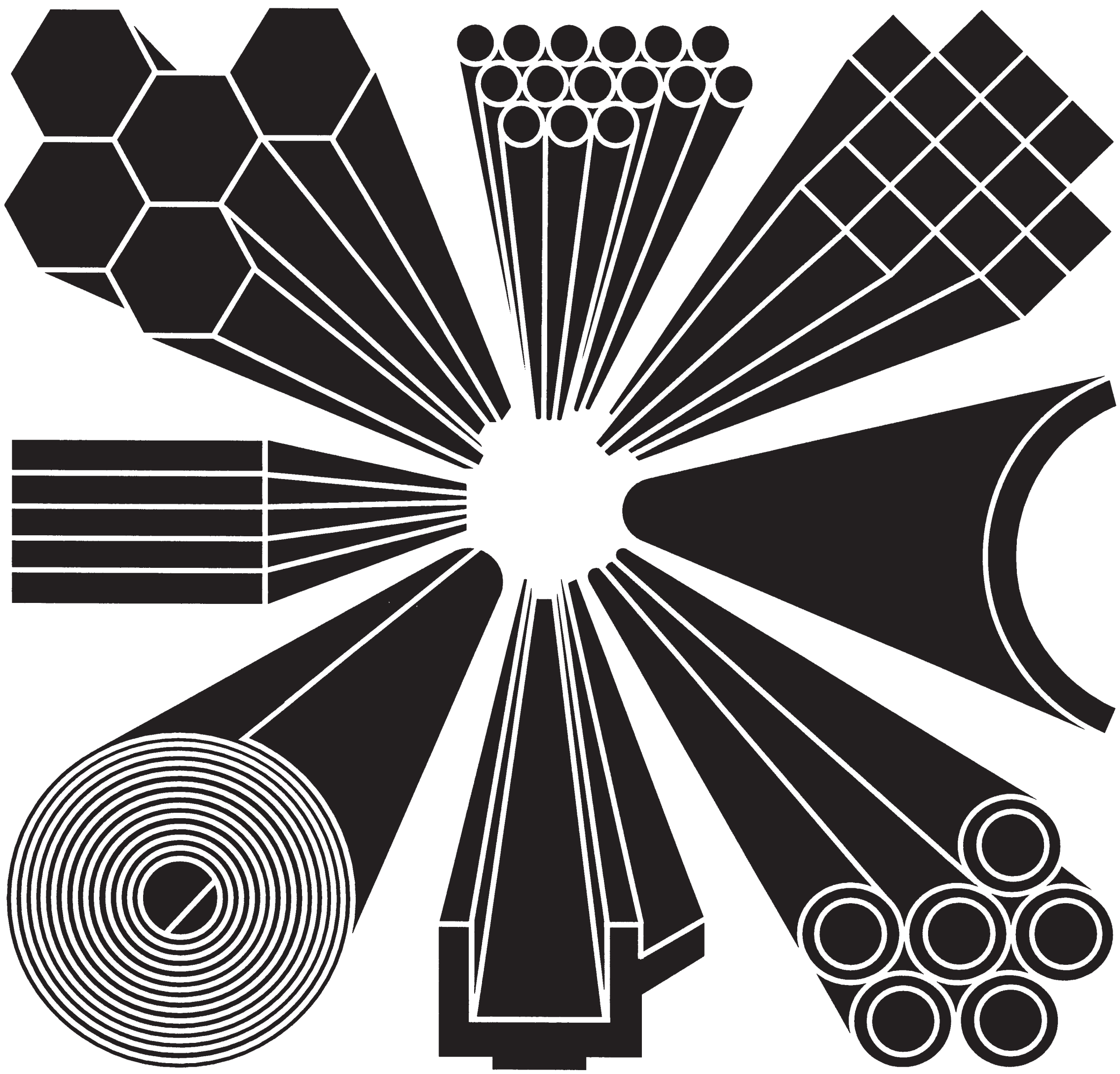
Aluminum standards and data 2009

The Aluminum Association
Incorporated



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Abbreviations Used in This Manual

ACSR	aluminum cable steel reinforced
BHN	Brinell hardness number
Btu	British thermal unit
cu	cubic
diam, D	diameter
dim.	dimension
°F	degree Fahrenheit
ft	foot
hr	hour
IACS	International Annealed Copper Standard
I. D.	inside diameter
in.	inch
kip	thousand pounds
ksi	thousand pounds per square inch or kips per square inch
lb	pound
max	maximum
MHZ	megahertz
mil	circular mil = 0.001 in.
min	minimum
mm	millimeter
O.D.	outside diameter
psi	pounds per square inch
sq	square

Other uses of single and combined letters (A, B, D, Y, AA, etc.) can be found in this publication. They represent linear measurements, radii, angles, and so forth, as shown on diagrams, formulas, and so on, contained in tables and shown as specific to that table.

Introduction

This manual contains useful information and data pertaining to chemical composition limits, mechanical and physical properties, tolerances and other characteristics of various aluminum and aluminum alloy wrought products. The content of the manual is subject to periodic revision to keep abreast of advances in production methods, to add data on new alloys and products, and to delete those that become inactive or whose usage becomes limited.

The criteria for adding or deleting alloy-tempers:

1. The alloy shall have been registered in accordance with the rules shown in the foreword to the "Registration Record of Aluminum Association Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys."
2. The temper shall have been registered as an AATD registration in accordance with the rules shown in the registration listing, "Tempers for Aluminum and Aluminum Alloy Products."
3. Entries shall be available for inclusion in all tables in Sections 1, 2, 3, 4, 6 and the applicable tolerance tables, unless the Technical Committee on Product Standards of The Aluminum Association considers some of the entries unnecessary or inappropriate.
4. Alloy-tempers shall be deleted when they become inactive or when their usage becomes limited.
5. All inclusions in or removals from ASD shall have been approved by formal ballot of the Technical Committee on Product Standards of The Aluminum Association.

Complete revision of the manual is customarily accomplished on a triennial basis. Important changes, additions or deletions that occur between issues are recorded in Addenda that may be published at appropriate intervals. Individual suppliers should be contacted for information concerning effectivity of changes included in the Addenda. This edition supersedes all previous editions and addenda.

The first three sections of the manual (blue pages) contain information of a general nature that may be useful in comparing materials. The typical properties and characteristics listed are not guaranteed and should not be used for design purposes. The fourth section (blue pages) contains information relating to testing, inspection and identification and the fifth section (yellow pages) lists the definitions of many terms used in the wrought aluminum industry. The remaining twelve sections (white pages) comprise chemical composition limits, mechanical property limits, dimensional tolerances and other data classified by product form.

Since a completely metric (SI) version is now available, the only metric values shown are those that have been customarily used.

Several typographical errors have been corrected from the previous edition. Vertical bars have been inserted in the margins to help the reader identify technical revisions. These revisions are summarized chronologically on the next page:

Chronological Summary of Changes to the 2009 Edition of Aluminum Standards and Data		
DATE	**PAGE (TABLE/PARAGRAPH)**	**DESCRIPTION OF CHANGE**
09-04-15	Cover Page	Changed date to 2009
09-04-15	1-3	Changed ANSI Date to 2009
09-04-15	1-4	Changed Definition for National Variations
09-04-15	1-4	Changed “Plus” to “Together With”
09-04-15	1-6	Changed Section Title
09-04-15	1-6	Changed to “Applicable” section
09-04-15	1-8	Correction to Footnote 9
09-04-15	1-9	Changed Section Title
09-04-15	1-9	Added Footnote 12
09-04-15	1-9	Corrected “Capability”
09-04-15	1-10	Changed Section Title
09-04-15	1-22	Correction to “AMS” Section
09-03-20	2-13 (Table II)	Added Density Factors for Scandium and Sodium
09-03-16	5-8	Modified Definition for Foil
09-03-16	5-17	Modified Definition for Sheet
09-03-16	9-2 (9.2)	Addition of New Gage Ranges
09-03-06	6-10 (6.7)	Corrected Temper T76510
09-02-13	7-9 (7.1)	Deleted Yield Strength Max for 5083-H32
09-02-13	7-10 (7.1)	Deleted Yield Strength Max for 5456-H32 and 5456-H321
09-01-26	7-19 (7.2)	Correction to Tensile Strength
09-01-26	7-25 (7.6)	Added H32 and H5456
08-10-08	6-5 (6.2)	Correction to Decimal Places
08-10-08	6-7 (6.4)	Replaced Footnotes 6 and 7 with Footnotes 4 and 9 to 7050-T74
08-10-08	6-8 (6.4)	Replaced Footnote 7 with Footnote 9 to 7175-T74
08-10-08	6-8 (6.4)	Added Definition for Footnote 9
08-10-08	6-8 (6.4)	Added “Suspect” to Lot Acceptance Status Column for 7075 and 7178
08-05-30	3-17 (3.5)	Added Alloy 6082
08-05-30	3-17 (3.5)	Deleted Footnote 4 to Alloy 7072
08-05-30	3-17 (3.5)	Added Footnote 4 to Alloy 7175
08-03-29	11-10 (11.8)	Replaced ‘Tolerance’ with ‘Tolerance Factor’
08-03-29	11-11 (11.9)	Replaced ‘Tolerance’ with ‘Tolerance Factor’
08-03-20	15-2 (15.1)	Corrected Ultimate Tensile Strength of 7050-T74
08-03-20	15-3 (15.2)	Inserted Short Transverse date for 2618-T61
08-03-20	15-3 (15.2)	Correction to Temper for 5083
08-03-20	15-4 (15.2)	Correction to Temper for 7049
08-03-20	15-4 (15.2)	Correction to Yield Strength of 7050-T7452
08-03-20	6-1	Changes to Mechanical Properties Definition
08-03-06	6-5 (6.2)	Correction to Footnote 4 Location
08-03-06	6-6 (6.2)	Correction to Footnote 4 Location
07-10-31	6-8 (6.4)	Added Alclad 7475-T761 Criteria
07-10-31	6-9 (6.6)	Added Alclad 7475-T61 and Alclad 7475-T761
07-10-31	7-21 (7.2)	Added Longitudinal Properties for Alclad 7475-T61 Sheet and Alclad 7475-T761 Sheet
07-10-25	2-2 (2.1)	Added Footnote 11 to 5083-H321
07-10-25	2-2 (2.1)	Added Footnote 11 to 5083-H116
07-10-25	2-2 (2.1)	Added Footnote 11 to 5456-H32
07-10-25	2-9 (2.2)	Added 7475-T651 Plate
07-10-25	7-9 (7.1)	Added Footnote 9 to 5083-H321
07-10-25	7-10 (7.1)	Added Footnote 9 to 5456-H321
07-10-25	7-21 (7.2)	Added 7475-T651 Longitudinal Properties
07-10-25	7-21 (7.2)	Added 7475-T651
07-10-25	7-37 (7.35)	Corrected Footnote 2

Chronological Summary of Changes to the 2009 Edition of Aluminum Standards and Data		
DATE	**PAGE (TABLE/PARAGRAPH)**	**DESCRIPTION OF CHANGE**
07-09-19	6-8 (6.4)	Added 7475-T761 Criteria
07-09-19	7-20 (7.2)	Added 7475-T61 Longitudinal Properties
07-09-19	7-21 (7.2)	Added 7475 -T761 Longitudinal Properties
07-07-25	5-8	Added Definition for 'Lot Cast'
07-07-25	5-8	Added Definition for 'Lot, Continuous Casting'
07-07-25	5-13	Modified the Definition for 'Sheet'
07-09-19	7-21 (7.2)	Added 7475 -T761 Longitudinal Properties
07-07-25	5-8	Added Definition for 'Lot Cast'
07-07-25	5-8	Added Definition for 'Lot, Continuous Casting'
07-07-25	5-13	Modified the Definition for 'Sheet'
07-06-05	3-10 (3.3)	Corrected T52 Temper for 6063
07-06-05	5-6	Modified the Definition for 'Foil'
07-06-01	3-10 (3.3)	Added B and A Corrosion Resistance Ratings for 6005
07-04-24	11-3 (11.1)	Added Footnote 14 to 6063 -T52
07-04-24	11-5 (11.1)	Added Footnote 14
07-04-24	12-4 (12.1)	Added Footnote 7 to 6063-T52
07-04-24	12-5 (12.1)	Added Footnote 7
07-03-26	11-6 (11.2)	Corrected Allowable Deviation from Specified Dimensions Under Column 3
07-03-26	11-10 (11.7)	Corrected Tolerance for Profiles, All Except 0 TX510 & TX511 3.0000 and Over
07-02-16	5-3	Added Definitions for Hard and Soft Conversion
07-02-16	5-7	Added Hard Conversion
07-02-16	5-14	Add Soft Conversion
07-01-25	2-2 (2.1)	Added 5083-H32
07-01-25	2-3 (2.1)	Added 5456-H32
07-01-25	2-7 (2.2)	Added 5083-H32
07-01-25	2-8 (2.2)	Added 5456-H32
07-01-25	3-3 (3.1)	Added H32 for 5083 Sheet & Plate
07-01-25	3-4 (3.1)	Added H32 for 5456 Sheet & Plate
07-01-25	3-9 (3.3)	Added H32 to 5083
07-01-25	3-9 (3.3)	Added H32 to 5456

1. General Information

A unique combination of properties makes aluminum one of our most versatile engineering and construction materials. A mere recital of its characteristics is impressive. It is light in mass, yet some of its alloys have strengths greater than that of structural steel. It has high resistance to corrosion under the majority of service conditions, and no colored salts are formed to stain adjacent surfaces or discolor products with which it comes into contact, such as fabrics in the textile industry and solutions in chemical equipment. It has no toxic reaction. It has good electrical and thermal conductivities and high reflectivity to both heat and light. The metal can easily be worked into any form and readily accepts a wide variety of surface finishes.

Lightness is one of aluminum's most useful characteristics. The specific gravity is about 2.7. The mass ("weight") of aluminum is roughly 35 percent that of iron and 30 percent that of copper.

Commercially pure aluminum has a tensile strength of about 13,000 pounds per square inch. Thus its usefulness as a structural material in this form is somewhat limited. By working the metal, as by cold rolling, its strength can be approximately doubled. Much larger increases in strength can be obtained by alloying aluminum with small percentages of one or more other elements such as manganese, silicon, copper, magnesium or zinc. Like pure aluminum, the alloys are also made stronger by cold working. Some of the alloys are further strengthened and hardened by heat treatments so that today aluminum alloys having tensile strengths approaching 100,000 pounds per square inch are available.

A wide variety of mechanical characteristics, or tempers, is available in aluminum alloys through various combinations of cold work and heat treatment. In specifying the temper for any given product, the fabricating process and the amount of cold work to which it will subject the metal should be kept in mind. In other words, the temper specified should be such that the amount of cold work the metal will receive during fabrication will develop the desired characteristics in the finished products.

Aluminum and its alloys lose part of their strength at elevated temperatures, although some alloys retain good strength at temperatures from 400˚F to 500˚F. At subzero temperatures, however, their strength increases without loss of ductility, so that aluminum is a particularly useful metal for low-temperature applications.

When aluminum surfaces are exposed to the atmosphere, a thin invisible oxide skin forms immediately, which protects the metal from further oxidation. This self-protecting characteristic gives aluminum its high resistance to corrosion. Unless exposed to some substance or condition that destroys this protective oxide coating, the metal remains fully protected against corrosion. Aluminum is highly resistant to weathering, even in industrial atmospheres that often corrode other metals. It is also corrosion resistant to many acids. Alkalis are among the few substances that attack the oxide skin and therefore are corrosive to aluminum. Although the metal can safely be used in the presence of certain mild alkalis with the aid of inhibitors, in general, direct contact with alkaline substances should be avoided.

