01
Sulfur		. . .[A]	0.01
Silicon	to 0.30 incl	0.02	0.03
	over 0.30 to 0.60 incl	0.05	0.05
Copper		0.02	. . .[A]
Nickel	to 1.00 incl	. . .[A]	0.03
Chromium	to 0.90 incl	. . .[A]	0.04
Molybdenum	to 0.20 incl	. . .[A]	0.01
Vanadium	to 0.10 incl	0.01[B]	0.01[B]
Columbium (Niobium)	to 0.10 incl	0.01[B]	0.01[B]
Titanium	to 0.15 incl	0.01[A]	0.01[B]
Aluminum	to 0.10 incl	0.03[C]	. . .[A]
Nitrogen	to 0.030 incl	0.005	0.005

[A] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

[B] If the minimum of the range is 0.01%, the under tolerance is 0.005%.

[C] If the minimum of the range is 0.01%, the under tolerance is 0.005% and if the minimum of the range is 0.02%, the under tolerance is 0.01%.

TABLE 3 List of Tables for Dimensions, Tolerances, and Allowances

Carbon[A] and High-Strength Low-Alloy Steel				
Dimensions	Table No.			
	Hot-Rolled Sheet		Cold-Rolled Sheet	
	Inch-Pound Units	SI Units	Inch-Pound Units	SI Units
Camber tolerances	12	A1.9	12, 22	A1.9, A1.19
Diameter tolerances of sheared circles	11	A1.8	11	A1.8
Flatness tolerances	15, 16	A1.12, A1.13	23	A1.20
Length tolerances	10	A1.7	19, 20	A1.16, A1.17
Out-of-square tolerances	13	A1.10	13	A1.10
Restricted Squareness tolerances	14	A1.11	14	A1.11
Thickness tolerances	4, 5, 6, 7	A1.1, A1.2, A1.3, A1.4	17, 18	A1.14, A1.15
Width tolerances of cut edge	9	A1.6	9, 21	A1.6, A1.18
Width tolerances of mill edge	8	A1.5	. . .	

[A] Tolerances for hot-rolled carbon sheet steel with 0.25 % maximum carbon, cast or heat analysis.

5.4.3 When the steel is not subject to tension test requirements, the samples for analysis must be taken by milling or drilling entirely through the sheet in a sufficient number of places so that the samples are representative of the entire sheet or strip. The sampling may be facilitated by folding the sheet both ways, so that several samples may be taken at one drilling. Steel subjected to certain heating operations by the purchaser may not give chemical analysis results that properly represent its original composition. Therefore, users must analyze chips taken from the steel in the condition in which it is received from the steel manufacturer.

5.5 *Specimen Preparation*—Drillings or chips must be taken without the application of water, oil, or other lubricant, and must be free of scale, grease, dirt, or other foreign substances. They must not be overheated during cutting to the extent of causing decarburization. Chips must be well mixed and those too coarse to pass a No. 10 sieve or too fine to remain on a No. 30 sieve are not suitable for proper analysis. Sieve size numbers are in accordance with Specification E11.

5.6 *Test Methods*—In case a referee analysis is required and agreed upon to resolve a dispute concerning the results of a chemical analysis, the procedure of performing the referee analysis must be in accordance with the latest issue of Test Methods, Practices, and Terminology A751, unless otherwise agreed upon between the manufacturer and the purchaser.

6. Mechanical Properties

6.1 The mechanical property requirements, number of specimens, and test locations and specimen orientation shall be in accordance with the applicable product specification.

6.2 Unless otherwise specified in the applicable product specification, test specimens must be prepared in accordance with Test Methods and Definitions A370.

6.3 Mechanical tests shall be conducted in accordance with Test Methods and Definitions A370.

6.4 Bend tests where required shall be conducted in compliance with Test Method E290.

6.5 To determine conformance with the product specification, a calculated value should be rounded to the nearest 1 ksi tensile strength and yield point or 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 off method given in Practice E29.

6.6 Structural sheet steels are commonly fabricated by cold bending. There are many interrelated factors that affect the ability of a given steel to cold form over a given radius under shop conditions. These factors include thickness, strength level, degree of restraint, relationship to rolling direction, chemistry and microstructure. Each of the appropriate product specifications lists in the appendix the suggested minimum inside radius for cold bending. These radii should be used as minima for 90° bends. They presuppose "hard way" bending (bend axis parallel to rolling direction) and reasonably good shop forming practices. Where possible, the use of larger radii or "easy way" bends are recommended for improved performance.

6.7 Fabricators should be aware that cracks may initiate upon bending a sheared or burned edge. 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.

7. General Requirements for Delivery

7.1 The products covered by this specification are produced to inch-pound or metric decimal thickness only and the appropriate thickness tolerances apply.

7.2 Steel may be produced as ingot-cast or strand-cast. When different grades of strand-cast steel are sequentially cast, identification and separation of the transition material is required.

8. Dimensions, Tolerances, and Allowances

8.1 Dimensions, tolerances, and allowances applicable to products covered by this specification are contained in Tables 3-23 [Annex A1, Tables A1.1-A1.20]. The appropriate tolerance tables shall be identified in each individual specification.

8.2 *Flatness Tolerances*:

8.2.1 Standard flatness tolerances are contained in Table 15 and Table 16 for hot-rolled sheet and Table 23 for cold-rolled sheet.

8.2.2 Measurement techniques for flatness characteristics are described in Practice A1030/A1030M.

8.2.3 Two alternative methods for flatness determination are the use of I-units and percent steepness. A description of these two alternative methods is contained in Practice A1030/A1030M, as well as Appendix X5.

TABLE 4 Standard Thickness Tolerances for Hot-Rolled Sheet (Carbon and Structural Steel Only)—⅜-in. (Cut Edge) and ¾-in. (Mill Edge) Minimum Edge Distance (Coils and Cut Lengths, Including Pickled)

NOTE 1—Thickness is measured at any point across the width not less than ⅜ in. from a cut edge and not less than ¾ in. from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 3—The thickness of material <1 in. wide shall be measured at mid-width.

Specified Width, in.	Specified Ordered Thickness, in.[A]					
	0.027 to 0.051, incl	Over 0.051 to 0.057, incl	Over 0.057 to 0.071, incl	Over 0.071 to 0.098, incl	Over 0.098 to 0.180, excl	0.180 to 0.230, excl
	Thickness Tolerances Over, in., No Tolerance Under[B]					
To 20 incl	0.010	0.010	0.012	0.012	0.014	0.014
Over 20 to 40 incl	0.010	0.010	0.012	0.014	0.014	0.016
Over 40 to 48 incl	0.010	0.012	0.012	0.014	0.016	0.018
Over 48 to 60 incl	. . .[C]	0.012	0.014	0.014	0.016	0.020
Over 60 to 72 incl	. . .[C]	0.014	0.014	0.016	0.016	0.022
Over 72	. . .[C]	. . .[C]	. . .[C]	0.016	0.016	0.024

[A] The specified thickness range captions apply independent of whether the ordered thickness is stated as a nominal or minimum.

[B] The tolerances provided in the table are based on minimum thickness (tolerance over, no tolerance under). For nominal thickness, the tolerance is divided equally over and under.

[C] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE 5 Restricted Thickness Tolerances for Hot-Rolled Sheet (Carbon and Structural Steel Only)—⅝-in. (Cut Edge) and 1-in. (Mill Edge) Minimum Edge Distance (Coils and Cut Lengths, Including Pickled)

NOTE 1—Thickness is measured at any point across the width not less than ⅝ in. from a cut edge and not less than 1 in. from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 3—This table was constructed by multiplying the values in the standard table by 0.75 and rounding to 3 decimal places using standard ASTM practice.

NOTE 4—The thickness of material <2 in. wide shall be measured at mid-width.

Specified Width, in.	Specified Ordered Thickness, in.[A]					
	0.027 to 0.051, incl	Over 0.051 to 0.057, incl	Over 0.057 to 0.071, incl	Over 0.071 to 0.098, incl	Over 0.098 to 0.180, excl	0.180 to 0.230, excl
	Thickness Tolerances Over, in., No Tolerance Under[B]					
To 20 incl	0.008	0.008	0.009	0.009	0.010	0.010
Over 20 to 40, incl	0.008	0.008	0.009	0.010	0.010	0.012
Over 40 to 48, incl	0.008	0.009	0.009	0.010	0.012	0.014
Over 48 to 60, incl	. . .[C]	0.009	0.010	0.010	0.012	0.015
Over 60 to 72, incl	. . .[C]	0.010	0.010	0.012	0.012	0.016
Over 72	. . .[C]	. . .[C]	. . .[C]	0.012	0.012	0.018

[A] The specified thickness range captions apply independent of whether the ordered thickness is stated as a nominal or minimum.

[B] The tolerances provided in the table are based on minimum thickness (tolerance over, no tolerance under). For nominal thickness, the tolerance is divided equally over and under.

[C] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

8.2.3.1 The use of I-units or percent steepness as a flatness standard is subject to negotiation between the purchaser and the producer.

8.2.3.2 Measurement techniques for I-units and percent steepness and rejection limits are subject to negotiation between the purchaser and the producer.

9. Finish and Condition

9.1 Hot-rolled sheet has a surface with an oxide or scale resulting from the hot-rolling operation. The oxide or scale can be removed by pickling or blast cleaning when required for press-work operations or welding. Hot-rolled and hot-rolled descaled sheet is not generally used for exposed parts where surface is of prime importance.

9.1.1 Hot-rolled sheet can be supplied with mill edges or cut edges as specified. Mill edges are the natural edges resulting from the hot-rolling operation. They do not conform to any particular contour. They may also contain some edge imperfections, the more common types of which are cracked edges, thin edges (feather), and damaged edges due to handling or processing and which should not extend in beyond the ordered width. These edge conditions are detrimental where joining of the mill edges by welding is practiced. When the purchaser intends to shear or to blank, a sufficient width allowance should

TABLE 6 Standard Thickness Tolerances for Hot-Rolled Sheet (High-Strength, Low-Alloy Steel)—⅜-in. (Cut Edge) and ¾-in. (Mill Edge) Minimum Edge Distance (Coils and Cut Lengths, Including Pickled)

NOTE 1—Thickness is measured at any point across the width not less than ⅜ in. from a cut edge and not less than ¾ in. from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 3—The thickness of material <1 in. wide shall be measured at mid-width.

Specified Width, in.	Specified Ordered Thickness, in.[A]						
	0.031 to 0.051, incl	Over 0.051 to 0.059, incl	Over 0.059 to 0.070, incl	Over 0.070 to 0.082, incl	Over 0.082 to 0.098, incl	Over 0.098 to 0.180, excl	0.180 to 0.230, excl
	Thickness Tolerances, Over, in., No Tolerance Under[B]						
To 15, incl	0.010	0.012	0.012	0.012	0.012	0.014	0.014
Over 15 to 20, incl	0.010	0.012	0.014	0.014	0.014	0.016	0.016
Over 20 to 32, incl	0.012	0.012	0.014	0.014	0.014	0.016	0.018
Over 32 to 40, incl	0.012	0.012	0.014	0.014	0.016	0.016	0.018
Over 40 to 48, incl	0.012	0.014	0.014	0.014	0.016	0.020	0.020
Over 48 to 60, incl	. . .[C]	0.014	0.014	0.014	0.016	0.020	0.020
Over 60 to 72, incl	. . .[C]	. . .[C]	0.016	0.016	0.018	0.022	0.022
Over 72 to 80, incl	. . .[C]	. . .[C]	. . .[C]	0.016	0.018	0.024	0.024
Over 80	. . .[C]	. . .[C]	. . .[C]	. . .[C]	0.020	0.024	0.024[C]

[A] The specified thickness range captions apply independent of whether the ordered thickness is stated as a nominal or minimum.
[B] The tolerances provided in the table are based on minimum thickness (tolerance over, no tolerance under). For nominal thickness, the tolerance is divided equally over and under.
[C] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE 7 Restricted Thickness Tolerances for Hot-Rolled Sheet (High-Strength, Low-Alloy Steel)—⅝-in. (Cut Edge) and 1-in. (Mill Edge) Minimum Edge Distance (Coils and Cut Lengths, Including Pickled)

NOTE 1—Thickness is measured at any point across the width not less than ⅝ in. from a cut edge and not less than 1 in. from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 3—This table was constructed by multiplying the values in the standard table by 0.75 and rounding to 3 places using standard ASTM practice.