Some alloys are less resistant to corrosion than others, particularly certain high-strength alloys. Such alloys in some forms can be effectively protected from the majority of corrosive influences, however, by cladding the exposed surface or surfaces with a thin layer of either pure aluminum or one of the more highly corrosion-resistant alloys.

A word of caution should be mentioned in connection with the corrosion-resistant characteristics of aluminum. Direct contacts with certain other metals should be avoided in the presence of an electrolyte; otherwise galvanic corrosion of the aluminum may take place in the vicinity of the contact area. Where other metals must be fastened to aluminum, the use of a bituminous paint coating or insulating tape is recommended.

The fact that aluminum is nontoxic was discovered in the early days of the industry. It is this characteristic that permits the metal to be used in cooking utensils without any harmful effect on the body, and today we find also a great deal of aluminum equipment in use by food processing industries. The same characteristic permits aluminum foil wrapping to be used safely in direct contact with food products.

Aluminum is one of the two common metals having an electrical conductivity high enough for use as an electric conductor. The conductivity of electric conductor grade (1350) is about 62 percent that of the International Annealed Copper Standard. Because aluminum has less than one-third the specific gravity of copper, however, a pound of aluminum will go about twice as far as a pound of copper when used for this purpose. Alloying lowers the conductivity somewhat, so that wherever possible alloy 1350 is used in electric conductor applications.

The high thermal conductivity of aluminum came prominently into play in the very first large-scale commercial application of the metal in cooking utensils. This characteristic is important wherever the transfer of thermal energy from one medium to another is involved, either heating or cooling. Thus aluminum heat exchangers are commonly used in the food, chemical, petroleum, aircraft and other industries. Aluminum is also an excellent reflector of radiant energy through the entire range of wavelengths, from ultraviolet, through the visible spectrum to infrared and heat waves, as well as electromagnetic waves of radio and radar.

Aluminum has a light reflectivity of over 80 percent, which has led to its wide use in lighting fixtures. Aluminum roofing reflects a high percentage of the sun's heat, so that buildings roofed with this material are cooler in summer.

The ease with which aluminum may be fabricated into any form is one of its most important assets. Often it can compete successfully with cheaper materials having a lower degree of workability. The metal can be cast by any method known to foundrymen; it can be rolled to any desired thickness down to foil thinner than paper; aluminum sheet can be stamped, drawn, spun or roll-formed. The metal also may be hammered or forged. Aluminum wire, drawn from rolled rod, may be stranded into cable of any desired size and type. There is almost no limit to the different profiles in which the metal may be extruded.

The ease and speed with which aluminum may be machined is one of the important factors contributing to the low cost of finished aluminum parts. The metal may be turned, milled, bored, or machined in other manners at the maximum speeds of which the majority of machines are capable. Another advantage of its flexible machining characteristics is that aluminum rod and bar may readily be employed in the highspeed manufacture of parts by automatic screw machines.

Almost any method of joining is applicable to aluminum: riveting, welding, brazing or soldering. A wide variety of mechanical aluminum fasteners simplifies the assembly of many products. Adhesive bonding of aluminum parts is widely employed, particularly in joining aircraft components.

For the majority of applications, aluminum needs no protective coating. Mechanical finishes such as polishing, sand blasting or wire brushing meet the majority of needs. In many instances, the surface finish supplied is entirely adequate without further finishing. Where the plain aluminum surface does not suffice, or where additional protection is required, any of a wide variety of surface finishes may be applied. Chemical, electrochemical and paint finishes are all used. Many colors are available in both chemical and electrochemical finishes. If paint, lacquer or enamel is used, any color possible with these finishes may be applied. Vitreous enamels have been developed for aluminum, and the metal may also be electroplated.

Aluminum sheet, because of its superior corrosion resistance and smooth continuous surface, is an excellent base for the high quality paints used in producing painted sheet. The chemical pretreatment plus the application of high quality thermally cured paint assures a finish that will exhibit no cracking, blistering, or peeling. Accidental damage to products made of painted aluminum sheet will not result in unsightly rust areas or streaks. Experience has shown that paint in the quality used for this product, properly formulated, applied and cured, will show little change in color or loss of gloss after one year's service in the adverse climatic conditions of south-central Florida. Highly industrialized areas may cause some color change due to atmospheric contaminants.

Proper maintenance can extend the service life considerably—even the finest automobiles require occasional washing and polishing if they are to retain their original appearance.

Even after many years of service most advantages of the painted sheet remain. It can be repainted with any good grade of house paint with no danger of cracking or peeling, such as is often experienced when paint is applied to other types of base materials.

Painted sheet and the products made from it should be handled with care to avoid damage to the paint film. Repair of large damaged areas is not recommended, but for repair of small areas air drying touch-up paint intended for brush application is available from paint suppliers. Your painted sheet supplier should be contacted for precise information. This touch-up paint cannot be expected to exhibit the same weathering and other characteristics as the original painted sheet, and touched-up areas will present appearance differences after weather exposure. For this reason, use of touch-up paint should be held to a minimum.

Many types of paint systems are used, and it is difficult to establish reasonable and meaningful standards for all of them. Specific applications require consideration of life expectancy, forming requirements and methods, economics, and so forth. Paint systems generally in use exhibit general characteristics as shown on pages 7-31 to 7-33, but for specific applications consult the painted sheet supplier.

These are the characteristics that give aluminum its extreme versatility. In the majority of applications, two or more of these characteristics come prominently into play—for example, light weight combined with strength in airplanes, railroad cars, trucks and other transportation equipment. High resistance to corrosion and high thermal conductivity are important in equipment for the chemical and petroleum industries; these properties combine with nontoxicity for food processing equipment.

Attractive appearance together with high resistance to weathering and low maintenance requirements have led to extensive use in buildings of all types. High reflectivity, excellent weathering characteristics, and light weight are all important in roofing materials. Light weight contributes to low handling and shipping costs, whatever the application.

Many applications require the extreme versatility that only aluminum has. Almost daily its unique combination of properties is being put to work in new ways. The metal now serves as a basic raw material for more than 20,000 businesses scattered throughout the country.

Alloy and Temper Designation Systems for Aluminum (ANSI H35.1 / H35.1(M))-2009

Information Note: The Aluminum Association is the registrar under ANSI H35.1 / H35.1(M) with respect to the designation and composition of aluminum alloys and tempers registered in the United States, and is also the registrar under an international accord on the composition and designation of registered wrought aluminum alloys. Since there is no international accord on designation and registration of tempers for wrought aluminum alloys and wrought aluminum alloy products, reference to ANSI H35.1 / H35.1(M) properties and characteristics of wrought aluminum alloy tempers registered with the Aluminum Association under ANSI H35.1 / H35.1(M) may not always reflect actual properties and characteristics associated with the particular aluminum alloy temper. The user may wish to confirm that expected properties denoted by specific temper designation(s) are furnished.

NOTE: The user of this Aluminum Standards and Data manual should be aware that the alloy and temper designation systems, as reprinted from ANSI H35.1 / H35.1(M), are those in effect at the time of this manual's publication but are subject to supersession by subsequent revisions of this ANSI standard as it is updated.

1. Scope

This standard provides systems for designating wrought aluminum and wrought aluminum alloys, aluminum and aluminum alloys in the form of castings and foundry ingot, and the tempers in which aluminum and aluminum alloy wrought products and aluminum alloy castings are produced. Specific limits for chemical compositions and for mechanical and physical properties to which conformance is required are provided by applicable product standards.

NOTE: A numerical designation assigned in conformance with this standard should only be used to indicate an aluminum or an aluminum alloy having chemical composition limits identical to those registered with The Aluminum Association and, for wrought aluminum and wrought aluminum alloys, with the signatories of the Declaration of Accord on an International Alloy Designation System for Wrought Aluminum and Wrought Aluminum Alloys.

2. Wrought Aluminum and Aluminum Alloy Designation System ①

A system of four-digit numerical designations is used to identify wrought aluminum and wrought aluminum alloys. The first digit indicates the alloy group as follows:

Aluminum, 99.00 percent and greater	1xxx
Aluminum alloys grouped by major alloying elements ② ③ ④	
Copper	2xxx
Manganese	3xxx
Silicon	4xxx
Magnesium	5xxx
Magnesium and silicon	6xxx
Zinc	7xxx
Other element	8xxx
Unused series	9xxx

The designation assigned shall be in the 1xxx group whenever the minimum aluminum content is specified as 99.00 percent or higher. The alloy designation in the 2xxx through 8xxx groups is determined by the alloying element (Mg_2Si for 6xxx alloys) present in the greatest mean percentage, except in cases in which the alloy being registered qualifies as a modification or national variation of a previously registered alloy. If the greatest mean percentage is common to more than one alloying element, choice of group will be in order of group sequence Cu, Mn, Si, Mg, Mg_2Si, Zn or others.

The last two digits identify the aluminum alloy or indicate the aluminum purity. The second digit indicates modifications of the original alloy or impurity limits.

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① Chemical composition limits and designations conforming to this standard for wrought aluminum and wrought aluminum alloys, and aluminum and aluminum alloy castings and foundry ingot may be registered with The Aluminum Association provided: (1) the aluminum or aluminum alloy is offered for sale, (2) the complete chemical composition limits are registered, and (3) the composition is significantly different from that of any aluminum or aluminum alloy for which a numerical designation already has been assigned.

② For codification purposes an alloying element is any element that is intentionally added for any purpose other than grain refinement and for which minimum and maximum limits are specified.

③ Standard limits for alloying elements and impurities are expressed to the following places:

Less than .001 percent	0.000X
.001 but less than .01 percent	0.00X
.01 but less than .10 percent	
Unalloyed aluminum made by a refining process	0.0XX
Alloys and unalloyed aluminum not made by a refining process	0.0X
.10 through .55 percent	0.XX
(It is customary to express limits of 0.30 percent through 0.55 percent as 0.X0 or 0.X5)	
Over .55 percent	0.X, X.X, etc.
(except that combined Si + Fe limits for 1xxx designations must be expressed as 0.XX or 1.XX)	

④ Standard limits for alloying elements and impurities are expressed in the following sequence: Silicon; Iron; Copper; Manganese; Magnesium; Chromium; Nickel; Zinc; Titanium (see Note 1); Other (see Note 2) Elements, Each; Other (see Note 2) Elements, Total; Aluminum (see Note 3).

Note 1—Additional specified elements having limits are inserted in alphabetical order according to their chemical symbols between Titanium and Other Elements, Each, or are listed in footnotes.

Note 2—"Other" includes listed elements for which no specific limit is shown as well as unlisted metallic elements. The producer may analyze samples for trace elements not specified in the registration or specification. However, such analysis is not required and may not cover all metallic "other" elements. Should any analysis by the producer or the purchaser establish that an "other" element exceeds the limit of "Each" or that the aggregate of several "other" elements exceeds the limit of "Total", the material shall be considered non-conforming.

Note 3—Aluminum is specified as minimum for unalloyed aluminum, and as a remainder for aluminum alloys.

2.1 Aluminum

In the 1xxx group for minimum aluminum purities of 99.00 percent and greater, the last two of the four digits in the designation indicate the minimum aluminum percentage. ⑤ These digits are the same as the two digits to the right of the decimal point in the minimum aluminum percentage when it is expressed to the nearest 0.01 percent. The second digit in the designation indicates modifications in impurity limits or alloying elements. If the second digit in the designation is zero, it indicates unalloyed aluminum having natural impurity limits; integers 1 through 9, which are assigned consecutively as needed, indicate special control of one or more individual impurities or alloying elements.

2.2 Aluminum Alloys

In the 2xxx through 8xxx alloy groups the last two of the four digits in the designation have no special significance but serve only to identify the different aluminum alloys in the group. The second digit in the alloy designation indicates alloy modifications. If the second digit in the designation is zero, it indicates the original alloy; integers 1 through 9, which are assigned consecutively, indicate alloy modifications. A modification of the original alloy is limited to any one or a combination of the following:

(a) Change of not more than the following amounts in arithmetic mean of the limits for an individual alloying element or combination of elements expressed as an alloying element or both.

Arithmetic Mean of Limits for Alloying Elements in Original Alloy	*Maximum Change*
Up thru 1.0 percent	0.15
Over 1.0 thru 2.0 percent	0.20
Over 2.0 thru 3.0 percent	0.25
Over 3.0 thru 4.0 percent	0.30
Over 4.0 thru 5.0 percent	0.35
Over 5.0 thru 6.0 percent	0.40
Over 6.0 percent	0.50

To determine compliance when maximum and minimum limits are specified for a combination of two or more elements in one alloy composition, the arithmetic mean of such a combination is compared to the sum of the mean values of the same individual elements, or any combination thereof, in another alloy composition.

(b) Addition or deletion of not more than one alloying element with limits having an arithmetic mean of not more than 0.30 percent or addition or deletion of not more than one combination of elements expressed as an alloying element with limits having a combined arithmetic mean of not more than 0.40 percent.

(c) Substitution of one alloying element for another element serving the same purpose.

(d) Change in limits for impurities expressed singly or as a combination.

(e) Change in limits for grain refining elements.

(f) Maximum iron or silicon limits of 0.12 percent and 0.10 percent, or less, respectively, reflecting use of high purity base metal.

An alloy shall not be registered as a modification if it meets the requirements for a national variation.

2.3 Experimental Alloys

Experimental alloys are also designated in accordance with this system, but they are indicated by the prefix X. The prefix is dropped when the alloy is no longer experimental. During development and before they are designated as experimental, new alloys are identified by serial numbers assigned by their originators. Use of the serial number is discontinued when the X number is assigned.

2.4 National Variations

National variations of wrought aluminum and wrought aluminum alloys registered by another country in accordance with this system are identified by a serial letter following the numerical designation. The serial letters are assigned internationally in alphabetical sequence starting with A but omitting I, O and Q.

A national variation has composition limits that are similar but not identical to a modification or an original alloy registered by another country, with differences such as:

(a) Change of not more than the following amounts in arithmetic mean of the limits for an individual alloying element or combination of elements expressed as an alloying element, or both:

Arithmetic Mean of Limits for Alloying Elements in Original Alloy or Modification	*Maximum Change*
Up thru 1.0 percent	0.15
Over 1.0 thru 2.0 percent	0.20
Over 2.0 thru 3.0 percent	0.25
Over 3.0 thru 4.0 percent	0.30
Over 4.0 thru 5.0 percent	0.35
Over 5.0 thru 6.0 percent	0.40
Over 6.0 percent	0.50

To determine compliance when maximum and minimum limits are specified for a combination of two or more ele-

⑤ The aluminum content for unalloyed aluminum made by a refining process is the difference between 100.00 percent and the sum of all other metallic elements together with silicon present in amounts of 0.0010 percent or more, each expressed to the third decimal before determining the sum, which is rounded to the second decimal before subtracting; for unalloyed aluminum not made by a refining process it is the difference between 100.00 percent and the sum of all other analyzed metallic elements together with silicon present in amounts of 0.010 percent or more, each expressed to the second decimal before determining the sum. For unalloyed aluminum made by a refining process, when the specified maximum limit is 0.0XX, an observed value or a calculated value greater than 0.0005 but less than 0.0010% is rounded off and shown as “less than 0.001”; for alloys and unalloyed aluminum not made by a refining process, when the specified maximum limit is 0.XX, an observed value or a calculated value greater than 0.005 but less than 0.010% is rounded off and shown as “less than 0.01”.

ments in one alloy composition, the arithmetic mean of such a combination is compared to the sum of the mean values of the same individual elements, or any combination thereof, in another alloy composition.

(b) Substitution of one alloying element for another element serving the same purpose.

(c) Different limits on impurities except for low iron. Iron maximum of 0.12 percent, or less, reflecting high purity base metal, should be considered as an alloy modification.

(d) Different limits on grain refining elements.

(e) Inclusion of a minimum limit for iron or silicon, or both.

Wrought aluminum and wrought aluminum alloys meeting these requirements shall not be registered as a new alloy or alloy modification.

3. Cast Aluminum and Aluminum Alloy Designation System ①

A system of four digit numerical designations is used to identify aluminum and aluminum alloys in the form of castings and foundry ingot. The first digit indicates the alloy group as follows:

Aluminum, 99.00 percent minimum and greater	1xx.x
Aluminum alloys grouped by major alloying elements ② ③ ④	
Copper	2xx.x
Silicon, with added copper and/or magnesium	3xx.x
Silicon	4xx.x
Magnesium	5xx.x
Zinc	7xx.x
Tin	8xx.x
Other element	9xx.x
Unused series	6xx.x

The alloy group in the 2xx.x through 9xx.x excluding 6xx.x alloys is determined by the alloying element present in the greatest mean percentage, except in cases in which the alloy being registered qualified as a modification of a previously registered alloy. If the greatest mean percentage is common to more than one alloying element, the alloy group will be determined by the sequence shown above.

The second two digits identify the aluminum alloy or indicate the aluminum purity. The last digit, which is separated from the others by a decimal point, indicates the product form: that is, castings or ingot. A modification of the original alloy or impurity limits is indicated by a serial letter before the numerical designation. The serial letters are assigned in alphabetical sequence starting with A but omitting I, O, Q and X, the X being reserved for experimental alloys.

A modification of the original alloy is limited to any one or a combination of the following:

(a) Change of not more than the following amounts in the arithmetic mean of the limits for an individual alloying element or combination of elements expressed as an alloying element or both:

Arithmetic Mean of Limits for Alloying Elements in Original Alloy	*Maximum Change*
Up thru 1.0 percent	0.15
Over 1.0 thru 2.0 percent	0.20
Over 2.0 thru 3.0 percent	0.25
Over 3.0 thru 4.0 percent	0.30
Over 4.0 thru 5.0 percent	0.35
Over 5.0 thru 6.0 percent	0.40
Over 6.0 percent	0.50

To determine compliance when maximum and minimum limits are specified for a combination of two or more elements in one alloy composition, the arithmetic mean of such a combination is compared to the sum of the mean values of the same individual elements, or any combination thereof, in another alloy composition.

(b) Addition or deletion of not more than one alloying element with limits having an arithmetic mean of not more than 0.30 percent or addition or deletion of not more than one combination of elements expressed as an alloying element with limits having a combined arithmetic mean of not more than 0.40 percent.

(c) Substitution of one alloying element for another element serving the same purpose.

(d) Change in limits for impurities expressed singly or as a combination.

(e) Change in limits for grain refining elements.

(f) Iron or silicon maximum limits of 0.12 percent and 0.10 percent, or less, respectively, reflecting use of high purity base metal.

3.1 Aluminum Castings and Ingot

In the 1xx.x group for minimum aluminum purities of 99.00 percent and greater, the second two of the four digits in the designation indicate the minimum aluminum percentage.⑤ These digits are the same as the two digits to the right of the decimal point in the minimum aluminum percentage when it is expressed to the nearest 0.01 percent. The last digit, which is to the right of the decimal point, indicates the product form: 1xx.0 indicates castings, and 1xx.1 indicates ingot.

3.2 Aluminum Alloy Castings and Ingot

In the 2xx.x through 9xx.x alloy groups the second two of the four digits in the designation have no special significance but serve only to identify the different aluminum alloys in the group. The last digit, which is to the right of the decimal point, indicates the product form: xxx.0 indicates castings, xxx.1 indicates ingot that has chemical composition limits conforming to 3.2.1, and xxx.2 indicates ingot that has chemical composition limits that differ but fall within the limits of xxx.1 ingot.

For all number footnotes, see page 1-3 and 1-4.

3.2.1 Limits for Alloying Elements and Impurities

Limits for alloying elements and impurities for xxx.1 ingot are the same as for the alloy in the form of castings, except for the following:

Maximum Iron Percentage:

For All Forms of Castings	*For Ingot, Fe Shall be At Least*
Up thru 0.15	0.03 less than castings
Over 0.15 thru 0.25	0.05 less than castings
Over 0.25 thru 0.6	0.10 less than castings
Over 0.6 thru 1.0	0.2 less than castings
Over 1.0	0.3 less than castings

Minimum Magnesium Percentage*:

For All Forms of Castings	*For Ingot*
Less than 0.50	0.05 more than castings
0.50 and greater	0.1 more than castings

Maximum Zinc Percentage:

For Die Castings	*For Ingot*
Over 0.25 thru 0.6	0.10 less than castings
Over 0.6	0.1 less than castings

3.2.2 Identifiers for 3xx.x and 4xx.x Foundry Ingot containing Structure Modifiers

One of the applicable suffixes in the table below should be added to the registered alloy designation whenever a structure modifier is intentionally added to that alloy.

Alloy Designation Suffix	Structure Modifying Element	Chemical Composition Limits Minimum (%)	Maximum (%)
N	Na	0.003	0.08
S	Sr	0.005	0.08
C	Ca	0.005	0.15
P	P	—	0.060

(a) The letter suffix follows and is separated from the registered foundry ingot designation by a hyphen (e.g., "A356.1-S")

(b) In cases where more than one modifier is intentionally added, only the modifier of greater concentration shall be identified by suffix letter affixed to the registered alloy designation.

(c) Where foundry alloy is sold with a suffix added to its alloy designation, the modifying element's concentration is not to be included in "Others, Each" or "Others, Total".

(d) It is not intended that these structure modifier identifiers be treated as new alloy registration, nor should these designations be listed in the Registration Record.

3.3 Experimental Alloys

Experimental alloys are also designated in accordance with this system, but they are indicated by the prefix X. The prefix is dropped when the alloy is no longer experimental. During development and before they are designated as experimental, new alloys are identified by serial numbers assigned by their originators. Use of the serial number is discontinued when the X number is assigned.

*Applicable only if Magnesium is an alloying element (i.e. has a registered minimum and maximum percentage).

4. Temper Designation System [6]

The temper designation system is used for all forms of wrought and cast aluminum and aluminum alloys except ingot. It is based on the sequences of basic treatments used to produce the various tempers. The temper designation follows the alloy designation, the two being separated by a hyphen. Basic temper designations consist of letters. Subdivisions of the basic tempers, where required, are indicated by one or more digits following the letter. These designate specific sequences of basic treatments, but only operations recognized as significantly influencing the characteristics of the product are indicated. Should some other variation of the same sequence of basic operations be applied to the same alloy, resulting in different characteristics, then additional digits are added to the designation.

4.1 Basic Temper Designations

F **as fabricated.** Applies to the products of shaping processes in which no special control over thermal conditions or strain hardening is employed. For wrought products, there are no mechanical property limits.

O **annealed.** Applies to wrought products that are annealed to obtain the lowest strength temper, and to cast products that are annealed to improve ductility and dimensional stability. The O may be followed by a digit other than zero.

H **strain-hardened (wrought products only).** Applies to products that have their strength increased by strain-hardening, with or without supplementary thermal treatments to produce some reduction in strength. The H is always followed by two or more digits.

W **solution heat-treated.** An unstable temper applicable only to alloys that spontaneously age at room temperature after solution heat-treatment. This designation is specific only when the period of natural aging is indicated; for example: W ½ hr.

T **thermally treated to produce stable tempers other than F, O, or H.** Applies to products that are thermally treated, with or without supplementary strain-hardening, to produce stable tempers. The T is always followed by one or more digits.

4.2 Subdivisions of Basic Tempers

4.2.1 Subdivision of H Temper: Strain-hardened

(a) The first digit following the H indicates the specific combination of basic operations, as follows:

H1 **strain-hardened only.** Applies to products that are strain-hardened to obtain the desired strength without supplementary thermal treatment. The number following this designation indicates the degree of strain-hardening.

H2 **strain-hardened and partially annealed.** Applies to products that are strain-hardened more than the desired final amount and then reduced in strength to the desired level by partial annealing. For alloys that age-soften at room temperature, the H2 tempers have the same minimum ultimate tensile strength as the corresponding H3 tempers. For other alloys, the H2 tempers have the same minimum ultimate tensile strength as the corresponding H1 tempers and slightly higher elongation. The number following this designation indicates the degree of strain-hardening remaining after the product has been partially annealed.

[6] Temper designations conforming to this standard for wrought aluminum and wrought aluminum alloys, and aluminum alloy castings may be registered with the Aluminum Association provided: (1) the temper is used or is available for use by more than one user, (2) mechanical property limits are registered, (3) the characteristics of the temper are significantly different from those of all other tempers that have the same sequence of basic treatments and for which designations already have been assigned for the same alloy and product, and (4) the following are also registered if characteristics other than mechanical properties are considered significant: (a) test methods and limits for the characteristics or (b) the specific practices used to produce the temper.

H3 strain-hardened and stabilized. Applies to products that are strain-hardened and whose mechanical properties are stabilized either by a low temperature thermal treatment or as a result of heat introduced during fabrication. Stabilization usually improves ductility. This designation is applicable only to those alloys that, unless stabilized, gradually age-soften at room temperature. The number following this designation indicates the degree of strain-hardening remaining after the stabilization treatment.

H4 strain-hardened and lacquered or painted. Applies to products which are strain-hardened and which are subjected to some thermal operation during the subsequent painting or lacquering operation. The number following this designation indicates the degree of strain-hardening remaining after the product has been thermally treated, as part of painting/lacquering cure operation. The corresponding H2X or H3X mechanical property limits apply.

(b) The digit following the designation H1, H2, H3, and H4 indicates the degree of strain-hardening as identified by the minimum value of the ultimate tensile strength. Numeral 8 has been assigned to the hardest tempers normally produced. The minimum tensile strength of tempers HX8 may be determined from Table 1 and is based on the minimum tensile strength of the alloy in the annealed temper. However, temper registrations prior to 1992 that do not conform to the requirements of Table 1 shall not be revised and registrations of intermediate or modified tempers for such alloy/temper systems shall conform to the registration requirements that existed prior to 1992.

Table 1

US Customary Units

Minimum tensile strength in annealed temper ksi	*Increase in tensile strength to HX8 temper* ksi
up to 6	8
7 to 9	9
10 to 12	10
13 to 15	11
16 to 18	12
19 to 24	13
25 to 30	14
31 to 36	15
37 to 42	16
43 and over	17

Metric Units

Minimum tensile strength in annealed temper MPa	*Increase in tensile strength to HX8 temper* MPa
up to 40	55
45 to 60	65
65 to 80	75
85 to 100	85
105 to 120	90
125 to 160	95
165 to 200	100
205 to 240	105
245 to 280	110
285 to 320	115
325 and over	120

Tempers between O (annealed) and HX8 are designated by numerals 1 through 7.

(a) Numeral 4 designates tempers whose ultimate tensile strength is approximately midway between that of the O temper and that of the HX8 tempers;

(b) Numeral 2 designates tempers whose ultimate tensile strength is approximately midway between that of the O temper and that of the HX4 tempers;

(c) Numeral 6 designates tempers whose ultimate tensile strength is approximately midway between that of the HX4 tempers and that of the HX8 tempers;

(d) Numerals 1, 3, 5 and 7 designate, similarly, tempers intermediate between those defined above.

(e) Numeral 9 designates tempers whose minimum ultimate tensile strength exceeds that of the HX8 tempers by 2 ksi or more. (For Metric Units by 10 MPa or more).

The ultimate tensile strength of the odd numbered intermediate (-HX1, -HX3, -HX5, and HX7) tempers, determined as described above, shall be rounded to the nearest multiple of 0.5 ksi. (For Metric Units when not ending in 0 or 5 shall be rounded to the next higher 0 or 5 MPa.)

(c) The third digit,[7] when used, indicates a variation of a two-digit temper. It is used when the degree of control of temper or the mechanical properties or both differ from, but are close to, that (or those) for the two-digit H temper designation to which it is added, or when some other characteristic is significantly affected. (See Appendix for assigned three-digit H tempers.) NOTE: The minimum ultimate tensile strength of a three-digit H temper must be at least as close to that of the corresponding two-digit H temper as it is to the adjacent two-digit H tempers. Products in the H temper whose mechanical properties are below H__1 shall be variations of H__1.

4.2.2 Subdivision of T Temper: Thermally Treated

(a) Numerals 1 through 10 following the T indicate specific sequences of basic treatments, as follows:[8]

T1 cooled from an elevated temperature shaping process and naturally aged to a substantially stable condition. Applies to products that are not cold worked after cooling from an elevated temperature shaping process, or in which the effect of cold work in flattening or straightening may not be recognized in mechanical property limits.

T2 cooled from an elevated temperature shaping process, cold worked, and naturally aged to a substantially stable condition. Applies to products that are cold worked to improve strength after cooling from an elevated temperature shaping process, or in which the effect of cold work in flattening or straightening is recognized in mechanical property limits.

[7] Numerals 1 through 9 may be arbitrarily assigned as the third digit and registered with the Aluminum Association for an alloy and product to indicate a variation of a two-digit H temper (see note [6]).

[8] A period of natural aging at room temperature may occur between or after the operations listed for the T tempers. Control of this period is exercised when it is metallurgically important.

T3 solution heat-treated,⑨ cold worked, and naturally aged to a substantially stable condition. Applies to products that are cold worked to improve strength after solution heat-treatment, or in which the effect of cold work in flattening or straightening is recognized in mechanical property limits.

T4 solution heat-treated ⑨ and naturally aged to a substantially stable condition. Applies to products that are not cold worked after solution heat-treatment, or in which the effect of cold work in flattening or straightening may not be recognized in mechanical property limits.

T5 cooled from an elevated temperature shaping process and then artificially aged. Applies to products that are not cold worked after cooling from an elevated temperature shaping process, or in which the effect of cold work in flattening or straightening may not be recognized in mechanical property limits.

T6 solution heat-treated ⑨ and then artificially aged. Applies to products that are not cold worked after solution heat-treatment, or in which the effect of cold work in flattening or straightening may not be recognized in mechanical property limits.

T7 solution heat-treated⑨ and overaged/stabilized. Applies to wrought products that are artificially aged after solution heat-treatment to carry them beyond a point of maximum strength to provide control of some significant characteristic⑩. Applies to cast products that are artificially aged after solution heat-treatment to provide dimensional and strength stability.

T8 solution heat-treated,⑨ cold worked, and then artificially aged. Applies to products that are cold worked to improve strength, or in which the effect of cold work in flattening or straightening is recognized in mechanical property limits.

T9 solution heat-treated,⑨ artificially aged, and then cold worked. Applies to products that are cold worked to improve strength.

T10 cooled from an elevated temperature shaping process, cold worked, and then artificially aged. Applies to products that are cold worked to improve strength, or in which the effect of cold work in flattening or straightening is recognized in mechanical property limits.

(b) Additional digits,⑪ the first of which shall not be zero, may be added to designations T1 through T10 to indicate a variation in treatment that significantly alters the product characteristics that are or would be obtained using the basic treatment. (See Appendix for specific additional digits for T tempers.)

⑨ Solution heat treatment is achieved by heating cast or wrought products to a suitable temperature, holding at that temperature long enough to allow constituents to enter into solid solution and cooling rapidly enough to hold the constituents in solution. Some 6xxx and some 7xxx series alloys attain the same specified mechanical properties whether furnace solution heat treated or cooled from an elevated temperature shaping process at a rate rapid enough to hold constituents in solution. In such cases the temper designations T3, T4, T6, T7, T8, and T9 are used to apply to either process and are appropriate designations.

⑩ For this purpose, *characteristic* is something other than mechanical properties. The test method and limit used to evaluate material for this characteristic are specified at the time of the temper registration.