NOTE 4—The thickness of material <2 in. wide shall be measured at mid-width.

Specified Width, in.	Specified Ordered Thickness, in.[A]						
	0.031 to 0.051, incl	Over 0.051 to 0.059, incl	Over 0.059 to 0.070, incl	Over 0.070 to 0.082, incl	Over 0.082 to 0.098, incl	Over 0.098 to 0.180, excl	0.180 to 0.230, excl
	Thickness Tolerances All Over, in., No Tolerance Under[B]						
To 15, incl	0.008	0.009	0.009	0.009	0.009	0.010	0.010
Over 15 to 20, incl	0.008	0.009	0.010	0.010	0.010	0.012	0.012
Over 20 to 32, incl	0.009	0.009	0.010	0.010	0.010	0.012	0.014
Over 32 to 40, incl	0.009	0.009	0.010	0.010	0.012	0.012	0.014
Over 40 to 48, incl	0.009	0.010	0.010	0.010	0.012	0.015	0.015
Over 48 to 60, incl	. . .[C]	0.010	0.010	0.010	0.012	0.015	0.015
Over 60 to 72, incl	. . .[C]	. . .[C]	0.012	0.012	0.014	0.016	0.016
Over 72 to 80, incl	. . .[C]	. . .[C]	. . .[C]	0.012	0.014	0.018	0.018
Over 80	. . .[C]	. . .[C]	. . .[C]	. . .[C]	0.015	0.018	0.018[C]

[A] The specified thickness range captions apply independent of whether the ordered thickness is stated as a nominal or minimum.
[B] The tolerances provided in the table are based on minimum thickness (tolerance over, no tolerance under). For nominal thickness, the tolerance is divided equally over and under.
[C] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

be made when purchasing to ensure obtaining the desired contour and size of the pattern sheet. The manufacturer may be consulted for guidance. Cut edges are the normal edges which result from the shearing, slitting, or trimming of mill-edge sheet.

9.1.1.1 The ends of plain hot-rolled mill-edge coils are irregular in shape and are referred to as uncropped ends. Where such ends are not acceptable, the purchaser's order should so specify. Processed coils such as pickled or blast cleaned are supplied with square-cut ends.

9.2 Cold-rolled carbon sheet (exposed) is intended for those applications where surface appearance is of primary importance. This class will meet requirements for controlled surface texture, surface quality, and flatness. It is normally processed by the manufacturer to be free of stretcher strain and fluting. Subsequent user roller leveling immediately before fabrication will minimize strain resulting from aging.

9.2.1 Cold-rolled carbon sheet, when ordered for exposed applications, can be supplied in the following finishes:

TABLE 8 Width Tolerances[A] of Hot-Rolled Mill Edge Sheet (All Designations)
(Coils and Cut Lengths, Including Pickled)

Specified Width, in.	Tolerances Over Specified Width, in. No Tolerance Under
Carbon	
Over 12 to 14 incl	7⁄16
Over 14 to 17 incl	1⁄2
Over 17 to 19 incl	9⁄16
Over 19 to 21 incl	5⁄8
Over 21 to 24 incl	11⁄16
Over 24 to 26 incl	13⁄16
Over 26 to 30 incl	15⁄16
Over 30 to 50 incl	1 1⁄8
Over 50 to 78 incl	1 1⁄2
Over 78	1 7⁄8
High-Strength Low-Alloy	
Over 12 to 14 incl	7⁄16
Over 14 to 17 incl	1⁄2
Over 17 to 19 incl	9⁄16
Over 19 to 21 incl	5⁄8
Over 21 to 24 incl	11⁄16
Over 24 to 26 incl	13⁄16
Over 26 to 28 incl	15⁄16
Over 28 to 35 incl	1 1⁄8
Over 35 to 50 incl	1 1⁄4
Over 50 to 60 incl	1 1⁄2
Over 60 to 65 incl	1 5⁄8
Over 65 to 70 incl	1 3⁄4
Over 70 to 80 incl	1 7⁄8
Over 80	2

[A] The above tolerances do not apply to the uncropped ends of mill edge coils (10.1.1.1).

TABLE 9 Width Tolerances of Hot-Rolled Cut Edge Sheet and Cold-Rolled Sheet (All Designations)
(Not Resquared, Coils and Cut Lengths, Including Pickled)

Specified Width, in.	Tolerances Over Specified Width, in. No Tolerance Under
To 30 incl	1⁄8
Over 30 to 48 incl	3⁄16
Over 48 to 60 incl	1⁄4
Over 60 to 80 incl	5⁄16
Over 80	3⁄8

9.2.1.1 Matte finish is a dull finish, without luster, produced by rolling on rolls that have been roughened by mechanical or chemical means to various degrees of surface texture depending upon application. With some surface preparation matte finish is suitable for decorative painting. It is not generally recommended for bright plating.

9.2.1.2 Commercial bright finish is a relatively bright finish having a surface texture intermediate between that of matte and luster finish. With some surface preparation commercial bright finish is suitable for decorative painting or certain plating applications. If sheet is deformed in fabrication the surface may roughen to some degree and areas so affected will require surface preparation to restore surface texture to that of the undeformed areas.

9.2.1.3 Luster finish is a smooth bright finish produced by rolling on ground rolls and is suitable for decorative painting or plating with additional special surface preparation by the user. The luster may not be retained after fabrication; therefore, the formed parts will require surface preparation to make them suitable for bright plating.

9.3 Cold-rolled carbon sheet, when intended for unexposed applications, is not subject to limitations on degree and frequency of surface imperfections, and restrictions on texture and mechanical properties are not applicable. When ordered as "annealed last," the product will have coil breaks and a tendency toward fluting and stretcher straining. Unexposed cold-rolled sheet may contain more surface imperfections than exposed cold-rolled sheet because steel applications, processing procedures, and inspection standards are less stringent.

TABLE 10 Length Tolerances of Hot-Rolled Sheet (All Designations)
(Cut Lengths Not Resquared, Including Pickled)

Specified Length, in.	Tolerances Over Specified Length, in. No Tolerance Under
To 15 incl	1⁄8
Over 15 to 30 incl	1⁄4
Over 30 to 60 incl	1⁄2
Over 60 to 120 incl	3⁄4
Over 120 to 156 incl	1
Over 156 to 192 incl	1 1⁄4
Over 192 to 240 incl	1 1⁄2
Over 240	1 3⁄4

TABLE 11 Diameter Tolerances of Circles Sheared from Hot-Rolled (Including Pickled) and Cold-Rolled Sheet (Over 12 in. Width) (All Designations)

Specified Thickness,[A] in.	Tolerances Over Specified Diameter, in. (No Tolerances Under)		
	Under 30	Over 30 to 48 incl	Over 48
0.044 to 0.057 incl	1⁄16	1⁄8	3⁄16
Over 0.057 to 0.098 incl	3⁄32	5⁄32	7⁄32
Over 0.098	1⁄8	3⁄16	1⁄4

[A] 0.071 in. minimum thickness for hot-rolled high-strength low-alloy steel sheet.

TABLE 12 Camber Tolerances[A] for Hot-Rolled (Including Pickled) and Cold-Rolled Sheet (All Designations)
(Cut Lengths, not Resquared)

NOTE 1—Camber is the greatest deviation of a side edge from a straight line, the measurement being taken on the concave side with a straightedge.

Cut Length, ft	Camber Tolerances, in.
To 4 incl	1⁄8
Over 4 to 6 incl	3⁄16
Over 6 to 8 incl	1⁄4
Over 8 to 10 incl	5⁄16
Over 10 to 12 incl	3⁄8
Over 12 to 14 incl	1⁄2
Over 14 to 16 incl	5⁄8
Over 16 to 18 incl	3⁄4
Over 18 to 20 incl	7⁄8
Over 20 to 30 incl	1 1⁄4
Over 30 to 40 incl	1 1⁄2

[A] The camber tolerance for coils is 1 in. in any 20 ft.

TABLE 13 Out-of-Square Tolerances of Hot-Rolled Cut-Edge (Including Pickled) and Cold-Rolled Sheet (All Designations)
(Cut Lengths Not Resquared)

Out-of-square is the greatest deviation of an end edge from a straight line at right angle to a side and touching one corner. It is also obtained by measuring the difference between the diagonals of the cut length. The out-of-square deviation is one half of that difference. The tolerance for all thicknesses and all sizes is 1⁄16 in./6 in. of width or fraction thereof.

TABLE 14 Restricted Squareness Tolerances of Hot-Rolled (Including Pickled) and Cold-Rolled Sheet (All Designations)
(Cut Lengths)

When cut lengths are specified resquared, the width and the length are not less than the dimensions specified. The individual tolerance for over-width, over-length, camber, or out-of-square should not exceed 1⁄16 in. up to and including 48 in. in width and up to and including 120 in. in length. For cut lengths wider or longer, the applicable tolerance is 1⁄8 in.

TABLE 15 Flatness Tolerances[A] of Temper Rolled or Pickled Hot-Rolled Sheet Cut Lengths[B] (All Designations)

Specified Minimum Thickness, in.	Specified Width, in.	Flatness Tolerances,[C] in. Specified Yield Strength, min, ksi	
		Under 45	45 to 50[D,E]
0.027 to 0.057 incl	To 36 incl	1⁄2	3⁄4
	over 36 to 60 incl	3⁄4	1 1⁄8
	over 60	1	. . .
0.057 to 0.180 excl	To 60 incl	1⁄2	3⁄4
	over 60 to 72 incl	3⁄4	1 1⁄8
	over 72	1	1 1⁄2
0.180 to 0.230 excl	To 60 incl	1⁄2	3⁄4
	over 60 to 72 incl	3⁄4	1 1⁄8
	over 72	1	1 1⁄2

[A] The above table also applies to lengths cut from coils by the consumer when adequate flattening operations are performed.
[B] Application of this table to product in coil form is not appropriate unless the coil has been rolled out and adequately flattened with all coil set removed.
[C] Maximum deviation from a horizontal flat surface.
[D] Tolerances for steels with specified minimum yield strength in excess of 50 ksi are subject to negotiation.
[E] 0.071 minimum thickness of HSLA.

9.4 Cold-rolled high-strength low-alloy sheet is supplied with a matte finish, unless otherwise specified.

9.5 The cold-rolled products covered by this specification are furnished with cut edges and square cut ends, unless otherwise specified.

9.6 *Oiling*:

9.6.1 Plain hot-rolled sheet is customarily furnished not oiled. Oiling must be specified, when required.

9.6.2 Hot-rolled pickled or descaled sheet is customarily furnished oiled. If the product is not to be oiled, it must be so specified since the cleaned surface is prone to rusting.

9.6.3 Cold-rolled products covered by this specification can be furnished oiled or not oiled as specified.

9.7 Sheet steel in coils or cut lengths may contain surface imperfections that can be removed with a reasonable amount of metal finishing by the purchaser.

TABLE 16 Flatness Tolerances[A] of Non-Processed Hot Rolled Sheet Cut Lengths[B] (All Designations)

Specified Minimum Thickness, in.	Specified Width, in.	Flatness Tolerances,[C] in. Specified Yield Strength, min, ksi	
		Under 45	45 to 50[D,E]
0.027 to 0.057 incl	over 12 to 36 incl	1 1⁄2	2 1⁄4
	over 36 to 60 incl	2 1⁄4	3 3⁄8
	over 60	3	. . .
over 0.057 to 0.180 excl	over 12 to 60 incl	1 1⁄2	2 1⁄4
	over 60 to 72 incl	2 1⁄4	3 3⁄8
	over 72	3	4 1⁄2
0.180 to 0.230 excl	over 12 to 60 incl	1 1⁄2	2 1⁄4
	over 60 to 72 incl	2 1⁄4	3 3⁄8
	over 72	3	4 1⁄2

[A] The above table also applies to lengths cut from coils by the consumer when adequate flattening operations are performed.
[B] Application of this table to product in coil form is not appropriate unless the coil has been rolled out and adequately flattened with all coil set removed.
[C] Maximum deviation from a horizontal flat surface.
[D] Tolerances for steels with specified minimum yield strength in excess of 50 ksi are subject to negotiation.
[E] 0.071 minimum thickness of HSLA.