⑪ Additional digits may be arbitrarily assigned and registered with The Aluminum Association for an alloy and product to indicate a variation of tempers T1 through T10 even though the temper representing the basic treatment has not been registered (see note ⑥). Variations in treatment that do not alter the characteristics of the product are considered alternate treatments for which additional digits are not assigned.

APPENDIX

4.3 Variations of O Temper: Annealed

A digit following the O, when used, indicates a product in the annealed condition having special characteristics. NOTE: As the O temper is not part of the strain-hardened (H) series, variations of O temper shall not apply to products that are strain-hardened after annealing and in which the effect of strain-hardening is recognized in the mechanical properties or other characteristics.

A1 Three-Digit H Tempers

(a) The following three-digit H temper designations have been assigned for wrought products in all alloys:

H_11 Applies to products that incur sufficient strain hardening after the final anneal that they fail to qualify as annealed but not so much or so consistent an amount of strain hardening that they qualify as H_1.

H112 Applies to products that may acquire some temper from working at an elevated temperature and for which there are mechanical property limits.

(b) The following three-digit H temper designations have been assigned for

pattern or embossed sheet	fabricated from
H114	O temper
H124, H224, H324	H11, H21, H31 temper, respectively
H134, H234, H334	H12, H22, H32 temper, respectively
H144, H244, H344	H13, H23, H33 temper, respectively
H154, H254, H354	H14, H24, H34 temper, respectively
H164, H264, H364	H15, H25, H35 temper, respectively
H174, H274, H374	H16, H26, H36 temper, respectively
H184, H284, H384	H17, H27, H37 temper, respectively
H194, H294, H394	H18, H28, H38 temper, respectively
H195, H295, H395	H19, H29, H39 temper, respectively

(c) The following three-digit H temper designations have been assigned only for wrought products in the 5xxx series, or which the magnesium content is 3% nominal or more:

H116 Applies to products manufactured from alloys in the 5xxx series, for which the magnesium content is 3% nominal or more. Products are normally strain hardened at the last operation to specified stable tensile property limits and meet specified levels of corrosion resistance in accelerated type corrosion tests. They are suitable for continuous service at temperature no greater than 150^0 F (66^0C). Corrosion tests include inter-granular and exfoliation.

H321 Applies to products from alloys in the 5xxx series, for which the magnesium content is 3% nominal or more. Products are normally thermally stablized at the last operation to specified stable tensile property limits and meet specified levels of corrosion resistance in accelerated type corrosion tests. They are suitable for continuous service at temperatures no greater than 150^0 F (66^0C). Corrosion tests include inter-granular and exfoliation.

A2 Additional Digits for T Tempers

A2.1 Assigned Additional Digits for Stress-Relieved Tempers

The following specific additional digits have been assigned for stress-relieved tempers of wrought products:

A2.1.1 Stress relieved by stretching [12]

T_51 Applies to plate and rolled or cold-finished rod or bar, die or ring forgings and rolled rings when stretched the indicated amounts after solution heat treatment or after cooling from an elevated temperature shaping process. The products receive no further straightening after stretching.

Plate . . . . 1½% to 3% permanent set.

Rolled or
Cold-Finished
Rod and Bar . . . . 1% to 3% permanent set.

Die or Ring
Forgings and
Rolled Rings. 1% to 5% permanent set.

T_510 Applies to extruded rod, bar, profiles and tube and to drawn tube when stretched the indicated amounts after solution heat treatment or after cooling from an elevated temperature shaping process. These products receive no further straightening after stretching.

Extruded Rod
Bar, Profiles
and Tube . . . . 1% to 3% permanent set.
Drawn Tube . . . . ½% to 3% permanent set.

T_511 Applies to extruded rod, bar, profiles and tube and to drawn tube when stretched the indicated amounts after solution heat treatment or after cooling from an elevated temperature shaping process. These products may receive minor straightening after stretching to comply with standard tolerances.

Extruded Rod,
Bar, Profiles
and Tube . . . . 1% to 3% permanent set.
Drawn Tube . . . . ½% to 3% permanent set.

A2.1.2 Stress relieved by compressing [12]

T_52 Applies to products that are stress-relieved by compressing after solution heat treatment or cooling from an elevated temperature shaping process to produce a permanent set of 1 percent to 5 percent.

A2.1.3 Stress relieved by combined stretching and compressing [12]

T_54 Applies to die forgings that are stress relieved by restriking cold in the finish die.

A2.2 Assigned Additional Digits for T7 Temper Variations

The following temper designations have been assigned to wrought products which are artificially overaged to obtain a good compromise among exfoliation corrosion resis tance, stress corrosion resistance, fracture toughness, and tensile strength.

These designations shall be applied when standardizing new alloy-temper-product combinations.

T79 Very limited overaging to achieve some improved corrosion resistance with limited reduction in strength as compared to the T6 temper.

T76 Limited overaged condition to achieve moderate corrosion resistance with some reduction in strength. The T76 temper has lower strength and better corrosion resistance than the T79 temper.

[12] The same digits (51, 510, 511, 52, 54) may be added to the designation W to indicate unstable solution heat-treated and stress-relieved tempers.

T74 Overaged condition to achieve good corrosion resistance with a greater reduction in strength than the T76 temper. The T74 temper strength and corrosion resistance properties are between those of the T73 and T76 tempers.

T73 Fully overaged condition to achieve the best corrosion resistance of the T7X tempers with a greater reduction in strength than the T74 temper.

T77 Aged condition which provides strength at or near T6 temper and corrosion resistance similar to T76 temper corrosion resistance similar to T76 temper.

The evolution of material properties from temper T79 to T73 is illustrated in Figure 1.*

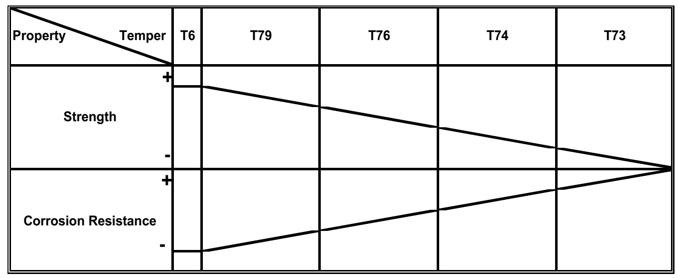

Figure 1

* The T77 temper does not fall within the continuous progression of the T7X tempers depicted in Figure 1.

A2.3 Assigned Temper Designations for Producer/Supplier and Purchaser/User Heat Treatment

A2.3.1 Temper Designations for Producer/Supplier Laboratory Demonstration of Response to Heat Treatment

The following temper designations have been assigned for wrought products test material, furnace heat-treated from annealed (O, O1, etc.) or F temper, to demonstrate response to heat-treatment.

T42 Solution heat-treated from annealed or F temper and naturally aged to a substantially stable condition.

T62 Solution heat-treated from annealed or F temper and artificially aged.

T7_2 Solution heat-treated from annealed or F temper and artificially overaged to meet the mechanical properties and corrosion resistance limits of the T7_ temper.

A2.3.2 Temper Designations for Producer/Supplier Demonstration of Response to Temper Conversion

Temper designation T_2 shall be used to indicate wrought product test material, which has undergone furnace heat-treatment for capability demonstration of temper conversion. When the purchaser requires capability demonstrations from T-temper, the seller shall note “Capability Demonstration” adjacent to the specified and ending tempers. Some examples are:

(a) “T3 to T82 Capability Demonstration for response to aging”;

(b) "T4 to T62 Capability Demonstration for response to aging";

(c) "T4 to T762 Capability Demonstration for response to over-aging";

(d) "T6 to T732 Capability Demonstration for response to over-aging";

(e) "T351 to T42 Capability Demonstration for response to re-solution heat-treatment".

A2.3.3 Temper Designation for Purchaser/User Heat-treatment

Temper designation T_2 should also be applied to wrought products heat-treated by the purchaser/user, in accordance with the applicable heat treatment specification, to achieve the properties applicable to the final temper.

A3 Assigned O Temper Variations

The following temper designation has been assigned for wrought products high temperature annealed to accentuate ultrasonic response and provide dimensional stability.

O1 Thermally treated at approximately same time and temperature required for solution heat treatment and slow cooled to room temperature. Applicable to products that are to be machined prior to solution heat treatment by the user. Mechanical property limits are not applicable.

A4 Designation of Unregistered Tempers

The letter P has been assigned to denote H, T and O temper variations that are negotiated between manufacturer and purchaser. The letter P immediately follows the temper designation that most nearly pertains. Specific examples where such designation may be applied include the following:

(a) The use of the temper is sufficiently limited so as to preclude its registration. (Negotiated H temper variations were formerly indicated by the third digit zero.)

(b) The test conditions (sampling location, number of samples, test specimen configuration, etc.) are different from those required for registration with The Aluminum Association.

(c) The mechanical property limits are not established on the same basis as required for registration with The Aluminum Association.

(d) For products such as Aluminum Metal Matrix Composites which are not included in any registration records.

general information/metallurgical aspects

Metallurgical Aspects

In high-purity form aluminum is soft and ductile. Most commercial uses, however, require greater strength than pure aluminum affords. This is achieved in aluminum first by the addition of other elements to produce various alloys, which singly or in combination impart strength to the metal. Further strengthening is possible by means that classify the alloys roughly into two categories, non-heat-treatable and heat-treatable.

non-heat-treatable alloys—The initial strength of alloys in this group depends upon the hardening effect of elements such as manganese, silicon, iron and magnesium, singly or in various combinations. The non-heat-treatable alloys are usually designated, therefore, in the 1xxx, 3xxx, 4xxx, or 5xxx series. Since these alloys are work-hardenable, further strengthening is made possible by various degrees of cold working, denoted by the "H" series of tempers. Alloys containing appreciable amounts of magnesium when supplied in strain-hardened tempers are usually given a final elevated-temperature treatment called stabilizing to ensure stability of properties.

heat-treatable alloys—The initial strength of alloys in this group is enhanced by the addition of alloying elements such as copper, magnesium, zinc, and silicon. Since these elements singly or in various combinations show increasing solid solubility in aluminum with increasing temperature, it is possible to subject them to thermal treatments that will impart pronounced strengthening.

The first step, called heat treatment or solution heat treatment, is an elevated-temperature process designed to put the soluble element or elements in solid solution. This is followed by rapid quenching, usually in water, which momentarily "freezes" the structure and for a short time renders the alloy very workable. It is at this stage that some fabricators retain this more workable structure by storing the alloys at below freezing temperatures until they are ready to form them. At room or elevated temperatures the alloys are not stable after quenching, however, and precipitation of the constituents from the super-saturated solution begins. After a period of several days at room temperature, termed aging or room-temperature precipitation, the alloy is considerably stronger. Many alloys approach a stable condition at room temperature, but some alloys, particularly those containing magnesium and silicon or magnesium and zinc, continue to age-harden for long periods of time at room temperature.

By heating for a controlled time at slightly elevated temperatures, even further strengthening is possible and properties are stabilized. This process is called artificial aging or precipitation hardening. By the proper combination of solution heat treatment, quenching, cold working and artificial aging, the highest strengths are obtained.

clad alloys—The heat-treatable alloys in which copper or zinc are major alloying constituents are less resistant to corrosive attack than the majority of non-heat-treatable alloys. To increase the corrosion resistance of these alloys in sheet and plate form, they are often clad with high-purity aluminum, a low magnesium-silicon alloy, or an alloy containing 1 percent zinc. The cladding, usually from 2½ percent to 5 percent of the total thickness on each side, not only protects the composite due to its own inherently excellent corrosion resistance but also exerts a galvanic effect, which further protects the core material.

Special composites may be obtained such as clad non-heat-treatable alloys for extra corrosion protection, for brazing purposes, or for special surface finishes. Some alloys in wire and tubular form are clad for similar reasons, and on an experimental basis extrusions also have been clad.

annealing characteristics—All wrought aluminum alloys are available in annealed form. In addition, it may be desirable to anneal an alloy from any other initial temper, after working, or between successive stages of working such as in deep drawing.

Effect of Alloying Elements

1xxx series—Aluminum of 99 percent or higher purity has many applications, especially in the electrical and chemical fields. These compositions are characterized by excellent corrosion resistance, high thermal and electrical conductivity, low mechanical properties and excellent workability. Moderate increases in strength may be obtained by strain-hardening. Iron and silicon are the major impurities.

2xxx series—Copper is the principal alloying element in this group. These alloys require solution heat-treatment to obtain optimum properties; in the heat treated condition mechanical properties are similar to, and sometimes exceed, those of mild steel. In some instances artificial aging is employed to further increase the mechanical properties. This treatment materially increases yield strength, with attendant loss in elongation; its effect on tensile (ultimate) strength is not so great. The alloys in the 2xxx series do not have as good corrosion resistance as most other aluminum alloys, and under certain conditions they may be subject to intergranular corrosion. Therefore, these alloys in the form of sheet are usually clad with a high-purity alloy or a magnesium-silicon alloy of the 6xxx series, which provides galvanic protection to the core material and thus greatly increases resistance to corrosion. Alloy 2024 is perhaps the best known and most widely used aircraft alloy.

3xxx series—Manganese is the major alloying element of alloys in this group, which are generally non-heat-treatable. Because only a limited percentage of manganese, up to about 1.5 percent, can be effectively added to aluminum, it is used as a major element in only a few instances. One of these, however, is the popular 3003, which is widely used as a general purpose alloy for moderate-strength applications requiring good workability.

4xxx series—The major alloying element of this group is silicon, which can be added in sufficient quantities to cause substantial lowering of the melting point without producing brittleness in the resulting alloys. For these reasons aluminum-silicon alloys are used in welding wire and as brazing alloys where a lower melting point than that of the parent metal is required. Most alloys in this series are non-heat-treatable, but when used in welding heat-treatable alloys they will pick up some of the alloying constituents of the latter and so respond to heat treatment to a limited extent. The alloys containing appreciable amounts of silicon become dark grey when anodic oxide finishes are applied, and hence are in demand for architectural applications.

5xxx series—Magnesium is one of the most effective and widely used alloying elements for aluminum. When it is used as the major alloying element or with manganese, the result is a moderate to high strength non-heat-treatable alloy. Magnesium is considerably more effective than manganese as a hardener, about 0.8 percent magnesium being equal to 1.25 percent manganese, and it can be added in considerably higher quantities. Alloys in this series possess good welding characteristics and good resistance to corrosion in marine atmosphere. However, certain limitations should be placed on the amount of cold work and on the safe operating temperatures permissible for the higher magnesium content alloys (over about 3½ percent for operating temperatures above about 150°F) to avoid susceptibility to stress corrosion.

6xxx series—Alloys in this group contain silicon and magnesium in approximate proportions to form magnesium silicide, thus making them heat-treatable. The major alloy in this series is 6061, one of the most versatile of the heat-treatable alloys. Though less strong than most of the 2xxx or 7xxx alloys, the magnesium-silicon (or magnesium-silicide) alloys possess good formability and corrosion resistance, with medium strength. Alloys in this heat-treatable group may be formed in the T4 temper (solution heat-treated but not artificially aged) and then reach full T6 properties by artificial aging.

7xxx series—Zinc is the major alloying element in this group, and when coupled with a smaller percentage of magnesium results in heat-treatable alloys of very high strength. Usually other elements such as copper and chromium are also added in small quantities. The outstanding member of this group is 7075, which is among the highest strength alloys available and is used in air-frame structures and for highly stressed parts.

TABLE 1.1 Nominal Chemical Composition—Wrought Alloys

The following values are shown as a basis for general comparison of alloys and are not guaranteed. Refer to Standards Section, Table 6.2, for composition limits.