10. Workmanship

10.1 Cut lengths shall have a workmanlike appearance and shall not have imperfections of a nature or degree for the product, the grade, class, and the quality ordered that will be detrimental to the fabrication of the finished part.

10.2 Coils may contain some abnormal imperfections that render a portion of the coil unusable since the inspection of coils does not afford the producer the same opportunity to remove portions containing imperfections as in the case with cut lengths.

10.3 *Surface Conditions*:

10.3.1 Exposed cold-rolled sheet is intended for applications where surface appearance is of primary importance, that is, exposed applications. Unexposed or annealed cold-rolled sheet is intended for applications where surface appearance is not of primary importance, that is, unexposed applications.

10.3.2 Cut lengths for exposed applications shall not include individual sheets having major surface imperfections (holes, loose slivers, and pipe) and repetitive minor surface imperfections. Cut lengths may contain random minor surface imperfections that can be removed with a reasonable amount of metal finishing by the purchaser. These imperfections shall be acceptable to the purchaser within the manufacturer's published standards.

10.3.3 For coils for exposed applications, it is not possible to remove the surface imperfections listed in 10.3.2. Coils will contain such imperfections which shall be acceptable to the purchaser within the manufacturer's published standards. Coils contain more surface imperfections than cut lengths because the producer does not have the same opportunity to sort portions containing such imperfections as is possible with cut lengths.

10.3.4 Cut lengths for unexposed applications shall not include individual sheets having major surface imperfections such as holes, loose slivers, and pipe. In addition, unexposed

TABLE 17 Standard Thickness Tolerances for Cold-Rolled Sheet (All Designations)^A—⅜-in. Minimum Edge Distance (Coils and Cut Lengths)

NOTE 1—Thickness is measured at any point across the width not less than ⅜ in. from a side edge.

NOTE 2—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 3—The thickness of material <1 in. wide shall be measured at mid-width.

Specified Width, in.	Specified Ordered Thickness, in.^{B}						
	To 0.014, excl	0.014 to 0.019, incl	Over 0.019^A to 0.039 incl	Over 0.039 to 0.057, incl	Over 0.057 to 0.071, incl	Over 0.071 to 0.098, incl	Over 0.098 to 0.142, incl
	Thickness Tolerances, Over, in., No Tolerance Under^C						
To 15, incl	0.002	0.004	0.006	0.008	0.010	0.010	0.010
Over 15 to 72, incl	0.002	0.004	0.006	0.008	0.010	0.010	0.012
Over 72	. . .^{D}	. . .^{D}	0.006	0.008	0.010	0.012	0.014

^{A} Minimum Thickness, 0.021 in. for high-strength, low-alloy.

^{B} The specified thickness range captions apply independent of whether the ordered thickness is stated as a nominal or minimum.

^{C} The tolerances provided in the table are based on minimum thickness (tolerance over, no tolerance under). For nominal thickness, the tolerance is divided equally over and under.

^{D} Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE 18 Restricted Thickness Tolerances for Cold-Rolled Sheet (All Designations)^A—1-in. Minimum Edge Distance (Coils and Cut Lengths)

NOTE 1—Thickness is measured at any point across the width not less than 1 in. from a side edge.

NOTE 2—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 3—This table was constructed by multiplying the values in the standard table by 0.50 and rounding to 3 places using standard ASTM practice.

NOTE 4—The thickness of material <2 in. wide shall be measured at mid-width.

Specified Width, in.	Specified Ordered Thickness, in.^{B}						
	To 0.014, excl	0.014 to 0.019, incl	Over 0.019^A to 0.039, incl	Over 0.039 to 0.057, incl	Over 0.057 to 0.071, incl	Over 0.071 to 0.098, incl	Over 0.098 to 0.142, incl
	Thickness Tolerances, Over, in., No Tolerance Under^C						
To 15, incl	0.001	0.002	0.003	0.004	0.005	0.005	0.005
Over 15 to 72, incl	0.001	0.002	0.003	0.004	0.005	0.005	0.006
Over 72	. . .^{D}	. . .^{D}	0.003	0.004	0.005	0.006	0.007

^{A} Minimum Thickness, 0.021 in. for high-strength, low-alloy.

^{B} The specified thickness range captions apply independent of whether the ordered thickness is stated as a nominal or minimum.

^{C} The tolerances provided in the table are based on minimum thickness (tolerance over, no tolerance under). For nominal thickness, the tolerance is divided equally over and under.

^{D} Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE 19 Length Tolerances of Cold-Rolled Sheet (All Designations)
(Cut Lengths Over 12 in. in Width, Not Resquared)

Specified Length, in.	Tolerances Over Specified Length, in. No Tolerances Under
Over 12 to 30, incl	⅛
Over 30 to 60, incl	¼
Over 60 to 96, incl	½
Over 96 to 120, incl	¾
Over 120 to 156, incl	1
Over 156 to 192, incl	1¼
Over 192 to 240 incl	1½
Over 240	1¾

TABLE 20 Length Tolerances of Cold-Rolled Sheet (All Designations)
(Cut Length Sheets, to 12 in. in Width, Not Resquared)

NOTE 1—This table applies to widths produced by slitting from wider sheet.

Specified Length, in.	Tolerances Over Specified Length, in. No Tolerance Under
24 to 60, incl	½
Over 60 to 120, incl	¾
Over 120 to 240, incl	1

cut lengths can be expected to contain more minor imperfections such as pits, scratches, sticker breaks, edge breaks, pinchers, cross breaks, roll marks, and other surface imperfections than exposed. These imperfections shall be acceptable to the purchaser without limitation.

10.3.5 For coils for unexposed applications, it is not possible to remove the surface imperfections listed in 10.3.4. Coils will contain surface imperfections that are normally not repairable. Minor imperfections shall be acceptable to the purchaser within the manufacturer's published standards. Unexposed coils contain more surface imperfections than exposed coils.

11. Retests and Disposition of Non-Conforming Material

11.1 *Retests*:

11.1.1 Unless otherwise prohibited by the product specification, retests are permitted under the following circumstances:

11.1.1.1 If any tension test specimen shows defective machining or develops flaws, it must be discarded and another specimen substituted.

TABLE 21 Width Tolerances for Cold-Rolled Sheet (All Designations)[A]
(Coils and Cut Lengths to 12 in. Width, Not Resquared)

Specified Width, in.	Width Tolerance, Plus and Minus, in.
To 6, incl	0.012
Over 6 to 9, incl	0.016
Over 9 to 12, incl	0.032

[A] 0.020 in. minimum thickness for high-strength low-alloy.

TABLE 22 Camber Tolerances of Cold-Rolled Sheet in Coils (All Designations)[A]
(Coils to 12 in. in Width)

NOTE 1—Camber is the greatest deviation of a side edge from a straight line, the measurement being taken on the concave side with a straightedge.
NOTE 2—This table applies to widths produced by slitting from wider sheet.

Width, in.	Camber Tolerance
To 12, incl	¼ in. in any 8 ft

[A] 0.020 in. minimum thickness for high-strength low-alloy.

TABLE 23 Flatness Tolerances of Cold-Rolled Sheet (All Designations)

NOTE 1—This table does not apply when product is ordered full hard, to a hardness range, or "annealed last" (dead soft).
NOTE 2—This table also applies to lengths cut from coils by the consumer when adequate flattening measures are performed.

Specified Thickness, in.	Specified Width, in.	Flatness Tolerance,[A] in.	
		Specified Yield Point, min, ksi	
		Under 45	45 to 50[B] incl.
To 0.044, incl	to 36 incl	⅜	¾
	over 36 to 60 incl	⅝	1⅛
	over 60	⅞	1½
Over 0.044	to 36 incl	¼	¾
	over 36 to 60 incl	⅜	¾
	over 60 to 72 incl	⅝	1⅛
	over 72	⅞	1½

[A] Maximum deviation from a horizontal flat surface.
[B] Tolerances for high-strength, low-alloy steel with specified minimum yield point in excess of 50 ksi are subject to negotiation.

11.1.1.2 If the percent 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 gauge length of a 2-in. [50 mm] specimen or is outside the middle half of the gauge length of an 8-in. [200 mm] specimen, as indicated by scribe scratches marked on the specimen before testing, a retest is allowed.

11.1.1.3 If the test result of any tension test specimen fails to meet the specification requirements and the failure is the result of improper adherence to tension test procedures, a retest is permitted.

11.1.1.4 If the test result of an original tension test specimen fails to meet the specification requirements and the failure is not related to the conditions described in 11.1.1.1, 11.1.1.2, and 11.1.1.3, but the results are within 2 ksi [14 MPa] of the required yield strength, within 2 ksi [14 MPa] of the required tensile strength, or within 2 percentage points of the required elongation, one retest shall be permitted to replace the failing test.

11.1.2 The retest specimen shall be taken either adjacent to the first failed specimen, or selected at random from the material to be certified to the specification.

11.1.3 If the results of a retest satisfy the specified tension test requirements and all other requirements of the applicable specification are satisfied, the material shall be accepted.

11.2 *Disposition of Non-Conforming Material*:

11.2.1 In those cases where the lot is found to be non-conforming, and resampling of non-conforming material is not prohibited by the specification, resampling is permitted under the following circumstances and using the following practices:

11.2.1.1 If the results of an original tension test or retest specimen fail to satisfy the specification requirements and the failed test results are not related to the conditions described in 11.1, the lot shall be quarantined and resampled for certification of the non-conforming material to the specification requirements.

11.2.1.2 Resampling for certification of the non-conforming material shall include the discarding of out-of-specification material and the resampling of the lot. The resampling shall be appropriate to the specific out-of-specification condition and the processing history of the lot.

11.2.1.3 A maximum of two resampling efforts shall be permitted. If after conducting two resampling efforts, the material does not satisfy the specification requirements, the lot shall be rejected.

12. Inspection

12.1 When purchaser's order stipulates that inspection and tests (except product analyses) for acceptance on the steel be made prior to shipment from the mill, the manufacturer shall afford the purchaser's inspector all reasonable facilities to satisfy him that the steel is being produced and furnished in accordance with the specification. Mill inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operation.

13. Rejection and Rehearing

13.1 Unless otherwise specified, any rejection shall be reported to the manufacturer within a reasonable time after receipt of material by the purchaser.

13.2 Material that is reported to be defective subsequent to the acceptance at the purchaser's works shall be set aside, adequately protected, and correctly identified. The manufacturer shall be notified as soon as possible so that an investigation may be initiated.

13.3 Samples that are representative of the rejected material shall be made available to the manufacturer. In the event that the manufacturer is dissatisfied with the rejection, he may request a rehearing.

14. Test Reports and Certification

14.1 When test reports are required by the purchase order or the material specification, the supplier shall report the results of all test required by the material specification and the order.

14.2 When certification is required by the purchase order, the supplier shall furnish a certification that the material has been manufactured and tested in accordance with the requirements of the material specification.

14.3 A signature is not required on test reports or certifications. However, the document shall clearly identify the organization submitting the document. Notwithstanding the absence of a signature, the organization submitting the document is responsible for the content of the document.

14.4 When test reports are required, copies of the original material manufacturer's test report shall be included with any subsequent test report.

14.5 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.

NOTE 4—The industry definition as invoked here is: EDI is the computer to computer exchange of business information in an agreed upon standard format such as ANSI ASC X12.