	PERCENT OF ALLOYING ELEMENTS—Aluminum and Normal Impurities Constitute Remainder							
Alloy	**Silicon**	**Copper**	**Manganese**	**Magnesium**	**Chromium**	**Nickel**	**Zinc**	**Titanium**
1050	. .	. .	99.50 percent minimum aluminum			. .	. .	. .
1060	. .	. .	99.60 percent minimum aluminum			. .	. .	. .
1100	. .	0.12	99.00 percent minimum aluminum			. .	. .	. .
1145	. .	. .	99.45 percent minimum aluminum			. .	. .	. .
1200	. .	. .	99.00 percent minimum aluminum			. .	. .	. .
1230	. .	. .	99.30 percent minimum aluminum			. .	. .	. .
1235	. .	. .	99.35 percent minimum aluminum			. .	. .	. .
1345	. .	. .	99.45 percent minimum aluminum			. .	. .	. .
1350 ⑥	. .	. .	99.50 percent minimum aluminum			. .	. .	. .
2011 ①	. .	5.5	. .	. .	. .	. .	. .	. .
2014	0.8	4.4	0.8	0.50	. .	. .	. .	. .
2017	0.50	4.0	0.7	0.6	. .	. .	. .	. .
2018	. .	4.0	. .	0.7	. .	2.0	. .	. .
2024	. .	4.4	0.6	1.5	. .	. .	. .	. .
2025	0.8	4.4	0.8	. .	. .	. .	. .	. .
2036	. .	2.6	0.25	0.45	. .	. .	. .	. .
2117	. .	2.6	. .	0.35	. .	. .	. .	. .
2124	. .	4.4	0.6	1.5	. .	. .	. .	. .
2218	. .	4.0	. .	1.5	. .	2.0	. .	. .
2219 ②	. .	6.3	0.30	. .	. .	. .	. .	0.06
2319 ②	. .	6.3	0.30	. .	. .	. .	. .	0.15
2618 ③	0.18	2.3	. .	1.6	. .	1.0	. .	0.07
3003	. .	0.12	1.2	. .	. .	. .	. .	. .
3004	. .	. .	1.2	1.0	. .	. .	. .	. .
3005	. .	. .	1.2	0.40	. .	. .	. .	. .
3105	. .	. .	0.6	0.50	. .	. .	. .	. .
4032	12.2	0.9	. .	1.0	. .	0.9	. .	. .
4043	5.2	. .	. .	. .	. .	. .	. .	. .
4045	10.0	. .	. .	. .	. .	. .	. .	. .
4047	12.0	. .	. .	. .	. .	. .	. .	. .
4145	10.0	4.0	. .	. .	. .	. .	. .	. .
4343	7.5	. .	. .	. .	. .	. .	. .	. .
4643	4.1	. .	. .	0.20	. .	. .	. .	. .
5005	. .	. .	. .	0.8	. .	. .	. .	. .
5050	. .	. .	. .	1.4	. .	. .	. .	. .
5052	. .	. .	. .	2.5	0.25	. .	. .	. .
5056	. .	. .	0.12	5.0	0.12	. .	. .	. .
5083	. .	. .	0.7	4.4	0.15	. .	. .	. .
5086	. .	. .	0.45	4.0	0.15	. .	. .	. .
5154	. .	. .	. .	3.5	0.25	. .	. .	. .
5183	. .	. .	0.8	4.8	0.15	. .	. .	. .
5252	. .	. .	. .	2.5	. .	. .	. .	. .
5254	. .	. .	. .	3.5	0.25	. .	. .	. .
5356	. .	. .	0.12	5.0	0.12	. .	. .	0.13
5454	. .	. .	0.8	2.7	0.12	. .	. .	. .
5456	. .	. .	0.8	5.1	0.12	. .	. .	. .
5457	. .	. .	0.30	1.0	. .	. .	. .	. .
5554	. .	. .	0.8	2.7	0.12	. .	. .	0.12
5556	. .	. .	0.8	5.1	0.12	. .	. .	0.12
5652	. .	. .	. .	2.5	0.25	. .	. .	. .
5654	. .	. .	. .	3.5	0.25	. .	. .	0.10
5657	. .	. .	. .	0.8	. .	. .	. .	. .

For all numbered footnotes, see page 1-13.

TABLE 1.1 Nominal Chemical Composition—Wrought Alloys (concluded)

The following values are shown as a basis for general comparison of alloys and are not guaranteed. Refer to Standards Section, Table 6.2, for composition limits.

	PERCENT OF ALLOYING ELEMENTS—Aluminum and Normal Impurities Constitute Remainder							
Alloy	Silicon	Copper	Manganese	Magnesium	Chromium	Nickel	Zinc	Titanium
6003	0.7	. .	. .	1.2	. .	. .	. .	. .
6005	0.8	. .	. .	0.50	. .	. .	. .	. .
6005A ⑪	0.7	. .	. .	0.55	. .	. .	. .	. .
6053	0.7	. .	. .	1.2	0.25	. .	. .	. .
6061	0.6	0.28	. .	1.0	0.20	. .	. .	. .
6063	0.40	. .	. .	0.7	. .	. .	. .	. .
6066	1.4	1.0	0.8	1.1	. .	. .	. .	. .
6070	1.4	0.28	0.7	0.8	. .	. .	. .	. .
6082	1.0	. .	0.7	0.9	. .	. .	. .	. .
6101	0.50	. .	. .	0.6	. .	. .	. .	. .
6105	0.8	. .	. .	0.6	. .	. .	. .	. .
6151	0.9	. .	. .	0.6	0.25	. .	. .	. .
6162	0.6	. .	. .	0.9	. .	. .	. .	. .
6201	0.7	. .	. .	0.8	. .	. .	. .	. .
6262 ⑤	0.6	0.28	. .	1.0	0.09	. .	. .	. .
6351	1.0	. .	0.6	0.6	. .	. .	. .	. .
6463	0.40	. .	. .	0.7	. .	. .	. .	. .
6951	0.35	0.28	. .	0.6	. .	. .	. .	. .
7005 ④	. .	. .	0.45	1.4	0.13	. .	4.5	0.04
7008	. .	. .	. .	1.0	0.18	. .	5.0	. .
7049	. .	1.6	. .	2.4	0.16	. .	7.7	. .
7050 ⑦	. .	2.3	. .	2.2	. .	. .	6.2	. .
7072	. .	. .	. .	. .	. .	. .	1.0	. .
7075	. .	1.6	. .	2.5	0.23	. .	5.6	. .
7108 ⑧	. .	. .	. .	1.0	. .	. .	5.0	. .
7175	. .	1.6	. .	2.5	0.23	. .	5.6	. .
7178	. .	2.0	. .	2.8	0.23	. .	6.8	. .
7475	. .	1.6	. .	2.2	0.22	. .	5.7	. .
8017 ⑨	. .	0.15	. .	0.03	. .	. .	. .	. .
8030 ⑩	. .	0.22	. .	. .	. .	. .	. .	. .
8176 ⑨	0.09	. .	. .	. .	. .	. .	. .	. .

Note: Listed herein are designations and chemical composition limits for some wrought unalloyed aluminum and for wrought aluminum alloys registered with The Aluminum Association. This does not include all alloys registered with The Aluminum Association. A complete list of registered designations is contained in the "Registration Record of International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys." These lists are maintained by the Technical Committee on Product Standards of The Aluminum Association.

① Lead and Bismuth, 0.40 percent each.
② Vanadium 0.10, Zirconium 0.18.
③ Iron 1.1.
④ Zirconium 0.14.
⑤ Lead and Bismuth, 0.55 percent each.
⑥ Formerly designated EC.
⑦ Zirconium 0.12.
⑧ Zirconium 0.18.
⑨ Iron 0.7.
⑩ Iron 0.55, Boron 0.02.
⑪ Maganeses and Chromium 0.12-0.50

AA Wrought Alloys and Similar Foreign Alloys

The following Table 1.2 lists the AA wrought alloys and the corresponding foreign alloys that are covered by standards as used in Austria, Canada, France, Germany, Great Britain, Italy, Spain and Switzerland and in the Recommendations of the International Organization for Standardization (ISO).

The table includes only those foreign alloys that are essentially equivalent in composition to the corrresponding AA alloys, but whose composition limits are not necessarily exactly the same as their AA counterparts. Standards are subject to change, and the actual issue of the specification or standard currently in effect should be consulted for full information.

TABLE 1.2 Foreign Alloy Designations and Similar AA Alloys

Foreign Alloy Designation	Designating Country	Equivalent or Similar AA Alloy
Al99	Austria (Önorm) ①	1200
Al99,5		1050
E-Al		1350
AlCuMg1		2017
AlCuMg2		2024
AlCuMg0,5		2117
AlMg5		5056
AlMgSi0,5		6063
E-AlMgSi		6101
AlZnMgCu1,5		7075
990C	Canada (CSA) ②	1100
CB60		2011
CG30		2117
CG42		2024
CG42 Alclad		Alclad 2024
CM41		2017
CN42		2018
CS41N		2014
CS41N Alclad		Alclad 2014
CS41P		2025
GM31N		5454
GM41		5083
GM50P		5356
GM50R		5056
GR20		5052
GS10		6063
GS11N		6061
GS11P		6053
MC10		3003
S5		4043
SG11P		6151
SG121		4032
ZG62		7075
ZG62 Alclad		Alclad 7075
A5/L	France (NF) ③	1350
A45		1100
A-G1		5050
A-G0.6		5005
A-G4MC		5086
A-GS		6063
A-GS/L		6101
A-M1		3003
A-M1G		3004
A-U4G		2017
A-U2G		2117
A-U2GN		2618
A-U4G1		2024
A-U4N		2218
A-U4SG		2014
A-S12UN		4032
A-Z5GU		7075

For all numbered footnotes, see page 1-16.

Foreign Alloy Designation	Designating Country	Equivalent or Similar AA Alloy
E-A1995 ④ / 3.0257 ⑤	Germany	1350
AlCuBiPb ④ / 3.1655 ⑤		2011
AlCuMg0.5 ④ / 3.1305 ⑤		2117
AlCuMg1 ④ / 3.1325 ⑤		2017
AlCuMg2 ④ / 3.1355 ⑤		2024
AlCuSiMn ④ / 3.1255 ⑤		2014
AlMg4.5Mn ④ / 3.3547 ⑤		5083
AlMgSi0.5 ④ / 3.3206 ⑤		6063
AlSi5 ④ / 3.2245 ⑤		4043
E-AlMgSi0.5 ④ / 3.3207 ⑤		6101
AlZnMgCu1.5 ④ / 3.4365 ⑤		7075
1E	Great Britain (BS) ⑥	1350
91E		6101
H14		2017
H19		6063
H20		6061
L.80, L.81		5052
L.86		2117
L.87		2117
L.93, L.94		2014A
L.95, L.96		7075
L.97, L.98		2024
2L.55, 2L.56		5052
2L.58		5056
3L.44		5050
5L.37		2017
6L.25		2218
N8		5083
N21		4043
150A	Great Britain (DTD) ⑦	2017
324A		4032
372B		6063
717, 724, 731A / 745, 5014, 5084		2618
5090		2024
5100		Alclad 2024

TABLE 1.2 Foreign Alloy Designations and Similar AA Alloys (concluded)

Foreign Alloy Designation	Designating Country	Equivalent or Similar AA Alloy
P-AlCu4MgMn	Italy (UNI) ⑧	2017
P-AlCu4.5MgMn		2024
P-AlCu4.5MgMnplacc.		Alclad 2024
P-AlCu2.5MgSi		2117
P-AlCu4.4SiMnMg		2014
P-AlCu4.4SiMnMgplacc.		Alclad 2014
P-AlMg0.9		5657
P-AlMg1.5		5050
P-AlMg2.5		5052
P-AlSi0.4Mg		6063
P-AlSi0.5Mg		6101
Al99.5E	Spain (UNE) ⑨	1350
L-313		2014
L-314		2024
L-315		2218
L-371		7075
Al-Mg-Si	Switzerland (VSM) ⑩	6101
Al1.5Mg		5050
Al-Cu-Ni		2218
Al3.5Cu0.5Mg		2017
Al4Cu1.2Mg		2027
Al-Zn-Mg-Cu		7075
Al-Zn-Mg-Cu-pl		Alclad 7075
Al99.0Cu	ISO ⑪	1100
AlCu2Mg		2117
AlCu4Mg1		2024
AlCu4SiMg		2014
AlCu4MgSi		2017
AlMg1		5005
AlMg1.5		5050
AlMg2.5		5052
AlMg3.5		5154
AlMg4		5086
AlMg5		5056
AlMn1Cu		3003
AlMg3Mn		5454
AlMg4.5Mn		5083
AlMgSi		6063
AlMg1SiCu		6061
AlZn6MgCu		7075

① Austrian Standard M3430.
② Canadian Standards Association.
③ Normes Françaises.
④ Deutsche Industrie-Norm.
⑤ Werkstoff-Nr.
⑥ British Standard.
⑦ Directorate of Technical Development.
⑧ Unificazione Nazionale Italiana.
⑨ Una Norma Espanol.
⑩ Verein Schweizerischer Maschinenindustrieller.
⑪ International Organization for Standardization.