15. Product Marking

15.1 As a minimum requirement, the material shall be identified by having the manufacturer's name, ASTM designation, weight, purchaser's order number, and material identification legibly stenciled on top of each lift or shown on a tag attached to each coil or shipping unit.

15.2 When specified in the contract or order, and for direct procurement by or direct shipment to the 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 in accordance with Fed. Std. No. 123 for civil agencies.

15.3 Bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the primary metals subcommittee of the AIAG bar code project team.

16. Packing and Package Marking

16.1 Unless otherwise specified, the sheet shall be packaged and loaded in accordance with Practices A700.

16.2 When coils are ordered, it is customary to specify a minimum or range of inside diameter, maximum outside diameter, and a maximum coil weight, if required. The ability of manufacturers to meet the maximum coil weights depends upon individual mill equipment. When required, minimum coil weights are subject to negotiation.

17. Keywords

17.1 carbon steel sheet; cold rolled steel sheet; general delivery requirements; high strength low alloy steel; hot rolled steel sheet; steel sheet; structural steel sheet

ANNEX

(Mandatory Information)

A1. PERMISSIBLE VARIATIONS IN DIMENSIONS AND MASS IN SI UNITS

A1.1 Listed in Tables A1.1–A1.20. are permissible variations in dimensions and mass expressed in the International System of Units (SI) terminology.

TABLE A1.1 Standard Thickness Tolerances [Metric] for Hot-Rolled Sheet (Carbon and Structural Steel Only)—10-mm (Cut Edge) and 20-mm (Mill Edge) Minimum Edge Distance (Coils and Cut Lengths, Including Pickled)

NOTE 1—Thickness is measured at any point across the width not less than 10 mm from a cut edge and not less than 20 mm from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 3—The thickness of material <25 mm wide shall be measured at mid-width.

Specified Width, mm	Specified Ordered Thickness, mm[A]			
	Through 2.0	Over 2.0 to 2.5, incl	Over 2.5 to 4.5, excl	4.5 to 6.0, excl
	Thickness Tolerances, Over, mm, No Tolerance Under[B]			
To 600, incl	0.30	0.30	0.35	0.40
Over 600 to 1200, incl	0.30	0.35	0.40	0.45
Over 1200 to 1500, incl	0.35	0.35	0.40	0.50
Over 1500 to 1800, incl	0.35	0.40	0.40	0.56
Over 1800	0.35	0.40	0.40	0.60

[A] The specified thickness range captions apply independent of whether the ordered thickness is stated as a nominal or minimum.

[B] The tolerances provided in the table are based on minimum thickness (tolerance over, not tolerance under). For nominal thickness, the tolerance is divided equally over and under.

TABLE A1.2 Restricted Thickness Tolerances [Metric] for Hot-Rolled Sheet (Carbon and Structural Steel Only)—15-mm (Cut Edge) and 25-mm (Mill Edge) Minimum Edge Distance (Coils and Cut Lengths, Including Pickled)

NOTE 1—Thickness is measured at any point across the width not less than 15 mm from a cut edge and not less than 25 mm from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 3—This table was constructed by multiplying the values in the standard table by 0.75 and rounding to 2 decimal places using standard ASTM practice.

NOTE 4—The thickness of material <50 mm wide shall be measured at mid-width.

Specified Width, mm	Specified Ordered Thickness, mm[A]			
	Through 2.0	Over 2.0 to 2.5, incl	Over 2.5 to 4.5, excl	4.5 to 6.0, excl
	Thickness Tolerances Over, mm, No Tolerance Under[B]			
To 600	0.22	0.22	0.26	0.30
Over 600 to 1200, incl	0.22	0.26	0.30	0.34
Over 1200 to 1500, incl	0.26	0.26	0.30	0.38
Over 1500 to 1800, incl	0.26	0.30	0.30	0.42
Over 1800	0.26	0.30	0.30	0.45

[A] The specified thickness range captions apply independent of whether the ordered thickness is stated as a nominal or minimum.

[B] The tolerances provided in the table are based on minimum thickness (tolerance over, not tolerance under). For nominal thickness, the tolerance is divided equally over and under.

TABLE A1.3 Standard Thickness Tolerances [Metric] for Hot-Rolled Sheet (High-Strength, Low-Alloy Steel)—10-mm (Cut Edge) and 20-mm (Mill Edge) Minimum Edge Distance (Coils and Cut Lengths, Including Pickled)

NOTE 1—Thickness is measured at any point across the width not less than 10 mm from a cut edge and not less than 20 mm from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 3—The thickness of material <25 mm wide shall be measured at mid-width.

Specified Width, mm	Specified Ordered Thickness, mm[A]			
	Through 2.0	Over 2.0 to 2.5, incl	Over 2.5 to 4.5, excl	4.5 to 6.0, excl
	Thickness Tolerances Over, mm, No Tolerance Under[B]			
To 600, incl	0.30	0.35	0.40	0.40
Over 600 to 1200, incl	0.35	0.40	0.45	0.50
Over 1200 to 1500, incl	0.35	0.40	0.50	0.50
Over 1500 to 1800, incl	0.40	0.45	0.55	0.56
Over 1800 to 2000, incl	0.40	0.45	0.60	0.60
Over 2000	. . .[C]	0.50	0.60	0.60[C]

[A] The specified thickness range captions apply independent of whether the ordered thickness is stated as a nominal or minimum.

[B] The tolerances provided in the table are based on minimum thickness (tolerance over, not tolerance under). For nominal thickness, the tolerance is divided equally over and under.

[C] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE A1.4 Restricted Thickness Tolerances of Hot-Rolled Sheet (High-Strength, Low-Alloy Steel)—15-mm (Cut Edge) and 25-mm (Mill Edge) Minimum Edge Distance (Coils and Cut Lengths, Including Pickled)

NOTE 1—Thickness is measured at any point across the width not less than 15 mm from a cut edge and not less than 25 mm from a mill edge. This table does not apply to the uncropped ends of mill edge coils.

NOTE 2—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 3—This table was constructed by multiplying the values in the standard table by 0.75 and rounding to 2 decimal places using standard ASTM practice.

NOTE 4—The thickness of material <50 mm wide shall be measured at mid-width.

Specified Width, mm	Specified Ordered Thickness, mm[A]			
	Through 2.0	Over 2.0 to 2.5, incl	Over 2.5 to 4.5, excl	4.5 to 6.0, excl
	Thickness Tolerances Over, mm, No Tolerance Under[B]			
To 600, incl	0.22	0.26	0.30	0.30
Over 600 to 1200, incl	0.26	0.30	0.34	0.38
Over 1200 to 1500, incl	0.26	0.30	0.38	0.38
Over 1500 to 1800, incl	0.30	0.34	0.41	0.42
Over 1800 to 2000, incl	0.30	0.34	0.45	0.45
Over 2000	. . .[C]	0.38	0.45	0.45[C]

[A] The specified thickness range captions apply independent of whether the ordered thickness is stated as a nominal or minimum.

[B] The tolerances provided in the table are based on minimum thickness (tolerance over, not tolerance under). For nominal thickness, the tolerance is divided equally over and under.

[C] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE A1.5 Width Tolerances[A] of Hot-Rolled Mill Edge Sheet (All Designations)
(Coils and Cut Lengths, Including Pickled)

Specified Width, mm		Width Tolerance, Over Only, mm	
Over	Through	Carbon	HSLA
300	600	16	16
600	1200	26	28
1200	1500	32	38
1500	1800	35	45
1800	. . .	48	50

[A] The above tolerances do not apply to the uncropped ends of mill edge coils (9.1.1.1).

TABLE A1.6 Width Tolerances of Hot-Rolled Cut Edge Sheet and Cold-Rolled Sheet (All Designations)
(Not Resquared Coils and Cut Lengths, Including Pickled)

Specified Width, mm		Width Tolerance, Over Only, mm
Over	Through	
. . .	600	3
600	1200	5
1200	1500	6
1500	1800	8
1800	. . .	10

TABLE A1.7 Length Tolerances of Hot-Rolled Sheet (All Designations)
(Cut Lengths Not Resquared, Including Pickled)

Specified Length, mm		Length Tolerance, Over Only, mm
Over	Through	
300	600	6
600	900	8
900	1500	12
1500	3000	20
3000	4000	25
4000	5000	35
5000	6000	40
6000	. . .	45

TABLE A1.8 Diameter Tolerances of Circles from Hot-Rolled (Including Pickled) and Cold-Rolled Sheet (Over 300 mm Width) (All Designations)

Specified Thickness[A], mm		Tolerances Over Specified Diameter, mm (No Tolerances Under)		
		Diameters, mm		
Over	Through	Through 600	Over 600 to 1200, incl	Over 1200
. . .	1.5	1.5	3.0	5.0
1.5	2.5	2.5	4.0	5.5
2.5	. . .	3.0	5.0	6.5

[A] 1.8 mm minimum thickness for hot-rolled high-strength low-alloy steel sheet.

TABLE A1.9 Camber Tolerances[A] for Hot-Rolled (Including Pickled) and Cold-Rolled Sheet (All Designations)
(Cut Lengths, Not Resquared)

NOTE 1—Camber is the greatest deviation of a side edge from a straight line, the measurement being taken on the concave side with a straightedge.

Cut Length, mm		Camber Tolerances[A], mm
Over	Through	
. . .	1200	4
1200	1800	5
1800	2400	6
2400	3000	8
3000	3700	10
3700	4300	13
4300	4900	16
4900	5500	19
5500	6000	22
6000	9000	32
9000	12 200	38

[A] The camber tolerance for coils is 25.0 mm in any 6000 mm.

TABLE A1.10 Out-of-Square Tolerances of Hot-Rolled Cut-Edge (Including Pickled) and Cold-Rolled Sheet (All Designations)
(Cut Lengths Not Resquared)

Out-of-square is the greatest deviation of an end edge from a straight line at right angle to a side and touching one corner. It is also obtained by measuring the difference between the diagonals of the cut length. The out-of-square deviation is one half of that difference. The tolerance for all thicknesses and all sizes is 1.0 mm/100 mm of width or fraction thereof.

TABLE A1.11 Restricted Squareness Tolerances of Hot-Rolled (Including Pickled) and Cold-Rolled Sheet (All Designations)
(Cut Lengths)

When cut lengths are specified resquared, the width and the length are not less than the dimensions specified. The individual tolerance for over-width, over-length, camber, or out-of-square should not exceed 1.6 mm up to and including 1200 mm in width and up to and including 3000 mm in length. For cut lengths wider or longer, the applicable tolerance is 3.2 mm.

TABLE A1.12 Flatness Tolerances[A] of Temper Rolled or Pickled Hot-Rolled Sheet Cut Lengths[B] (All Designations)

Specified Thickness, mm		Specified Width, mm	Flatness Tolerance[C], mm Specified Yield Strength, min, MPa[D]	
Over	Through		Under 310	310 to 340 MPa Yield Point, min, MPa
1.2	1.5	to 900, incl	15	20
		over 900 to 1500, incl	20	30
		over 1500	25	. . .
1.5	4.5	to 1500, incl	15	20
		over 1500 to 1800, incl	20	30
		over 1800	25	40
4.5	6.0 excl	to 1500, incl	15	20
		over 1500 to 1800, incl	20	30
		over 1800	25	40

[A] The above table also applies to lengths cut from coils by the consumer when adequate flattening operations are performed.
[B] Application of this table to product in coil form is not appropriate unless the coil has been rolled out and adequately flattened with all coil set removed.
[C] Maximum deviation from a horizontal surface.
[D] Tolerances for high-strength, low-alloy steels with specified minimum yield strength in excess of 340 MPa are subject to negotiation.