TABLE 1.3 Aluminum Mill Product Specifications ① ② ③ ④

ALLOY	PRODUCT	SPECIFICATIONS					
		ASTM	Military	Federal	AMS	ASME	AWS
1060	Sheet and plate	B209	. .	. .	4000 ⑤	SB-209	. .
	Wire, rod, bar, rolled or cold finished	B211	. .	. .	. .	. .	. .
	Wire, rod, bar, profiles and tube; extruded	B221	. .	. .	. .	SB-221	. .
	Tube; extruded, seamless	B241/B241M	. .	. .	. .	SB-241/SB-241M	
		B345/B345M	. .	. .	. .	. .	. .
	Tube; drawn	B483/B483M					
	Tube; drawn, seamless	B210	. .	. .	. .	SB-210	. .
	Tube; condenser	B234	. .	. .	. .	SB-234	. .
	Pipe; gas and oil transmission	B345/B345M	. .	. .	. .	. .	. .
	Tube; condenser with integral fins	B404/B404M	. .	. .	. .	. .	. .
1100	Sheet and plate	B209	. .	. .	4001, 4003	SB-209	. .
					AMS-QQ-A-250/1		
	Wire, rod, bar; rolled or cold finished	B211	. .	. .	. .	. .	. .
					AMS-QQ-A-225/1	. .	
	Wire, rod, bar; profiles and tube; extruded	B221	. .	. .	. .	SB-221	. .
	Tube; extruded, seamless	B241/B241M	. .	. .	. .	SB-241/SB-241M	. .
	Tube; extruded, coiled	B491/B491M	. .	. .	. .	. .	. .
	Tube; drawn	B483/B483M	. .	. .	. .	. .	. .
	Tube; drawn, seamless	B210	. .	WW-T-700/1	4062	. .	. .
	Tube; welded	B313/B313M	. .	. .	. .	. .	. .
		B547/B547M					
	Rivet wire and rod	B316/B316M	. .	QQ-A-430	AS7220	. .	. .
	Spray gun wire	. .	. .	. .	4180	. .	C2.25/C2.25M
	Forgings and forging stock	B247	. .	. .	. .	. .	. .
	Welding rod and electrodes; bare	. .	. .	. .	. .	. .	A5.10/A5.10M
	Impacts	B221	. .	. .	. .	. .	. .
	Foil	B479	. .	QQ-A-1876	. .	. .	. .
1145	Foil	B373, B479	. .	QQ-A-1876	4011	. .	. .
1235	Foil	B373, B479	. .	QQ-A-1876	. .	. .	. .
	Tube; extruded, coiled	B491/B491M	. .	. .	. .	. .	. .
1350	ACSR	B232/B232M, B401	. .	. .	. .	. .	. .
	Bus conductors	B236	. .	. .	. .	. .	. .
	Rolled redraw rod	B233	. .	. .	. .	. .	. .
	Stranded conductors	B231/B231M, B400	. .	. .	. .	. .	. .
	Wire; H19 temper	B230/B230M	. .	. .	. .	. .	. .
	Wire; H14 temper	B609/B609M	. .	. .	. .	. .	. .
	Wire; rectangular and square	B324	. .	. .	. .	. .	. .
	Round solid conductor	B609/B609M	. .	. .	. .	. .	. .
2011	Tube; drawn, seamless	B210	. .	. .	. .	. .	. .
	Wire, rod, bar; rolled or cold finished	B211	. .	. .	AMS-QQ-A-225/3	. .	. .
2014	Sheet and Plate	B209	. .	. .	4028, 4029	. .	. .
	Wire, rod, bar; rolled or cold finished	B211	. .	. .	4121	SB-211	. .
					AMS-QQ-A-225/4		
	Wire, rod, bar; profiles and tube; extruded	B221	. .	. .	4153	. .	. .
					AMS-QQ-A-200/2		
	Tube; extruded, seamless	B241/B241M	. .	. .	. .	. .	. .
	Tube; drawn, seamless	B210	. .	. .	. .	. .	. .
	Forgings and forging stock	B247	. .	. .	4133, 4134	. .	. .
					AMS-A-22771		
	Rings; forged and rolled	. .	. .	. .	4314	. .	
	Impacts	B221	. .	. .	. .	. .	. .
Alclad 2014	Sheet and plate	B209	. .	. .	AMS-QQ-A-250/3	. .	. .
2017	Wire, rod, bar; rolled or cold finished	B211	. .	. .	4118	. .	. .
					AMS-QQ-A-225/5		
	Rivet wire and rod	B316/B316M	. .	QQ-A-430	. .	. .	. .
2018	Forgings and forging stock	B247	. .	. .	4140	. .	
2024	Sheet and plate	B209	. .	. .	4035, 4037	. .	. .
					4193, 4297		
					AMS-QQ-A-250/4		
	Wire, rod, bar; rolled or cold finished	B211	. .	. .	4120, 4339	SB-211	. .
					AMS-QQ-A-225/6		
	Wire, rod, bar; profiles and tube; extruded	B221	. .		4152, 4164, 4165	SB-221	. .
					AMS-QQ-A-200/3		
	Tube; extruded, seamless	B241/B241M	. .	. .	. .	. .	. .
	Tube; drawn, seamless	B210	. .	WW-T-700/3	4087, 4088	. .	. .
	Tube; hydraulic	. .	. .	. .	4086	. .	. .
	Rivet wire and rod	B316/B316M	. .	QQ-A-430	. .	. .	. .
	Foil	. .	. .	. .	AMS-A-81596	. .	. .

For all numbered footnotes, see page 1-22

TABLE 1.3 Aluminum Mill Product Specifications ① ② ③ ④ (continued)

ALLOY	PRODUCT	SPECIFICATIONS					
		ASTM	Military	Federal	AMS	ASME	AWS
Alclad 2024	Plate and Sheet	B209	..	..	4040, 4041 4194, 4195, 4279 AMS-QQ-A-250/5	..	..
Alclad One Side 2024	Sheet and plate	B209	..	..	4036, 4077	..	..
2025	Forgings and forging stock	B247	..	..	4130	..	..
2117	Rivet Wire and Rod	B316/B316M	..	QQ-A-430	AS 7222	..	..
2124	Plate	B209	..	..	4101, 4221 AMS-QQ-A-250/29	..	..
2218	Forgings and forging stock	B247	..	..	4142	..	..
2219	Sheet and plate	B209	..	..	4031, 4295 AMS-QQ-A-250/30	..	..
	Wire, rod and bar; rolled or cold finished	B211	..	..		..	..
	Wire, rod, bar, profiles and tubes; extruded	B221	..	..	4162	..	..
	Tube; extruded, seamless	B241/B241M	..	..	4068	..	..
	Tube; drawn, seamless	B210	..	..	4066	..	..
	Forgings and forging stock	B247	..	..	4143, 4144, AMS-A-22771	..	..
	Armor, Extruded	..	MIL-DTL-46083	..	..	..	..
	Armor, Forgings	..	MIL-DTL-46118	..	..	..	..
	Armor plate	..	MIL-DTL-46118	..	..	..	..
	Rings, rolled or forged	..	..	..	4313	..	..
	Rivet wire and rod	B316/B316M	..	QQ-A-430	..	..	..
Alclad 2219	Sheet and plate	B209	..	..	4094, 4095, 4096	..	..
2319	Welding rod and electrodes; bare	..	..	..	4191	..	A5.10/A5.10M
2519	Armor plate	..	MIL-DTL-46192	..	..	..	..
2618	Forgings and forging stock	B247	..	..	4132, AMS-A-22771	..	..
3003	Sheet and plate	B209	..	..	4006, 4008 AMS-QQ-A-250/2	SB-209	..
	Tread Plate	B632/B632M	..	..	..	..	..
	Wire, rod and bar; rolled or cold finished	B211	..	..	AMS-QQ-A-225/2	..	..
	Wire, rod, bar, profiles and tube; extruded	B221	..	..	AMS-QQ-A-200/1	SB-221	..
	Tube; extruded, seamless	B241/B241M	..	..	..	SB-241/SB-241M	..
	Tube; extruded, coiled	B491/B491M	..	..	..	..	..
	Tube; drawn	B483/B483M	..	..	..	..	..
	Tube, drawn seamless	B210	..	WW-T-700/2	4065, 4067	SB-210	..
	Tube; condenser	B234	..	..	..	SB-234	..
	Tube; condenser with integral fins	B404/B404M	..	..	..	..	..
	Tube; welded	B313/B313M B547/B547M	..	..	..	..	..
	Pipe	B241/B241M	MIL-DTL-25995	..	..	SB-241/SB-241M	..
	Pipe; gas and oil transmission	B345/B345M	..	..	..	..	..
	Rivet wire and rod	B316/B316M	..	QQ-A-430	..	..	..
	Forgings and forging stock	B247	..	..	..	SB-247	..
	Foil	..	..	..	4010 AMS-A-81596	..	..
Alclad 3003	Sheet and plate	B209	..	..	..	SB-209	..
	Brazing Sheet	..	..	..	4063, 4064	..	..
	Tube; drawn, seamless	B210	..	..	..	SB-210	
	Tube; extruded	B221	..	..	..	..	..
	Tube; extruded, seamless	B241/B241M	..	..	..	SB-241/SB-241M	..
	Tube; condenser	B234	..	..	..	SB-234	..
	Tube; condenser with integral fin	B404/B404M	..	..	..	..	..
	Tube; welded	B547/B547M	..	..	..	..	..
	Pipe; gas and oil transmission	B345/B345M	..	..	..	..	..
3004	Sheet and plate	B209	..	..	..	SB-209	..
	Tube; extruded	B221	..	..	..	..	..
	Tube; welded	B313/B313M B547/B547M	..	..	..	..	..
Alclad 3004	Sheet and plate	B209	..	..	..	SB-209	..
	Tube; welded	B313/B313M B547/B547M	..	..	..	..	..
3005	Sheet	B209	..	..	..	..	..
3102	Wire, rod, bar, profiles and tube; extruded	B221	..	..	..	SB-221	..
3105	Sheet	B209	..	..	..	..	..
4032	Rods and Bars; Rolled or Cold Finished	..	..	..	4318, 4319	..	..
	Forgings and forging stock	B247	..	..	..	..	..

For all numbered footnotes, see page 1-22

TABLE 1.3 Aluminum Mill Product Specifications ① ② ③ ④ (continued)

ALLOY	PRODUCT	SPECIFICATIONS					
		ASTM	Military	Federal	AMS	ASME	AWS
4043	Welding rod and electrodes; bare Spray gun wire				4190		A5.10/A5.10M C2.25/C2.25M
4045	Brazing filler metal	..	..	..	AMS-B-20148	..	..
4047	Brazing filler metal Welding rod and electrodes; bare	.. ..	.. ..	.. ..	4185 AMS-B-20148 ..	 ..	 A5.10/A5.10M
4145	Brazing filler metal Welding rod and electrodes; bare	.. ..	.. ..	.. ..	4184, AMS-B-20148 ..	 ..	 A5.10/A5.10M
4343	Brazing filler metal	..	..	..	AMS-B-20148	..	..
4643	Welding electrode	..	..	..	4189	..	A5.10/A5.10M
5005	Sheet and plate Wire; H19 temper Stranded conductor Rivet wire and rod Rod; rolled Tube, drawn, seamless Tube, drawn	B209 .. .. B316/B316M .. B210 B483/B483M	.. ..	.. .. .. QQ-A-430	.. ..	.. ..	.. ..
5050	Sheet and plate Tube; drawn, seamless Tube, drawn Tube; welded	B209 B210 B483/B483M B313/B313M B547/B547M	.. ..	.. ..	.. ..	SB-209	.. ..
5052	Sheet and plate Wire, rod and bar; rolled or cold finished Tube; drawn Tube; drawn, seamless Tube; hydraulic Tube; extruded Tube; extruded, seamless Tube; condenser Tube; condenser with integral fins Tube; welded Rivet wire and rod Foil	B209 B211 B483/B483M B210 .. B221 B241/B241M B234 B404/B404M B313/B313M B547/B547M B316/B316M ..	.. ..	 .. WW-T-700/4 .. .. QQ-A-430 ..	4015, 4016, 4017 AMS-QQ-A-250/8 4114 AMS-QQ-A-225/7 .. 4069, 4070 4071 .. .. 4004 AMS-A-81596	SB-209 .. .. SB-210 .. .. SB-241/SB-241M SB-234 SB-234	.. ..
5056	Rivet Wire and Rod Wire, rod and bar; rolled or cold finished Foil	B316/B316M B211 ..	.. .. ..	QQ-A-430	.. 4182 4005 ⑤ AMS-A-81596		.. .. ..
5083	Sheet and plate Marine Sheet and Plate Wire, rod, bar, profiles and tube; extruded Tube; extruded, seamless Tube; drawn, seamless Tube; welded Forgings and forging stock Pipe; gas and oil transmission Armor plate Extruded armor Forged armor	B209 B928/B928M B221 B241/B241M B210 B547/B547M B247 B345/B345M	.. .. MIL-DTL-46027 MIL-DTL-46083 MIL-DTL-45225		4056 AMS-QQ-A-250/6 .. AMS-QQ-A-200/4	SB-209 .. SB-221 SB-241/SB-241M SB-247	.. ..
5086	Sheet and plate Marine Sheet and Plate Wire, rod, bar, profiles and tube; extruded Tube; extruded, seamless Tube; drawn, seamless Tube; welded Pipe; gas and oil transmission	B209 B928/B928M B221 B241/B241M B210 B313/B313M B547/B547M B345/B345M	.. ..	.. .. WW-T-700/5	AMS-QQ-A-250/7 AMS-QQ-A-250/19 .. AMS-QQ-A-200/5	SB-209 .. SB-221 SB-241/SB-241M	.. ..

For all numbered footnotes, see page 1-22

TABLE 1.3 Aluminum Mill Product Specifications [1] [2] [3] [4] (continued)

ALLOY	PRODUCT	SPECIFICATIONS					
		ASTM	Military	Federal	AMS	ASME	AWS
5154	Sheet and plate	B209	. .	. .	. .	SB-209	. .
	Wire, rod and bar; rolled or cold finished	B211	. .	. .	. .	. .	. .
	Wire, rod, bar, profiles and tube; extruded	B221	. .	. .	. .	SB-221	. .
	Tube; drawn, seamless	B210	. .	. .	. .	SB-210	. .
	Tube; welded	B313/B313M B547/B547M	. .	. .	. .	. .	. .
5183	Welding rod and electrodes; bare	. .	. .	. .	. .	. .	A5.10/A5.10M
5252	Sheet	B209	. .	. .	. .	. .	. .
5254	Sheet and plate	B209	. .	. .	. .	SB-209	. .
	Tube; extruded, seamless	B241/B241M	. .	. .	. .	. .	. .
5356	Welding rod and electrodes; bare	. .	. .	. .	. .	. .	A5.10/A5.10M
5454	Sheet and plate	B209	. .	. .	AMS-QQ-A-250/10	SB-209	. .
	Wire, rod, bar, profiles and tube; extruded	B221	. .	. .	AMS-QQ-A-200/6	SB-221	. .
	Tube; extruded, seamless	B241/B241M	. .	. .	. .	SB-241/SB-241M	. .
	Tube; condenser	B234	. .	. .	. .	SB-234	. .
	Tube; condenser with integral fins	B404/B404M	. .	. .	. .	. .	. .
	Tube; welded	B547/B547M	. .	. .	. .	. .	. .
5456	Sheet and plate	B209	. .	. .	AMS-QQ-A-250/9 AMS-QQ-A-250/20	SB-209	. .
	Marine Sheet and Plate	B928/B928M	. .	. .	. .	. .	. .
	Wire, rod, bar, profiles and tube; extruded	B221	. .	. .	AMS-QQ-A-200/7	SB-221	. .
	Tube; extruded, seamless	B241/B241M	. .	. .	. .	SB-241/SB-241M	. .
	Tube; drawn, seamless	B210	. .	. .	. .	. .	. .
	Armor plate	. .	MIL-DTL-46027	. .	. .	. .	. .
	Extruded armor	. .	MIL-DTL-46083	. .	. .	. .	. .
	Forged armor	. .	MIL-DTL-45225	. .	. .	. .	. .
5457	Sheet	B209	. .	. .	. .	. .	. .
5554	Welding rod and electrodes; bare	. .	. .	. .	. .	. .	A5.10/A5.10M
5556	Welding rod and electrodes; bare	. .	. .	. .	. .	. .	A5.10/A5.10M
5654	Welding rod and electrodes; bare	. .	. .	. .	. .	. .	A5.10/A5.10M
5657	Sheet	B209	. .	. .	. .		. .
6005	Wire, rod, bar, profiles and tube; extruded	B221	. .	. .	. .	. .	. .
6005A	Wire, rod, bar, profiles and tube; extruded	B221	. .	. .	. .	SB-221	. .
6053	Rivet wire and rod	B316/B316M	. .	QQ-A-430	. .	. .	. .
6060	Wire, rod, bar, profiles and tube; extruded	B221	. .	. .	. .	. .	. .
6061	Sheet and plate	B209	. .	. .	4025, 4026, 4027 AMS-QQ-A-250/11	SB-209	. .
	Tread Plate	B632/B632M	. .	. .	. .	. .	. .
	Wire, rod and bar; rolled or cold finished	B211	. .	. .	4115, 4116, 4117, 4128 AMS-QQ-A-225/8	SB-211	. .
	Wire, rod, bar, profiles and tube; extruded	B221	. .	. .	4150, 4160, 4161, AMS-QQ-A-200/8 4172, 4173	SB-221	. .
	Structural profiles	B308/B308M	. .	. .	4113 AMS-QQ-A-200/16	SB-308/SB-308M	. .
	Tube, drawn	B483/B483M	. .	. .	. .	. .	. .
	Tube; extruded, seamless	B241/B241M	. .	. .	. .	SB-241/SB-241M	. .
	Tube; drawn, seamless	B210	. .	WW-T-700/6	4079, 4080, 4082	SB-210	. .
	Tube; hydraulic	. .	. .	. .	4081, 4083	. .	. .
	Tube; condenser	B234	. .	. .	. .	SB-234	. .
	Tube; condenser with integral fins	B404/B404M	. .	. .	. .	. .	. .
	Tube; welded	B313/B313M B547/B547M	. .	. .	. .	. .	. .
	Pipe	B241/B241M	MIL-DTL-25995	. .	. .	SB-241/SB-241M	. .
	Pipe; gas and oil transmission	B345/B345M	. .	. .	. .	. .	. .
	Forgings and forging stock	B247	. .	. .	4127, 4146[5], 4248 AMS-A-22771	SB-247	. .
	Rings; forged or rolled	. .	. .	. .	4312	. .	. .
	Rivet Wire and Rod	B316/B316M	. .	QQ-A-430	. .	. .	. .
	Impacts	B221	. .	. .	. .	. .	. .
	Structural pipe and tube; extruded	B429	. .	. .	. .	. .	. .
	Foil	. .	. .	. .	4009[5]	. .	. .

For all numbered footnotes, see page 1-22

TABLE 1.3 Aluminum Mill Product Specifications ① ② ③ ④ (continued)

ALLOY	PRODUCT	SPECIFICATIONS					
		ASTM	Military	Federal	AMS	ASME	AWS
Alclad 6061	Sheet and plate	B209	. .	. .	4021⑤	SB-209	. .
6063	Wire, rod, bar, profiles and tube; extruded	B221	. .	. .	4156 AMS-QQ-A-200/9	SB-221	. .
	Tube; extruded, seamless	B241/B241M	. .	. .	. .	SB-241/SB-241M	. .
	Tube; extruded, coiled	B491/B491M	. .	. .	. .	. .	. .
	Tube; drawn	B483/B483M	. .	. .	. .	. .	. .
	Pipe	B241/B241M	MIL-DTL-25995	. .	. .	SB-241/SB-241M	. .
	Pipe; gas and oil transmission, seamless	B345/B345M	. .	. .	. .	. .	. .
	Structural pipe and tube; extruded	B429	. .	. .	. .	. .	. .
6066	Wire, rod, bar, profiles and tube; extruded	B221	. .	. .	AMS-QQ-A-200/10	. .	. .
	Forgings and forging stock	B247	. .	. .	. .	. .	. .
6070	Rod, bar, profiles and tube; extruded	B221	. .	. .	. .	. .	. .
	Impacts	B221	. .	. .	. .	. .	. .
	Pipe; gas and oil transmission	B345/B345M	. .	. .	. .	. .	. .
6082	Wire, rod, bar, profiles and tube; extruded	B221	. .	. .	. .	SB-221	. .
6101	Bus conductor	B317/B317M	. .	. .	. .	. .	. .
6105	Wire, rod, bar, profiles and tube; extruded	B221	. .	. .	. .	. .	. .
6151	Forgings and forging stock	B247	. .	. .	4125, AMS-A-22771	. .	. .
6201	Wire ; T81 temper	B398/B398M	. .	. .	. .	. .	. .
	Standard conductor; T81 temper	B399/B399M	. .	. .	. .	. .	. .
6162	Wire, rod, bar, profiles and tube; extruded	B211	. .	. .	. .	. .	. .
6262	Wire, rod and bar; rolled or cold finished	B211	. .	. .	AMS-QQ-A-225/10	. .	. .
	Wire, rod, bar, profiles and tube; extruded	B221	. .	. .	. .	. .	. .
	Tube, drawn seamless	B210 B483/B483M	. .	. .	. .	. .	. .
6351	Pipe; gas and oil transmission	B345/B345M	. .	. .	. .	. .	. .
	Seamless pipe and tube, extruded,	B241/B241M B345/B345M	. .	. .		. .	. .
	Wire, rod, bar, profiles and tube; extruded	B221	. .	. .	. .	. .	. .
6463	Wire, rod, bar, profiles and tube; extruded	B221	. .	. .	. .	. .	. .
7005	Wire, rod, bar, profiles and tube; extruded	B221	. .	. .	. .	. .	. .
7039	Armor plate	. .	MIL-DTL-46063	. .	. .	. .	. .
	Armor, Extruded	. .	MIL-DTL-46083	. .	. .	. .	. .
	Armor, Forgings	. .	MIL-DTL-45225	. .	. .	. .	. .
7049	Forgings	B247	. .	. .	4111, AMS-A-22771	. .	. .
	Extrusions	. .	. .	. .	4157, 4159	. .	. .
	Hand forgings	. .	. .	. .	4247	. .	. .
	Forging	. .	. .	. .	4321	. .	. .
	Plate	. .	. .	. .	4200	. .	. .
7050	Plate	. .	. .	. .	4050, 4201	. .	. .
	Wire, rod, bar; extruded	. .	. .	. .	4340, 4341, 4342	. .	. .
	Forgings	B247	. .	. .	4107, 4108, AMS-A-22771	. .	. .
	Die forgings	B247	. .	. .	4333	. .	. .
	Rivet Wire and Rod	B316/B316M	. .	QQ-A-430	. .	. .	. .
Alclad 7050	Sheet	. .	. .	. .	4243	. .	. .
7075	Sheet and plate	B209	. .	. .	4044, 4045, 4078 AMS-QQ-A-250/12 AMS-QQ-A-250/24	. .	. .
	Sheet; fine grained				4277		
	Wire, rod and bar; rolled or cold finished	B211	. .	. .	4122, 4123, 4124, 4186, 4187 ⑤ AMS-QQ-A-225/9	. .	. .
	Wire, rod, bar, profiles and tube; extruded	B221	. .	. .	4154, 4166, 4167, 4168, 4169 AMS-QQ-A-200/11	. .	. .
	Wire, rod, bar, profiles and tube; extruded (Exfoliation Resistant)	. .	. .	. .	AMS-QQ-A-200/15	. .	. .
	Tube; extruded	B241/B241M	. .	. .	. .	. .	. .
	Tube; drawn, seamless	B210	. .	WW-T-700/7	. .	. .	. .
	Forgings and forging stock	B247	. .	. .	4126, 4131, 4141, 4147, AMS-A-22771	. .	. .
	Hand forging	B247			4323		
	Rings, forged or rolled	B247	. .	. .	4310, 4311	. .	. .
	Impacts	B221	. .	. .	. .	. .	. .
	Rivet Wire	B316/B316M	. .	QQ-A-430	. .	. .	

For all numbered footnotes, see page 1-22

TABLE 1.3 Aluminum Mill Product Specifications ① ② ③ ④ (concluded)

ALLOY	PRODUCT	SPECIFICATIONS					
		ASTM	Military	Federal	AMS	ASME	AWS
Alclad 7075	Sheet and plate Sheet; fine grained	B209	..	..	4048, 4049 AMS-QQ-A-250/13 AMS-QQ-A-250/25 AMS-QQ-A-250/26 4278	..	..
Alclad One Side 7075	Sheet and plate	B209	..	..	4046 AMS-QQ-A-250/18	..	..
7116	Wire, rod, bar, profiles and tube; extruded	B221	..	..	..	..	..
7129	Wire, rod, bar, profiles and tube; extruded	B221	..	..	..	..	..
7175	Extruded Forgings and forging stock	.. B247	.. ..	.. ..	4344 4148, 4149, 4179, AMS-A-22771	.. ..	.. ..
7178	Sheet and plate Wire, rod, bar, profiles and tube; extruded Rivet Wire Tube; extruded, seamless	B209 B221 B316/B316M B241/B241M	.. ..	.. ..	AMS-QQ-A-250/14 AMS-QQ-A-250/21 AMS-QQ-A-200/13 AMS-QQ-A-200/14	.. .. ..	.. ..
Alclad 7178	Sheet and plate	B209	..	..	.. AMS-QQ-A-250/15 AMS-QQ-A-250/22 AMS-QQ-A-250/28	..	..
7475	Sheet and plate	..	..	..	4084, 4085, 4089, 4090, 4202	..	..
Alclad 7475	Sheet	..	..	..	4100, 4207	..	..

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② This cross-reference index lists the basic specification or standard number and no attempt is made to reflect the latest revision or amendment to any particular document. The appropriate specification index published by the specification issuing body should be consulted to determine the latest issue of any particular specification or standard. The aluminum industry generally prefers to use the latest issue of any given specification or standard.

③ Different organizations' specifications for the same alloy and product may contain different requirements.

④ Copies of specifications can be obtained from:

(Aerospace Material Specifications) (AMS)
SAE, Inc.
400 Commonwealth Drive
Warrendale, PA 15096-0001

ASTM
100 Barr Harbor Drive
West Conshohocken, PA
19428-2959

(Military and Federal)
Standardization Documents Order Desk
Building 4D, 700 Robins Avenue
Philadelphia, PA 19111-5094

(AWS)
American Welding Society
550 N.W. LeJeune Road
Miami, FL 33126

(ASME)
American Society of Mechanical Engineers
345 East 47th Street
New York, NY 10017

⑤ Noncurrent

TABLE 1.4 Specifications Covering Aluminum Mill Products ① ②

SPECIFICATION NUMBER	ALLOYS AND PRODUCT OR PROCESS COVERED
	FEDERAL SPECIFICATIONS
FED-STD-123	Marking for domestic shipment (civilian agencies)
FED-STD-184	Item identification marking for aluminum products
FED-STD-245	Tolerances for aluminum wrought products finished wire, rod, bar and special shapes
QQ-A-430	1100, 2017, 2024, 2117, 2219, 3003, 5005, 5052, 5056, 6053, 6061, 7050, and 7075 wire and rod for rivets and cold heading
QQ-A-1876	Aluminum Foil; 1100, 1145, 1235
WW-T-700	General specification for drawn tube, seamless
WW-T-700/1	1100 drawn tube, seamless
WW-T-700/2	3003 drawn tube, seamless
WW-T-700/3	2024 drawn tube, seamless
WW-T-700/4	5052 drawn tube, seamless
WW-T-700/5	5086 drawn tube, seamless
WW-T-700/6	6061 drawn tube, seamless
WW-T-700/7	7075 drawn tube, seamless
	MILITARY SPECIFICATIONS
MIL-STD-129	Marking for shipment and storage
MIL-C-5541	Chemical films for aluminum and aluminum alloys
MIL-A-8625	Anodic coatings for aluminum alloys
MIL-DTL-25995	3003, 6061 and 6063 pipe
MIL-DTL-45225	5083, 5456 and 7039 forged armor
MIL-DTL-46027	5083 and 5456 armor plate
MIL-DTL-46063	7039 armor plate
MIL-DTL-46083	5083, 5456, 2219 and 7039 extruded armor
MIL-DTL-46118	2219 armor plate and forgings
MIL-DTL-46192	2519 armor plate
	THE AMERICAN WELDING SOCIETY (AWS)
A5.3/A5.3M	Specification for Aluminum and Aluminum Alloy Electrodes for Shielded Gas Metal Arc Welding
A5.10/A5.10M	Specification for Bare Aluminum and Aluminum Welding Electrodes and Rods, 1100, 2319, 4043, 4047, 4145, 4643, 5183, 5356, 5554, 5556, 5654
C2.25/C2.25M	Thermal Spray - Solid and Composite Wire and Ceramic Rods
	AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)
B36.10M	Standard dimensions for welded and seamless (steel) pipe
B36.19M	Standard dimensions for (stainless steel) pipe
SB-209	1060, 1100, 3003, Alclad 3003, 3004, Alclad 3004, 5052, 5083, 5086, 5154, 5254, 5454, 5456, 5652, 6061, and Alclad 6061 sheet and plate
SB-210	1060, 3003, Alclad 3003, 5052, 5154, 6061, and 6063 drawn seamless tube
SB-211	2014, 2024, and 6061 rolled, drawn, or cold finished wire, rod and bar
SB-221	1060, 1100, 2024, 3003, 5083, 5086, 5154, 5454, 5456, 6005A, 6061 and 6063 extruded rod, bar and shapes
SB-234	1060, 3003, Alclad 3003, 5052, 5454, and 6061 drawn, seamless tube for condensers and heat exchangers
SB-241/SB-241M	3003, 6061 and 6063 seamless pipe; 1060, 1100, 3003, Alclad 3003, 5052, 5083, 5086, 5454, 5456, 6061 and 6063 seamless extruded tube
SB-247	5083 and 6061 hand forgings; 2014, 3003, 5083 and 6061 die forgings
SB-308/SB-308M	6061 rolled or extruded standard structural shapes

SPECIFICATION NUMBER	ALLOYS AND PRODUCT OR PROCESS COVERED
	AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)
B209	1060, 1100, 2014, Alclad 2014, 2024, Alclad 2024, Alclad one side 2024, 2124, 2219, Alclad 2219, 3003, Alclad 3003, 3004, Alclad 3004, 3005, 3105, 5005, 5050, 5052, 5083, 5086, 5154, 5252, 5254, 5454, 5456, 5457, 5652, 5657, 6061, Alclad 6061, 7075, Alclad 7075, Alclad one side 7075, 7178, and Alclad 7178 sheet and plate
B210	1060, 1100, 2011, 2014, 2024, 3003, Alclad 3003, 5005, 5050, 5052,5083, 5086, 5154, 5456, 6061, 6063, 6262 and 7075 drawn seamless tube
B211	1060, 1100, 2011, 2014, 2017, 2024, 2219, 3003, 5052,5056, 5154, 6061, 6063, 6262 and 7075 rolled, drawn or cold finished wire, rod and bar
B221	1060, 1100, 2014, 2024, 2219, 3003, Alclad 3003, 3004, 3102, 5052,5083, 5086, 5154, 5454, 5456, 6005, 6005A, 6060, 6061, 6063, 6066, 6070, 6105, 6162, 6262, 6351, 6463, 7005, 7072, 7075, 7116, 7129 and 7178 extruded wire, rod, bar, shapes and tube
B230/B230M	1350-H19 wire
B231/B231M	Aluminum conductors, concentric-lay-stranded
B232/B232M	1350 Aluminum conductors, steel reinforced, concentric-lay-stranded (ACSR)
B233	1350 drawing stock for electrical purposes
B234	1060, 3003, Alclad 3003, 5052, 5454, and 6061 drawn, seamless tube for condensers and heat exchangers
B236	1350 bus conductor
B241/B241M	3003, 6061, 6063, and 6351 seamless pipe; 1060, 1100, 2014, 2024, 2219, 3003, Alclad 3003, 5052, 5083, 5086, 5254, 5454, 5456, 5652, 6061, 6063, 6351, 7075, and 7178 seamless extruded tube
B247	2014, 2219, 2618, 5083, 6061, 7049, 7050, 7075, and 7175 hand forgings; 1100, 2014, 2018, 2025, 2218, 2219, 2618, 3003, 4032, 5083, 6061, 6066, 6151, 7049, 7050, 7075, 7076 and 7175 die forgings; 2014, 2219, 2618, 6061, 6151, and 7075 rolled ring forgings
B308/B308M	6061 rolled or extruded standard structural shapes
B313/B313M	1100, 3003, 3004, Alclad 3004, 5050, 5052, 5086, 5154, and 6061 round welded tube
B316/B316M	1100, 2017, 2024, 2117, 2219, 3003, 5005, 5052, 5056, 6053, 6061, 7050, 7075 and 7178 rivet and cold heading wire and rod
B317/B317M	6101 extruded rod, bar, structural shapes and pipe for electrical purposes
B324	1350 rectangular and square wire
B345/B345M	3003, 6061, 6063, and 6351 seamless pipe; 1060, 3003, Alclad 3003, 5083, 5086, 6061, 6063, 6070, and 6351 seamless extruded tube
B373	1145 and 1235 foil for capacitors
B398/B398M	6201-T81 wire for electrical purposes
B399/B399M	Concentric-lay-stranded, 6201-T81 conductors
B400	Compact round concentric-lay-stranded, 1350 conductors, hard-drawn
B401	1350 Compact round concentric-lay-stranded aluminum conductors, steel reinforced (ACSR)
B404/B404M	1060, 3003, Alclad 3003, 5052, 5454, and 6061 seamless condenser and heat exchanger tube with integral fins
B429	6061 and 6063 extruded structural pipe and tube
B479	1100, 1145, and 1235 foil for flexible barrier
B483/B483M	1060, 1100, 1435, 3003, 5005, 5050, 5052, 6061, 6063 and 6262 drawn tube
B491/B491M	1050, 1100, 1200, 1235, 3003 and 6063 extruded round coiled tube
B547/B547M	1100, 3003, Alclad 3003, 3004 Alclad 3004, 5050, 5052, 5083, 5086, 5154, 5454 and 6061 formed and arc welded round tube

For all numbered footnotes, see page 1-26.