TABLE A1.13 Flatness Tolerances[A] of Non-Processed Hot-Rolled Sheet Cut Lengths[B] (All Designations)

Specified Thickness, mm		Specified Width, mm	Flatness Tolerance[C], mm Specified Yield Strength, min, MPa[D]	
Over	Through		Under 310	310 to 340 MPa Yield Point, min, MPa
1.2	1.5	to 900, incl	45	60
		over 900 to 1500, incl	60	90
		over 1500	75	. . .
1.5	4.5	to 1500, incl	45	60
		over 1500 to 1800, incl	60	90
		over 1800	75	120
4.5	6.0 excl	to 1500, incl	45	60
		over 1500 to 1800, incl	60	90
		over 1800	75	120

[A] The above table also applies to lengths cut from coils by the consumer when adequate flattening operations are performed.
[B] Application of this table to product in coil form is not appropriate unless the coil has been rolled out and adequately flattened with all coil set removed.
[C] Maximum deviation from a horizontal surface.
[D] Tolerances for high-strength, low-alloy steels with specified minimum yield strength in excess of 340 MPa are subject to negotiation.

TABLE A1.14 Standard Thickness Tolerances [Metric] for Cold-Rolled Sheet (All Designations)[A]—10-mm Minimum Edge Distance

NOTE 1—Thickness is measured at any point across the width not less than 10 mm from a side edge.

NOTE 2—Widths up to and including 300 mm in this table apply to widths produced by slitting from wider sheet.

NOTE 3—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 4—The thickness of material <25-mm wide shall be measured at mid-width.

Specified Width, mm		Specified Ordered Thickness, mm[B]				
Over	Through	Through 0.4	Over 0.4 to 1.0, incl	Over 1.0 to 1.2, incl	Over 1.2 to 2.5, incl	Over 2.5 to 4.0, incl
		Thickness Tolerances Over, mm, No Tolerance Under[C]				
...	1800	0.10	0.15	0.20	0.25	0.30
1800	2000	. . .[D]	0.15	0.20	0.30	0.35
2000	. . .[D]	. . .[D]	0.30	0.30	0.35	0.40

[A] 0.55-mm minimum thickness for high-strength low-alloy.
[B] The specified thickness range captions apply independent of whether the ordered thickness is stated as a nominal or minimum.
[C] The tolerances provided in the table are based on minimum thickness (tolerance over, no tolerance under). For nominal thickness, the tolerance is divided equally over and under.
[D] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE A1.15 Restricted Thickness Tolerances of Cold-Rolled Sheet (All Designations)[A]—25-mm Minimum Edge Distance

NOTE 1—Thickness is measured at any point across the width not less than 25 mm from a side edge.

NOTE 2—Widths up to and including 300 mm in this table apply to widths produced by slitting from wider sheet.

NOTE 3—Micrometers used for measurement of thickness shall be constructed with anvils and spindles having minimum diameters of 0.188 in. [4.80 mm]. The tip of the spindle shall be flat, and the tip of the anvil shall be flat or rounded with a minimum radius of curvature of 0.10 in. [2.55 mm]. Micrometers with pointed tips are not suitable for thickness measurements.

NOTE 4—This table was constructed by multiplying the values in the standard table by 0.50 and rounding to 2 decimal places using standard ASTM practice.

NOTE 5—The thickness of material <50 mm wide shall be measured at mid-width.

Specified Width, mm		Specified Ordered Thickness, mm[B]				
Over	Through	Through 0.4	Over 0.4 to 1.0, incl	Over 1.0 to 1.2, incl	Over 1.2 to 2.5, incl	Over 2.5 to 4.0, incl
		Thickness Tolerances Over, mm, No Tolerance Under[C]				
...	1800	0.05	0.08	0.10	0.12	0.15
1800	2000	. . .[D]	0.08	0.10	0.15	0.18
2000	. . .[D]	. . .[D]	0.15	0.15	0.18	0.20

[A] 0.55 mm minimum thickness for high-strength low-alloy.
[B] The specified thickness range captions apply independent of whether the ordered thickness is stated as a nominal or minimum.
[C] The tolerances provided in the table are based on minimum thickness (tolerance over, no tolerance under). For nominal thickness, the tolerance is divided equally over and under.
[D] Where an ellipsis (. . .) appears in the table, the requirements have not been defined.

TABLE A1.16 Length Tolerances of Cold-Rolled Sheet (All Designations)
(Cut Lengths Over 300 mm in Width, Not Resquared)

Specified Length, mm		Tolerance Over Specified Length (No Tolerance Under), mm
Over	Through	
300	1500	6
1500	3000	20
3000	6000	35
6000	. . .	45

TABLE A1.17 Length Tolerances of Cold-Rolled Sheet (All Designations)
(Cut Length Sheets, to 300 mm in Width, Not Resquared)

NOTE 1—This table applies to widths produced by slitting from wider sheet.

Specified Length, mm		Tolerances Over Specified Length (No Tolerance Under), mm
Over	Through	
600	1500	15
1500	3000	20
3000	6000	25

TABLE A1.18 Width Tolerances for Cold-Rolled Sheet (All Designations)[A]
(Coils and Cut Lengths to 300 mm in Width, Not Resquared)

NOTE 1—This table applies to widths produced by slitting from wider sheet.

Specified Width, mm		Width Tolerance, Over and Under, mm
Over	Through	
50	100	0.3
100	200	0.4
200	300	0.8

[A] 0.50 mm thickness for high-strength low-alloy.

TABLE A1.19 Camber Tolerances of Cold-Rolled Sheet in Coils (All Designations)
(Coils to 300 mm in Width, Not Resquared)

NOTE 1—Camber is the greatest deviation of a side edge from a straight line, the measurements being taken on the concave side with a straight-edge.
NOTE 2—This table applies to widths produced by slitting from wider sheet.

Width, mm	Camber Tolerances
Through 300, incl	5.0 mm in any 2000 mm

TABLE A1.20 Flatness Tolerances of Cold-Rolled Sheet (All Designations)[A]

NOTE 1—This table does not apply when product is ordered full hard, to a hardness range or "annealed last" (dead soft).
NOTE 2—This table also applies to lengths cut from coils by the consumer when adequate flattening measures are performed.
NOTE 3—Application of this table to product in coil form is not appropriate unless the coil has been rolled out and adequately flattened with all coil set removed.

Specified Thickness, mm	Specified Width, mm		Flatness Tolerance, mm Specified Yield Point, min, MPa	
	Over	Through	Under 310 MPa	310 to 340 MPa[B]
Through 1.0	. . .	900	10	20
	900	1500	15	30
	1500		20	40
Over 1.0	. . .	900	8	20
	900	1500	10	20
	1500	1800	15	30
	1800	. . .	20	40

[A] Maximum deviation from a horizontal flat surface.
[B] Tolerances for high-strength, low-alloy steel with specified minimum yield point in excess of 340 MPa are subject to negotiation.

APPENDIXES

(Nonmandatory Information)

X1. AGING EFFECTS ON FORMABILITY OF COLD-ROLLED CARBON-STEEL SHEET PRODUCTS

X1.1 Cold-rolled carbon-steel sheet products exhibit maximum formability in the annealed last, or dead-soft, condition. However, many sheet products are not suitable for exposed applications in the dead-soft condition because Luder's lines (sometimes referred to as "stretcher strains" or "fluting") may develop during subsequent forming. This problem is avoided in most cases by temper rolling the sheet after annealing. After temper rolling, however, some sheet products are susceptible to aging. Aging refers to a gradual increase in yield strength and corresponding decrease in ductility during storage after temper rolling. Aging always has a negative effect on formability and, when aging leads to the redevelopment of an upper yield point, can result in renewed susceptibility to fluting.

X1.2 Aging can occur when interstitial solute atoms, carbon or nitrogen, are present in the steel. Solute carbon or nitrogen atoms are those not chemically combined with other elements in the steel (as carbides or nitrides, for example). Over time, these carbon or nitrogen interstitial solute atoms diffuse to crystalline imperfections within the steel and, in so doing, give rise to aging. The extent to which aging occurs depends on the interstitial solute level and the combination of temperature and time to which the steel is exposed after temper rolling. In general, higher interstitial solute levels result in larger strength increases during storage; the rate of aging increases with increasing temperature. As described as follows, the final interstitial solute level and aging characteristics depend on the chemical composition of the steel as well as specific sheet-processing methods used by the steel producer.

X1.3 *Low-Carbon Steels*—In conventional aluminum-killed low-carbon steels, the level of interstitial solute is affected mainly through the formation of aluminum nitride and iron carbides within the steel during processing, which is influenced by the manner in which annealing is performed.

X1.3.1 Many sheet products are annealed in batches of large, tightly wound coils. During heating, any solute nitrogen present in the full-hard sheet combines with aluminum to form aluminum nitride. Subsequent cooling is very slow and allows essentially all of the carbon to precipitate as iron carbide. Final interstitial solute levels are very low and, as a result, batch-annealed low-carbon steels have excellent resistance to aging.

X1.3.1.1 Deep drawing steel (DDS) sheet typically is batch-annealed and has excellent aging resistance. With temper rolling, DDS sheet is suitable for use in many exposed applications with severe forming requirements.

X1.3.2 Cold-rolled low-carbon steels are sometimes processed in a continuous annealing line, in which the full-hard sheet is uncoiled, passed through an annealing furnace, and then rewound in a continuous manner. Heating and cooling rates are much higher than those found in batch annealing. The faster cooling, in particular, results in higher levels of interstitial solute in the product as compared with batch annealing. The manner in which the sheet is cooled can be controlled to minimize the solute carbon level, and temper rolling is effective for reducing fluting tendencies. However, continuous-annealed low-carbon steels are more prone to subsequent aging than batch-annealed steels.

X1.3.2.1 Low-carbon commercial steel (CS) and drawing steel (DS) sheet are available as either batch- or continuous-annealed products, depending on the facilities of a given producer. To minimize aging effects in continuous-annealed products, rotation of stock by fabricating the oldest material first is recommended.

X1.4 *Interstitial-Free Steels*—Interstitial-free steels have essentially no interstitial solutes and, as a result, are nonaging. Processing involves vacuum degassing during refining of the liquid steel, as well as additions of elements that form very stable carbides and nitrides, such as titanium or columbium (niobium). These steps ensure that total interstitial levels are very low, and that the interstitials are all chemically combined (or stabilized) in the form of alloy carbides or nitrides. Interstitial-free steels are nonaging regardless of whether annealing is conducted in a continuous or batch manner.

X1.4.1 Extra-deep drawing steel (EDDS) must be vacuum degassed and stabilized. This nonaging, interstitial-free product is suitable for exposed applications with the most severe forming requirements.

X1.5 *Bake-Hardenable Steels*—Bake-hardenable steels are a special product class with controlled interstitial solute levels and aging behavior. These steels are processed to have moderate aging resistance, to permit forming while the steel is in its most ductile condition. Aging occurs largely during a subsequent thermal treatment (for example, paint-curing), which results in desirable hardening of the final part for better durability.

X1.5.1 Continuous-annealed low-carbon steels can exhibit significant bake-hardening, as well as certain vacuum-degassed and batch-annealed steels.

TABLE X2.1 Standard Steels—Carbon Sheet Steel Compositions

Steel Designation No.	Chemical Composition Limits, %			
	C	Mn	P max	S max
1001	0.01 max	0.35 max	0.030	0.035
1002	0.02 max	0.35 max	0.030	0.035
1003	0.04 max	0.35 max	0.030	0.035
1004	0.02/0.06	0.35 max	0.030	0.035
1005	0.06 max	0.35 max	0.030	0.035
1006A	0.02/0.08	0.45 max	0.030	0.035
1006	0.08 max	0.45 max	0.030	0.035
1007	0.02/0.10	0.50 max	0.030	0.035
1008	0.10 max	0.50 max	0.030	0.035
1009	0.15 max	0.60 max	0.030	0.035
1010	0.08–0.13	0.30–0.60	0.030	0.035
1012	0.10–0.15	0.30–0.60	0.030	0.035
1015	0.13–0.18	0.30–0.60	0.030	0.035
1016	0.13–0.18	0.60–0.90	0.030	0.035
1017	0.15–0.20	0.30–0.60	0.030	0.035
1018	0.15–0.20	0.60–0.90	0.030	0.035
1019	0.15–0.20	0.70–1.00	0.030	0.035
1020	0.18–0.23	0.30–0.60	0.030	0.035
1021	0.18–0.23	0.60–0.90	0.030	0.035
1022	0.18–0.23	0.70–1.00	0.030	0.035
1023	0.20–0.25	0.30–0.60	0.030	0.035
1025	0.22–0.28	0.30–0.60	0.030	0.035
1026	0.22–0.28	0.60–0.90	0.030	0.035
1030	0.28–0.34	0.60–0.90	0.030	0.035
1033	0.30–0.36	0.70–1.00	0.030	0.035
1035	0.32–0.38	0.60–0.90	0.030	0.035
1037	0.32–0.38	0.70–1.00	0.030	0.035
1038	0.35–0.42	0.60–0.90	0.030	0.035
1039	0.37–0.44	0.70–1.00	0.030	0.035
1040	0.37–0.44	0.60–0.90	0.030	0.035
1042	0.40–0.47	0.60–0.90	0.030	0.035
1043	0.40–0.47	0.70–1.00	0.030	0.035
1045	0.43–0.50	0.60–0.90	0.030	0.035
1046	0.43–0.50	0.70–1.00	0.030	0.035
1049	0.46–0.53	0.60–0.90	0.030	0.035
1050	0.48–0.55	0.60–0.90	0.030	0.035
1055	0.50–0.60	0.60–0.90	0.030	0.035
1060	0.55–0.65	0.60–0.90	0.030	0.035
1064	0.59–0.70	0.50–0.80	0.030	0.035
1065	0.60–0.70	0.60–0.90	0.030	0.035
1070	0.65–0.75	0.60–0.90	0.030	0.035
1074	0.70–0.80	0.50–0.80	0.030	0.035
1078	0.72–0.85	0.30–0.60	0.030	0.035
1080	0.75–0.88	0.60–0.90	0.030	0.035
1084	0.80–0.93	0.60–0.90	0.030	0.035
1085	0.80–0.93	0.70–1.00	0.030	0.035
1086	0.80–0.93	0.30–0.50	0.030	0.035
1090	0.85–0.98	0.69–0.90	0.030	0.035
1095	0.90–1.03	0.30–0.50	0.030	0.035
1524	0.19–0.25	1.35–1.65	0.030	0.035
1527	0.22–0.29	1.20–1.50	0.030	0.035
1536	0.30–0.37	1.20–1.50	0.030	0.035
1541	0.36–0.44	1.35–1.65	0.030	0.035
1548	0.44–0.52	1.10–1.40	0.030	0.035
1552	0.47–0.55	1.20–1.50	0.030	0.035

NOTE—When silicon is required, the following ranges and limits are commonly used.

To 1015, excl	0.10 max
1015 to 1025, incl	0.10 max, 0.10–0.25, or 0.15–0.30
Over 1025	0.10–0.25 or 0.15–0.30

X2. STANDARD CHEMICAL RANGES AND LIMITS

X2.1 Standard chemical ranges and limits are prescribed for carbon steels in Table X2.1 and Table X2.2.

TABLE X2.2 Standard Chemical Ranges and Limits

NOTE 1—The carbon ranges shown in the column headed “Range” apply when the specified maximum limit for manganese does not exceed 1.00 %. When the maximum manganese limit exceeds 1.00 %, add 0.01 to the carbon ranges shown below.

Element	Carbon Steels Only, Cast or Heat Analysis		
	Maximum Specified Element, %	Range	Lowest max
Carbon (see Note)	to 0.15 incl	0.05	0.08
	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 to 1.35 incl	0.14	
Manganese	to 0.50 incl	0.20	0.40
	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	0.030[A]
	over 0.08 to 0.015 incl	0.05	
Sulfur	to 0.08 incl	0.03	0.035[A]
	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	0.10
	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 min is commonly specified.		

[A] Certain individual specifications provide for lower standard limits for phosphorus and sulfur.

X3. PROCEDURE FOR DETERMINING BREAKAGE ALLOWANCE LEVELS (APPLICABLE TO CARBON STEEL SHEET ONLY)

X3.1 In spite of the many extra precautions exercised in making sheet for drawing purposes, certain manufacturing variables may be encountered, all beyond the manufacturer's reasonable control, which may contribute to breakage in fabrication and must be considered as part of the normal hazard of the purchaser's use. The manufacturer will undertake to establish with the purchaser's concurrence a breakage allowance level.

X3.2 Breakage, for the purpose of this proposal, is defined as unrepairable parts, broken during drawing and classed as scrap. Parts showing laminations, resulting from pipe, may be excluded provided they are separately identified. Broken parts that can be salvaged are not covered in this procedure.

X3.3 This procedure is intended to establish a breakage allowance without the need for reinspection of each broken stamping. It will apply to overall breakage on a given part (as calculated by the method outlined below) in excess of 1 % up to and including 8 %. Inherent variations in steel and normal variables in the stamping operation preclude 100 % satisfactory performance. Therefore, it is accepted that practical perfection is attained when 99 % of the stampings are produced without breakage. When the overall breakage is in excess of 8 %, it is considered to be the result of abnormal stamping conditions, and this method does not apply.

X3.4 When there are two or more suppliers, the recommended procedure for determining a breakage allowance for an identified part is based on the average percentage of breakage of at least 75 % of the blanks run on that part, on one set of dies, during at least one month (3000 piece minimum). The total production of all suppliers used to obtain this 75 % minimum is to be included in the calculation starting with the best performance. The average breakage thus determined shall be considered the allowance for the part.

X3.4.1 *Example*:

Vendor	Parts Produced	Parts Scrap	% Scrap
A	32 466	630	1.94
B	27 856	579	2.08
C	67 120	1477	2.20
D	56 200	1349	2.40
E	40 900	1125	2.75
F	850	60	7.05
11	225 392 total	5220 total	2.32 avg

X3.4.2 Seventy-five percent of 225 392 equals to 169 044; therefore, it is necessary to include the total production of vendors A, B, C, and D (A + B + C + D = total production of 183 642 parts) since the total of A, B, and C is only 127 442, which is less than 75 % of the total. Total production of 183 642 parts (A + B + C + D) with 4035 parts being rejected, results in a percentage allowance of 2.20 %. On this basis, vendors D, E, and F exceed the allowance.

X4. PROCEDURES FOR DETERMINING THE EXTENT OF PLASTIC DEFORMATION ENCOUNTERED IN FORMING OR DRAWING

X4.1 Introduction

X4.1.1 The preferred method for determining plastic strain is the circle grid and forming limit curve. The scribed square and change in thickness methods may also be used to evaluate deformation during the forming of a flat sheet into the desired shape.

X4.2 Circle Grid Method

X4.2.1 The test system employs photographic or electrochemically etched circle patterns on the surface of a sheet metal blank of known "quality" and a forming limit curve for the evaluation of strains developed by forming in press operations. It is useful in the laboratory and in the press room. Selection from the various steels that are commercially available can be done effectively by employing this technique. In addition, corrective action in die or part design to improve performance is indicated.

X4.2.2 The forming limit curve in Fig. X4.1 has been developed from actual measurements of the major (e_1) and associated minor (e_2) strains found in critical areas of production type stampings. Strain combinations that locate below this curve are safe, while those that fail above the curve are critical. For analysis of metal strain on production stampings, one must recognize that day-to-day variations of material, lubrication, and die settings will affect the strain level. To ensure trouble-free press performance a zone below the forming limit curve bounded by the dashed and solid lines is designated as the "safety band." Therefore, strain combinations falling below the dashed lines should not exceed the forming limit curve in normal production operations. The left of zero portion of the curve defines the limiting biaxial tension-compression strain combination while the right side defines the forming limit curve. Because the production stampings used to develop for forming limit curve represented all qualities of low-carbon light-gauge sheet steel, this single forming limit curve can be used successfully for these products.

X4.2.3 The circle grid method can also be used for other low-carbon sheet categories if the following adjustments to the forming limit curve are made:

X4.2.3.1 *Material Thickness*—As the metal thickness increases the forming limit curve shifts upwards in a parallel manner, 0.2 % (e_1) strain for each 0.025-mm increase in metal thickness above 0.75 mm.

X4.2.3.2 *Material Properties*—When material properties are considerably different from that of conventional low-carbon sheet steel (for example, higher strength-low ductility),

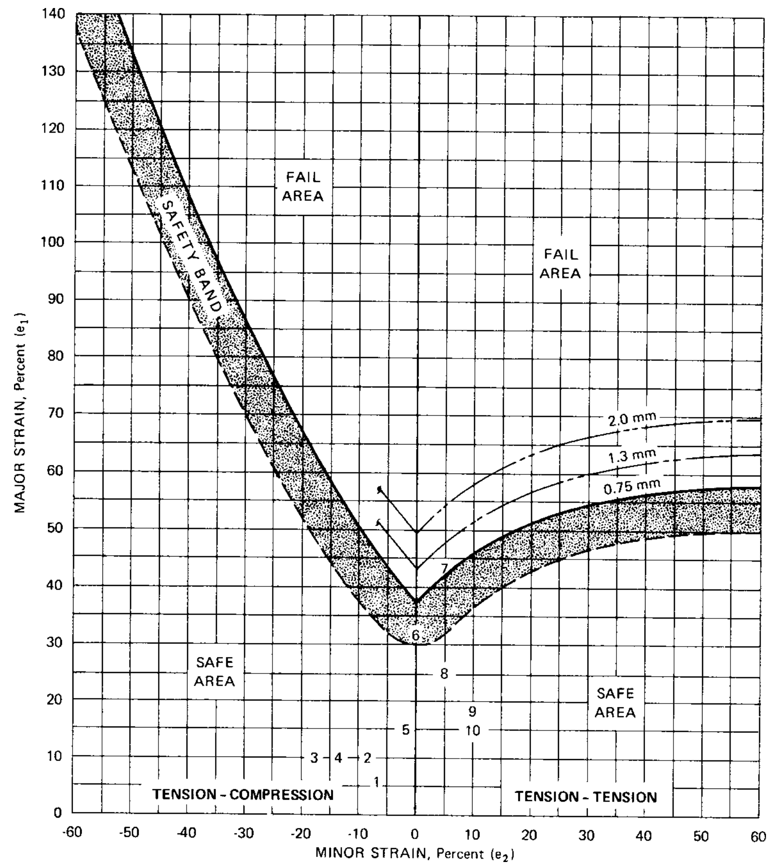

FIG. X4.1 Forming Limit Curve

the forming limit curve is lower. The magnitude of the downgrade displacement is specific to each material; therefore, current material information should be consulted to determine placement of the forming limit curve.

X4.3 Procedure

X4.3.1 Obtain a sheet sample of "known quality," the sheet quality being established by either supplier designation, consumer purchase order, or most preferred tensile data obtained from a companion sheet sample.

X4.3.2 Obtain or prepare a negative on stencil with selected circles in a uniform pattern. The circles may be 2.5 to 25.0 mm in diameter; the most convenient diameter is 5.0 mm because it is easy to read and the gauge spacing is short enough to show the maximum strain in a specific location on the part.

X4.3.3 The sheet metal blanks should be cleaned to remove excess oil and dirt; however, some precoated sheets can be etched without removing the coating. The area(s) to be etched should be determined from observation of panels previously formed; generally, the area that has a split problem is selected for etching. Normally, the convex side of the radius is gridded. If sufficient time is available, the entire blank may be etched, since valuable information can be obtained about the movement of metal in stamping a part when strains can be evaluated in what may appear to be noncritical areas. Additionally, for complex shapes it may be desirable to etch both surfaces of blanks so that the strains that occur in reverse draws can be determined.

X4.3.4 The sheet metal blanks may be etched by a photographic or electrochemical method. In the former method of photosensitive solution, for example, 50 % Kodak Photo Resist (KPR) emulsion and 50 % KPR-thinner, is sprayed onto the sheet. The emulsion is dried by baking the sheet at 65°C for 15 min or by just standing it for several hours at room temperature in a dark room. The latter should be employed in materials that age and, hence, become stronger when baked at 65°C. The negative is placed on the emulsion, held intimately in contact with the sheet, and exposed to a strong ultraviolet light source for 1 to 1½ min. The sheet is developed for 30 to 45 s in KPR developer, rinsed with water, and sprayed with alcohol to set the resist. It is again rinsed with water and then sprayed with KPR black dye to reveal the etched circles.

X4.3.5 In the electrochemical method, the etch pad is saturated with an appropriate electrolyte. Various electrolytes are available from suppliers of the etching equipment. Some electrolytes are more effective than others for etching certain surfaces, such as terne plate and other metallic coated steels. A rust-inhibiting solution is preferred for steel sheets.

X4.3.6 A ground clamp for the transformer of suitable amperage (10 to 50 A is usually used) is fastened to the blank and the second lead is attached to the etch pad. Although the current may be turned on at this time, caution should be taken not to lay the pad on the sheet blank as it will arc. It is advisable to refrain from touching the metal of the etch pad and the grounded sheet blank.

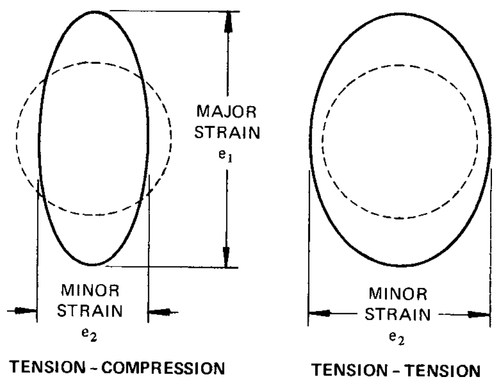

FIG. X4.2 Major and Minor Strain Axes

X4.3.7 The stencil is placed with the plastic coating against the sheet surface in the area to be etched. Wetting the stencil with a minimum amount of electrolyte will assist in smoothing out the wrinkles and gives a more uniform etch. The etch pad is now positioned on the stencil and the current turned on, if it is not already on. Apply suitable pressure to the pad. Only the minimum time necessary to produce a clear etched pattern should be used. The etching time will vary with the amperage available from the power source and the stencil area, as well as the pad area in contact with the stencil. Rocker-type etch pads give good prints and require less amperage than flat-surfaced pads. Excessive current causes stencil damage.

X4.3.8 The etching solution activates the surface of the metal and may cause rusting unless it is inhibited. After the desired area has been etched, the blank should be wiped or rinsed, dried, and neutralized.

X4.3.9 The etched blank is now ready for forming. The lubricants and press conditions should simulate production situations. If a sequence of operations is used in forming a part, it is desirable to etch sufficient blanks so that each operation can be studied.

X4.4 Measurement of Strain After Forming

X4.4.1 After forming, the circles are generally distorted into elliptical shapes (Fig. X4.2). These ellipses have major and minor strain axes. The major strain (e_1) is always defined to be the direction in which the greatest positive strain has occurred without regard to original blank edges or the sheet rolling direction. The minor strain (e_2) is defined to be 90° to the major strain direction.

X4.4.2 There are several methods for determining the major and minor strains of the formed panel. Typical tools are a pair of dividers and a scale ruled in 0.5 mm. For sharp radii, a thin plastic scale that can follow the contour of the stamping can be used to determine the dimensions of the ellipses. (Scales are available to read the percent strain directly.)

X4.5 Evaluation of Strain Measurements

X4.5.1 The e_1 strain is always positive while the e_2 strain may be zero, positive, or negative, as indicated on the forming limit curve chart (Fig. X4.1). The maximum e_1 and associated e_2 values measured in critical areas on the formed part are plotted on the graph paper containing the forming limit curve by locating the point of intersections of the e_1, e_2 strains.

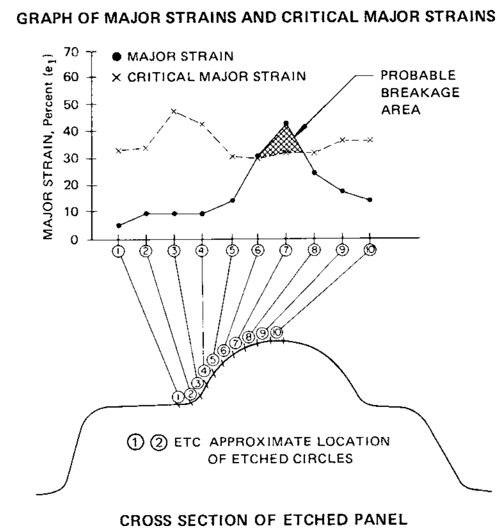

FIG. X4.3 Graph of Major Strains and Critical Major Strains and Cross Section of Etched Panel

X4.5.2 If this point is on or below the "safety band" of the forming limit curve, the strain should not cause breakage. Points further below the curve indicate that a less ductile material of a lower grade may be applied. Points above the "safety band" show that fabrication has induced strains that could result in breakage. Therefore, in evaluation on stampings exhibiting these strains, efforts should be made to provide an e_1, e_2 strain combination that would lie on or below the "safety band" of the forming limit curve. A different e_1, e_2 strain combination can be obtained through changes of one or more of the forming variables such as die conditions, lubricants, blank size, thickness, or material grade. It should be noted at this time that these conclusions are derived from a reference base being the steel "quality" used to fabricate the grid stamping.

X4.5.3 When attempting to change the relationship of e_1 and e_2 strains, it should be noted that on the forming limit curve the most severe condition for a given e_1 strain is at 0 % e_2 strain. This means the metal works best when it is allowed to deform in two dimensions, e_1 and e_2, rather than being restricted in one dimension. A change in e_2 to decrease the severity can be made by changing one of the previously mentioned forming variables of the die design, for example, improving lubrication on the tension-tension side will increase e_2 and decrease the severity.

X4.5.4 In addition to the forming limit curve, the $e_1 e_2$ strain measurements may be used to evaluate the material requirements on the basis of strain gradients, as illustrated in Fig. X4.3, or by plotting contours of equivalent strain levels on the surface of the formed part. Even when the level of strain is relatively low, parts in which the e_1 strain is changing rapidly either in magnitude or direction over a short span on the surface may require more ductile grades of sheet metal, change in lubrication, or change in part design.

X4.6 Example of Major and Minor Strain Distribution

X4.6.1 A formed panel (Fig. X4.4) with a cross section as shown in Fig. X4.3 is used to illustrate major and minor strain

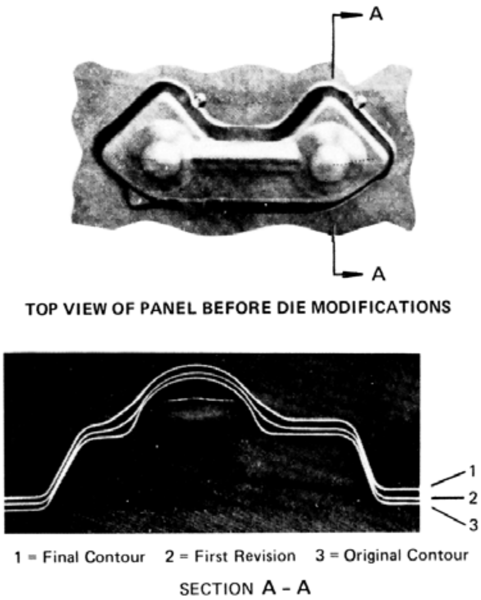

FIG. X4.4 Formed Panel and Cross Section

combinations. A plot of the major strain distribution should be made by finding the ellipse with the largest major strain (circle 7) and measuring both the major and minor strains in the row of ellipses running in the direction of the major strain. The solid dots (Fig. X4.3) are the measured major strains for each ellipse. The Xs are the critical major strains as determined from the forming limit curve at the corresponding minor strain (intersection of the measured minor strain and the severity curve).

X4.6.2 Usually a single row of ellipses will suffice to determine the most severe strain distribution. The resulting strain distribution plot (Fig. X4.3) illustrates both severity of the strain compared to the critical strain limits and the concentration of strain in the stamping. Steep strain gradients should be avoided because they are inherent to fracture sites.

X4.7 Example for Reducing Splitting Tendency

X4.7.1 In an area such as that represented in Fig. X4.3, the splitting tendency can be reduced as follows:

X4.7.1.1 If the radius of the part in the region of circle 1 is increased, some strain can be induced to take place in this area which will allow the major strain in circle 7 to be reduced sufficiently to bring the strain combination below the critical limit. This course of action requires no binding nor reshaping of the punch, only grinding in the radius.

X4.7.1.2 The total average major strain required to make this formation is only 17.5 %; yet in a 5.0-mm circle the strain is as high as 40 %. The strain distribution curve puts forth graphically the need to distribute the strain over the length of the time by some means as described above.

X4.7.1.3 Change in lubrication can also improve the strain distribution of a stamping. If the strain over the punch is critical, the amount of stretch (strain) required to make the shape can be reduced by allowing metal to flow in over the punch by decreasing the friction through the use of a more effective lubricant in the hold-down era.

X4.7.1.4 If the part is critical, a change in material may help. That is, a material having a better uniform elongation will distribute the strain more uniformly or a material having a higher "r" value will make it possible to "draw" in more metal from the hold-down area so that less stretch is necessary to form the part.

X4.8 Scribed Square Method

X4.8.1 The basic technique is to draw a panel from a blank that has been scribed both longitudinally and transversely with a series of parallel lines spaced at 25.0-mm intervals. The lines on the panel are measured after drawing and the stretch or draw calculated as the percent increase in area of a 25.0-mm square. This is a fairly simple procedure for panels having generous radii and fairly even stretch or draw. Many major panels fall in this category, and in these instances it is quite easy to pick out the square area exhibiting the greatest increase.

X4.8.2 If the square or line to be measured is no longer a flat surface, place a narrow strip of masking (or other suitable tape) on the formed surface and mark the points which are to be measured. Remove the tape, place on a plane surface, and determine the distance between the points with a steel scale.

X4.8.3 There will be cases of minor increase in area with major elongation in the one direction. In these instances, the percent elongation should be recorded.

X4.9 Thickness Method

X4.9.1 There are instances when the maximum stretch is continued to an area smaller than 645 mm^2 or the shape of the square has been distorted irregularly, making measurements difficult and calculation inaccurate. When either of these conditions exists, an electronic thickness gauge may be used at the area in question or this area may be sectioned and the decrease in metal thickness measured with a ball-point micrometer. The increase in unit area can be calculated by dividing the original thickness by the final thickness.

X4.9.2 *Example*

Assuming the blank thickness to be 0.80 mm and the final thickness to be 0.60 mm, the increase in unit area would be a $[(0.80 - 0.60)/0.80] \times 100 = 25\ \%$ increase.

X5. ALTERNATIVE METHODS FOR EXPRESSING FLATNESS

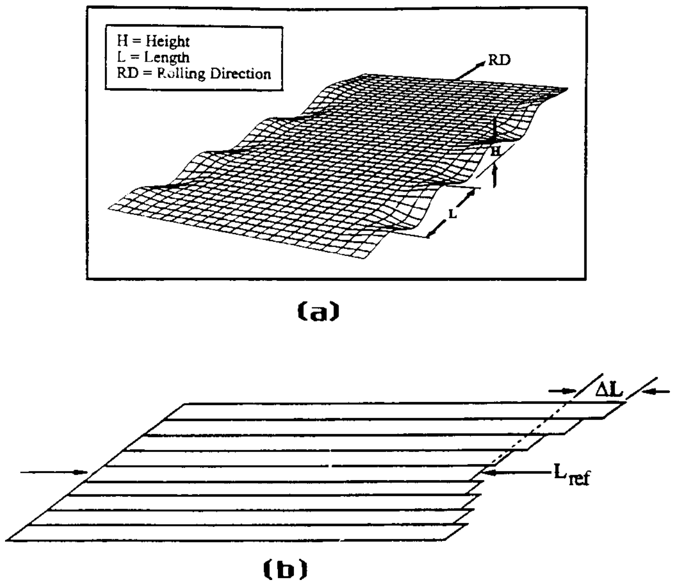

FIG. X5.1 Representation of Sheet Sample With Edge Waves (*a*) and Strips of Differing Length That Result from Making Longitudinal Cuts Along the Sample (*b*)

X5.1 Introduction and Definitions

X5.1.1 In addition to the conventional expression of flatness, the "maximum deviation from a horizontal flat surface," at least two other flatness parameters have been developed and are in use for characterizing sheet with longitudinal waves or buckles. These are *steepness index* and *flatness index* (or "I-unit"), that are illustrated using the example in Fig. X5.1.

X5.1.2 *Steepness Index*—Fig. X5.1(*a*) shows a representation of a sheet sample exhibiting edge waves of height, H, and interval, L. The steepness index value for this sample is defined as:

$$\textit{steepness index} = H/L$$

Often, the steepness value is expressed as a percentage:

$$\%\ \textit{steepness} = S = (H/L) \times 100$$

X5.1.3 *I-Units*—Making a series of lengthwise cuts to the sample in Fig. X5.1(*a*) relaxes elastic stresses present in the sheet and results in narrow strips of differing lengths, as shown in Fig. X5.1(*b*). Using the length of one of these strips as a reference (L_{ref}), the I-unit value (I) for an individual strip is defined as:

$$I = (\Delta L/L_{ref}) \times 10^5$$

where:

ΔL is the difference between the length of a given strip and the reference strip.

X5.1.4 For the special case of waves/buckles that are perfectly sinusoidal in character, the following relationship applies:

$$I = \left[\left(\frac{\pi}{2}\right)\left(\frac{H}{L}\right)\right]^2 \times 10^5$$

or:

$$I = 24.7S^2$$

Table X5.1 provides I-unit values based on the sinusoidal approximation for wave heights up to ½-in. (increments of 1⁄32 in.) and intervals between 10 and 40 in. (increments of 1 in.). Mathematical relationships between the three representations of flatness described here are given in Table X5.2; these relationships can be used to convert between I-unit, % steepness, and wave height values (see examples in Table X5.2).

X5.2 Flatness Evaluation Example and Determination of I-Unit or % Steepness Value

X5.2.1 While the strip is on an inspection table, find the locations on the strip that are not lying flat on the table. If no flatness deviation can be found, that portion of the coil (head/middle/tail) can be described as flat (that is, zero I-unit or zero % steepness).

X5.2.2 If the coil is not totally flat, the height of the deviation must be determined and recorded. If the coil has edge waves, a step gauge (incremented in intervals of 1⁄16 or 1⁄32 in.) can be inserted under a wave to determine the height. If the coil exhibits flatness deviation in the center of the strip, a lightweight straight edge can be placed on the highest portion of the buckle and on the highest portion of the next repeating buckle. The height can then be determined by inserting a step gauge between the straight edge and the strip.

X5.2.3 Along with the height, the wave period or wave interval must also be determined. The wave interval can be obtained by using a standard tape measure or straight edge to measure the distance between the highest point of one flatness deviation to the highest point of the next repeating flatness deviation.

X5.2.4 After determining height and wave interval, either the I-unit or % steepness value can be obtained. To determine the I-unit flatness, locate the appropriate height and wave interval in Table X5.1 and read the I-unit value at the intersection of the two measurements. To determine % steepness, divide the height by the wave interval and multiply the result by 100.

TABLE X5.1 I-Unit Conversion Chart

Wave Height (in.)	Wavelength (in.) 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1/32	2	2	2	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1/16	10	8	7	6	5	4	4	3	3	3	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3/32	22	18	15	13	11	10	8	8	7	6	5	5	4	4	4	3	3	3	3	3	2	2	2	2	2	2	2	2	2	1	1
1/8	39	32	27	23	20	17	15	13	12	11	10	9	8	7	7	6	6	5	5	5	4	4	4	4	3	3	3	3	3	3	2
5/32	60	50	42	36	31	27	24	21	19	17	15	14	12	11	10	10	9	8	8	7	7	6	6	6	5	5	5	4	4	4	4
3/16	87	72	60	51	44	39	34	30	27	24	22	20	18	16	15	14	13	12	11	10	10	9	8	8	8	7	7	6	6	6	5
7/32	118	98	82	70	60	53	46	41	36	33	30	27	24	22	21	19	17	16	15	14	13	12	12	11	10	10	9	9	8	8	7
1/4	154	128	107	91	79	69	60	53	48	43	39	35	32	29	27	25	23	21	20	18	17	16	15	14	13	13	12	11	11	10	10
9/32	195	161	136	116	100	87	76	68	60	54	49	44	40	37	34	31	29	27	25	23	22	20	19	18	17	16	15	14	14	13	12
5/16	241	199	168	143	123	107	94	83	74	67	60	55	50	46	42	39	36	33	31	29	27	25	24	22	21	20	19	18	17	16	15
11/32	292	241	203	173	149	130	114	101	90	81	73	66	60	55	51	47	43	40	37	35	32	30	29	27	25	24	23	21	20	19	18
3/8	347	287	241	206	177	154	136	120	107	96	87	79	72	66	60	56	51	48	44	41	39	36	34	32	30	28	27	25	24	23	22
13/32	408	337	283	241	208	181	159	141	126	113	102	92	84	77	71	65	60	56	52	48	45	42	40	37	35	33	31	30	28	27	25
7/16	473	391	328	280	241	210	185	164	146	131	118	107	98	89	82	76	70	65	60	56	53	49	46	43	41	39	36	35	33	31	30
15/32	543	449	377	321	277	241	212	188	168	150	136	123	112	103	94	87	80	74	69	65	60	56	53	50	47	44	42	40	38	36	34
1/2	618	510	429	365	315	274	241	214	191	171	154	140	128	117	107	99	91	85	79	73	69	64	60	57	53	50	48	45	43	41	39

Wave Height (mm)	Wavelength (mm) 250	275	300	325	350	375	400	425	450	475	500	525	550	575	600	625	650	675	700	725	750	775	800	825	850	875	900	925	950	975	1000
0.5	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.0	4	3	3	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1.5	9	7	6	5	5	4	3	3	3	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2.0	16	13	11	9	8	7	6	5	5	4	4	4	3	3	3	3	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1
2.5	25	20	17	15	13	11	10	9	8	7	6	6	5	5	4	4	4	3	3	3	3	3	2	2	2	2	2	2	2	2	2
3.0	36	29	25	21	18	16	14	12	11	10	9	8	7	7	6	6	5	5	5	4	4	4	3	3	3	3	3	3	2	2	2
3.5	48	40	34	29	25	22	19	17	15	13	12	11	10	9	8	8	7	7	6	6	5	5	5	4	4	4	4	4	3	3	3
4.0	63	52	44	37	32	28	25	22	20	18	16	14	13	12	11	10	9	9	8	8	7	7	6	6	5	5	5	5	4	4	4
4.5	80	66	56	47	41	36	31	28	25	22	20	18	17	15	14	13	12	11	10	10	9	8	8	7	7	7	6	6	6	5	5
5.0	99	82	69	58	50	44	39	34	30	27	25	22	20	19	17	16	15	14	13	12	11	10	10	9	9	8	8	7	7	6	6
5.5	120	99	83	71	61	53	47	41	37	33	30	27	25	23	21	19	18	16	15	14	13	12	12	11	10	10	9	9	8	8	7
6.0	142	118	99	84	73	63	56	49	44	39	36	32	29	27	25	23	21	20	18	17	16	15	14	13	12	12	11	10	10	9	9
6.5	167	138	116	99	85	74	65	58	52	46	42	38	34	32	29	27	25	23	21	20	19	17	16	15	14	14	13	12	12	11	10
7.0	194	160	134	115	99	86	76	67	60	54	48	44	40	37	34	31	29	27	25	23	22	20	19	18	17	16	15	14	13	13	12
7.5	222	184	154	132	113	99	87	77	69	62	56	50	46	42	39	36	33	30	28	26	25	23	22	20	19	18	17	16	15	15	14
8.0	253	209	176	150	129	112	99	88	78	70	63	57	52	48	44	40	37	35	32	30	28	26	25	23	22	21	20	18	18	17	16
8.5	286	236	198	169	146	127	112	99	88	79	71	65	59	54	50	46	42	39	36	34	32	30	28	26	25	23	22	21	20	19	18
9.0	320	265	222	189	163	142	125	111	99	89	80	73	66	61	56	51	47	44	41	38	36	33	31	29	28	26	25	23	22	21	20
9.5	357	295	248	211	182	159	139	123	110	99	89	81	74	67	62	57	53	49	45	42	40	37	35	33	31	29	28	26	25	23	22
10.0	395	327	274	234	202	176	154	137	122	109	99	90	82	75	69	63	58	54	50	47	44	41	39	36	34	32	30	29	27	26	25

TABLE X5.2 Flatness Conversion Factors[A]

NOTE 1— "L" is the wave interval as defined in Fig. X5.1 (*a*).

	I Unit	Height	% Steepness
I Unit (I)	1	$\frac{2L}{\pi}\sqrt{I\,10^{-5}}$	$\frac{2}{\pi}\sqrt{I\,10^{-1}}$
Height (H) (peak to peak)	$\left(\frac{H\pi}{2L}\right)^2 10^5$	1	$\frac{(100\,H)}{L}$
% Steepness (S)	$2.5\,(\pi\,S)^2$	$\frac{(LS)}{100}$	1

[A] Examples—(*1*) Assume % steepness is given as 1.5 and the corresponding I-unit value is desired. From Table X5.2, I = $2.5(\pi S)^2 = 2.5[(3.14)(1.5)]^2 = 55.5$. (*2*) Assume an I-unit value of 25 is given and the corresponding % steepness is desired. From Table X5.2, S = $2/\pi(I \times 10^{-1})^{1/2} = 2/3.14\,(25 \times 10^{-1})^{1/2} = 1.0$.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A568/A568M – 07a) that may impact the use of this standard. (Approved May 1, 2009.)

(*1*) Section 2.3—Reference to Fed. Std. No. 183 removed.
(*2*) Section 3.1.5 *(1)*—Width limits changed and thickness errors corrected for carbon and structural and high-strength low-alloy limits.
(*3*) Section 3.1.6 *(2)*—Size value corrected in note A.
(*4*) Tables 4-7—Width limits changed and notes added.
(*5*) Table 9—Width limits changed.
(*6*) Tables 12-14—Title change dropping 12 in. width limit.
(*7*) Table 15—Width limits changed.
(*8*) Tables A1.1-A1.4—Width limits changed and notes added.
(*9*) Table A1.6—Width limits changed.
(*10*) Tables A1.9-A1.11—Title change dropping 300 mm width limit.
(*11*) Table A1.15—Thickness tolerance entry corrected.

Committee A01 has identified the location of selected changes to this standard since the last issue, A568/A568M – 07, that may impact the use of this standard. (Approved November 1, 2007.)

(*1*) Table 5 corrected for material 0.180 to 0.230 excl, over 72 in. wide.
(*2*) Section 3.1.6 enlarged to cover all cold roll up to 0.142 in.[4.0 mm] in all widths.
(*3*) Table 9 changed to denote it covers only material over 12 in. in width
(*4*) Table 17 enlarged to include material covered by deleted Table 19 and note added on measuring thickness of material <1 in width.
(*5*) Table 18 enlarged to match Table 17 but note deals with material <2 in width.
(*6*) Table 19 deleted as product now in Table 17.
(*7*) Table 20 deleted as product now in Table 18.
(*8*) Thickness restrictions deleted from Tables 19-22.
(*9*) Width limitation deleted from Table 23.
(*10*) Table A1.15 modified to allow for material less than 50 mm in width and note added to deal with narrow widths.
(*11*) Table A1.16 modified to agree with Table A1.15.
(*12*) Thickness limitations deleted from Table A1.17 and Table A1.18.
(*13*) Table A1.19 added comment that it deals with coils to 300 mm in width.
(*14*) Table Table 24 deleted reference to width limitations.