TABLE 1.4 Specifications Covering Aluminum Mill Products [1] [2]

SPECIFICATION NUMBER	ALLOYS AND PRODUCT OR PROCESS COVERED
B609/B609M	Aluminum 1350 round wire, annealed and intermediate tempers, for electrical purposes
B632/B632M	Aluminum-alloy 6061 rolled tread plate
B660	Packaging/Packing of Aluminum and Magnesium Products
B666/B666M	Practice for Identification Marking of Aluminum Products
B928/B928M	High Magnesium Aluminum Alloy Sheet and Plate for Marine Service

SAE — AEROSPACE MATERIAL SPECIFICATIONS (AMS)

SPECIFICATION NUMBER	ALLOYS AND PRODUCT OR PROCESS COVERED
2469	Process and Performance Requirement for Hard-Anodic Coating Treatment of Aluminum Alloys
2470	Chromic-Acid Anodizing of Aluminum Alloys
2471	Undyed Coating Sulfuric-Acid Process, Anodizing of Aluminum Alloys
2472	Dyed Coating Sulfuric-Acid Anodizing of Aluminum Alloys
2473	Chemical Film Treatment for Aluminum Alloys, General Purpose Coating
2474	Low Electrical Resistant Coating, Chemical Treatments for Aluminum Alloys
2808	Identification Markings for Forgings
2816	Color Code identification Marking of Welding Wire
4000 [3]	1060-O Sheet and Plate
4001	1100-O Sheet and Plate
4003	1100-H14 Sheet and Plate
4004	5052-H191 Foil
4005 [3]	5056-H191 Foil
4006	3003-O Sheet and Plate
4008	3003-H14 Sheet and Plate
4009 [3]	6061-O Foil
4010	3003-H18 Foil
4011	1145-O Foil
4013	Laminated Shim Stock, Surface Bonded
4015	5052-O Sheet and Plate
4016	5052-H32 Sheet and Plate
4017	5052-H34 Sheet and Plate
4021 [3]	Alclad 6061-O Sheet and Plate
4025	6061-O Sheet and Plate
4026	6061-T4 and T451 Sheet and Plate
4027	6061-T6 and T651 Sheet and Plate
4028	2014-O Sheet and Plate
4029	2014-T6 Sheet and 2014-T651 Plate
4031	2219-O Sheet and Plate
4035	2024-O Sheet and Plate
4036	Alclad one side 2024-T3 Sheet and T351 Plate
4037	2024-T3 Sheet and T351 Plate
4040	Alclad 2024-O and 1½% Alclad 2024-O Sheet and Plate
4041	Alclad 2024 and 1½% Alclad 2024-T3 Flat Sheet; Alclad 2024-T351 Plate
4044	7075-O Sheet and Plate
4045	7075-T6 Sheet and T651 Plate
4046	Alclad One Side 7075-T6 Sheet and Alclad One Side, 7075-T651 Plate
4048	Alclad 7075-O Sheet and Plate
4049	Alclad 7075-T6 Sheet and Alclad 7075-T651 Plate
4050	7050-T7451 (formerly T73651) Plate
4056	5083-O Sheet and Plate
4062	1100-H14 Drawn Seamless Tube
4063	Clad One Side 3003 Sheet (Brazing Sheet No. 11-O)
4064	Clad Two Sides 3003 Sheet (Brazing Sheet No. 12-O)
4065	3003-O Drawn Tube, Seamless
4066	2219-T851 Drawn Tube, Seamless
4067	3003-H14 Drawn Tube, Seamless
4068	2219-T351 Drawn Tube, Seamless
4069	5052-O Drawn Tube, Special Tolerances, Seamless
4070	5052-O Drawn Tube, Seamless
4071	5052-O Drawn, Hydraulic Tube, Seamless
4077	Alclad one side 2024-O Sheet and Plate
4078	7075-T7351 Plate
4079	6061-O Drawn Seamless Tube, Special Tolerances
4080	6061-O Drawn Seamless Tube
4081	6061-T4 Drawn, Seamless Hydraulic Tube
4082	6061-T6 Seamless Drawn Tube
4083	6061-T6 Drawn, Seamless Hydraulic Tube
4084	7475-T61 Sheet
4085	7475-T761 Sheet
4086	2024-T3 Drawn, Seamless Hydraulic Tube
4087	2024-O Drawn Seamless Tube
4088	2024-T3 Drawn Seamless Tube
4089	7475-T7651 Plate
4090	7475-T651 Plate
4094	Alclad 2219-T81 Sheet and T851 Plate
4095	Alclad 2219-T31 Sheet and T351 Plate
4096	Alclad 2219-O Sheet and Plate
4100	Alclad 7475-T761 Sheet
4101	2124-T851 Plate
4107	7050-T74 (formerly T736) Die Forgings
4108	7050-T7452 (formerly T73652) Hand Forgings
4111	7049-T73 Forgings and Forging Stock
4113	6061-T6 Extruded Profiles
4114	5052-F Rolled or Cold Finished, Rods and Bars
4115	6061-O Rolled, Drawn or Cold Finished Wire, Rod, Bar and Flash Welded Rings
4116	6061-T4 Cold Finished Wire, Rod and Bar
4117	6061-T6 and T651 Rolled or Cold Finished Wire, Rod, Bar and Flash Welded Rings
4118	2017-T4 and T451 Rolled Cold Finished Wire, Rod and Bar
4120	2024-T4 and T351 Rolled or Cold Finished Wire, Rod and Bar
4121	2014-T6 Rolled or Cold Finished Wire, Rod and Bar
4122	7075-T6 Rolled or Cold Finished Wire, Rod, Bar and Rings
4123	7075-T651 Rolled or Cold Finished Rod and Bar
4124	7075-T7351 Rolled or Cold Finished Bars, Rods and Wire
4125	6151-T6 Die Forgings and Rolled or Forged Rings
4126	7075-T6 Die and Hand Forgings and Rolled Rings
4127	6061-T6 Forgings and Rolled or Forged Rings
4128	6061-T451 Bars, Rolled or Cold Finished
4130	2025-T6 Die Forgings
4131	7075-T74 Die and Hand Forgings
4132	2618-T61 Die and Hand Forgings, Rolled Rings and Forging Stock
4133	2014-T6 Forgings and Rolled Rings
4134	2014-T4 Die Forgings
4140	2018-T61 Die Forgings
4141	7075-T73 Die Forgings
4143	2219-T6 Forgings and Rolled or Forged Rings
4144	2219-T852 and -T851 Hand Forgings and Rings
4146 [3]	6061-T4 Forgings and Rolled or Forged Rings
4147	7075-T7352 Forgings
4148	7175-T66 Die Forgings
4149	7175-T74 Die and Hand Forgings
4150	6061-T6 Extrusions and Rings
4152	2024-T3 Extrusions
4153	2014-T6 Extrusions
4154	7075-T6 Extrusions
4156	6063-T6 Extrusions
4157	7049-T73511 Extrusions
4159	7049-T76511 Extrusions
4160	6061-O Extrusions
4161	6061-T4 Extrusions
4162	2219-T8511 Extrusions
4163	2219-T3511 Extrusions
4164	2024-T3510 Extrusions
4165	2024-T3511 Extrusions
4166	7075-T73 Extrusions
4167	7075-T73511 Extrusions
4168	7075-T6510 Extrusions
4169	7075-T6511 Extrusions
4172	6061-T4511 Extrusions
4173	6061-T6511 Extrusions
4179	7175-T7452 Forgings
4180	1100-H18 Wire for Metal Spraying
4184	4145 Brazing Filler Metal
4185	4047 Brazing Filler Metal
4186	7075-F Wire, Rod and Bar ; Rolled or Cold Finished
4187 [3]	7075-O Wire, Rod and Bar ; Rolled, Drawn or Cold Finished
4189	4643 Welding Wire

For all numbered footnotes, see page 1-26.

TABLE 1.4 Specifications Covering Aluminum Mill Products ① ②

SPECIFICATION NUMBER	ALLOYS AND PRODUCT OR PROCESS COVERED
4190	4043 Welding Wire
4191	2319 Welding Wire
4193	2024-T861 Sheet and Plate
4194 ③	Alclad 2024-T361 Sheet and Plate
4195	Alclad 2024-T861 Sheet and Plate
4200	7049-T7351 Plate
4201	7050-T7651 Plate
4202	7475-T7351 Plate
4203	7010-T7351 Plate
4204	7010-T7651 Plate
4205	7010-T7451 (formerly T73651) Plate
4206	7055-T7751 Plate
4207	Alclad 7475-T61 Sheet
4208	2004-F Sheet
4209	Alclad 2004-F Sheet
4221	2124-T8151 Plate
4232	2090-T86 Extrusions
4243	Alclad 7050-T76 Sheet
4247	7049-T7352 Hand Forgings
4248	6061-T652 Hand Forgings and Rolled Rings
4251	2090-T83 Sheet
4252	7150-T7751 Plate
4255	Clad One Side 6951 Sheet (No. 21 Brazing Sheet) As Fabricated
4256	Clad Two Sides 6951 Sheet (No. 22 Brazing Sheet) As Fabricated
4259 ③	8090-T6 Sheet (Unrecrystallized)
4270	Alclad 2424-T3 Sheet
4273	2424-T3 Sheet and Plate
4274	Alclad 2424-O Sheet, Fine Grained
4276	2424-O Sheet, Fine Grained
4277	7075-O Sheet, Fine Grained
4278	Alclad 7075-O Sheet, Fine Grained
4279	Alclad 2024-T4 Sheet
4295	2219 Sheet and Plate
4296	Alclad 2524-T3 Sheet and Plate
4297	2024-T4 Sheet
4303	2090-T81 Plate
4306	7150-T6151 Plate
4307 ③	7150-T61511 Extrusions
4308 ③	8009-H112 Sheet
4309 ③	8009-H112 Extrusions
4310	7075-T651 and T652 Rings, Forged or Rolled
4311	7075-T7351 and T7352 Rings, Forged or Rolled
4312	6061-T651 and T652 Rings, Rolled or Forged
4313	2219-T351 and T352 Rings, Forged or Rolled
4314	2014-T651 and T652 Rings, Forged or Rolled
4319	4032-T651 Rolled or Cold Finished Bars and Rods
4320	7149-T73 Forgings
4321	7049-O1 Forgings
4323	7075-T7452 Hand Forgings
4333	7050-T7452 Die Forgings
4334 ③	7249-T74 and T7452 Forgings
4337	7055-T77511 Extruded Profiles
4339	2024-T851 Rolled or Cold Finished Bars and Rods
4340	7050-T76511 Extrusions
4341	7050-T73511 Extrusions
4342	7050-T74511 (formerly T736511) Extrusions
4343	7149-T73511 Extrusions
4344	7175-T73511 Extrusions
4345	7150-T77511 Extrusions
4347	6013-T4 Sheet
AMS-QQ-A-200	Aluminum Alloy, Bar, Rod, Shapes, Structural Shapes, Tube and Wire, Extruded, General Specification for
AMS-QQ-A-200/1	3003, Bar, Rod, Shapes, Tube and Wire, Extruded
AMS-QQ-A-200/2	2014, Bar, Rod, Shapes, Tube and Wire, Extruded
AMS-QQ-A-200/3	2024, Bar, Rod, Shapes, Tube and Wire, Extruded
AMS-QQ-A-200/4	5083, Bar, Rod, Shapes, Tube and Wire, Extruded
AMS-QQ-A-200/5	5086, Bar, Rod, Shapes, Tube and Wire, Extruded
AMS-QQ-A-200/6	5454, Bar, Rod, Shapes, Tube and Wire, Extruded
AMS-QQ-A-200/7	5456, Bar, Rod, Shapes, Tube and Wire, Extruded
AMS-QQ-A-200/8	6061, Bar, Rod, Shapes, Tube and Wire, Extruded
AMS-QQ-A-200/9	6063, Bar, Rod, Shapes, Tube and Wire, Extruded
AMS-QQ-A-200/10	6066, Bar, Rod, Shapes, Tube and Wire, Extruded
AMS-QQ-A-200/11	7075, Bar, Rod, Shapes, Tube and Wire, Extruded
AMS-QQ-A-200/13	7178, Bar, Rod, Shapes, Tube and Wire, Extruded
AMS-QQ-A-200/14	7178-T76, Bar, Rod, Shapes and Wire, Extruded (Exfoliation Resistant)
AMS-QQ-A-200/15	7075-T76, Bar, Rod and Shapes, Extruded (Exfoliation Resistant)
AMS-QQ-A-200/16	6061, Structural Shapes, Extruded
AMS-QQ-A-200/17	6162, Bar, Rod, Shapes, Tube and Wire, Extruded
AMS-QQ-A-225	Aluminum and Aluminum Alloy, Bar, Rod, Wire, or Special Shapes; Rolled, Drawn or Cold Finished; General Specification for
AMS-QQ-A-225/1	1100 Aluminum Alloy, Bar, Rod, Wire; Rolled, Drawn or Cold Finished
AMS-QQ-A-225/2	3003 Aluminum Alloy, Bar, Rod, Wire; Rolled, Drawn or Cold Finished
AMS-QQ-A-225/3	2011 Aluminum Alloy, Bar, Rod, Wire; Rolled, Drawn or Cold Finished
AMS-QQ-A-225/4	2014 Aluminum Alloy, Bar, Rod, Wire, and Special Shapes; Rolled, Drawn or Cold Finished
AMS-QQ-A-225/5	2017 Aluminum Alloy, Bar, Rod, Wire; Rolled, Drawn or Cold Finished
AMS-QQ-A-225/6	2024 Aluminum Alloy, Bar, Rod, Wire; Rolled, Drawn or Cold Finished
AMS-QQ-A-225/7	5052 Aluminum Alloy, Bar, Rod, Wire; Rolled, Drawn or Cold Finished
AMS-QQ-A-225/8	6061 Aluminum Alloy, Bar, Rod, Wire, and Special Shapes; Rolled, Drawn or Cold Finished
AMS-QQ-A-225/9	7075 Aluminum Alloy, Bar, Rod, Wire, and Special Shapes; Rolled, Drawn or Cold Finished
AMS-QQ-A-225/10	6262 Aluminum Alloy, Bar, Rod, Wire; Rolled, Drawn or Cold Finished
AMS-QQ-A-250	Aluminum and Aluminum Alloy, Plate and Sheet, General Specification for
AMS-QQ-A-250/1	1100 Aluminum Sheet and Plate
AMS-QQ-A-250/2	3003 Aluminum Alloy Plate and Sheet
AMS-QQ-A-250/3	Alclad 2014 Aluminum Alloy Plate and Sheet
AMS-QQ-A-250/4	2024 Aluminum Alloy Plate and Sheet
AMS-QQ-A-250/5	Alclad 2024 Aluminum Alloy Plate and Sheet
AMS-QQ-A-250/6	5083 Aluminum Alloy Plate and Sheet
AMS-QQ-A-250/7	5086 Aluminum Alloy Plate and Sheet
AMS-QQ-A-250/8	5052 Aluminum Alloy Plate and Sheet
AMS-QQ-A-250/9	5456 Aluminum Alloy Plate and Sheet
AMS-QQ-A-250/10	5454 Aluminum Alloy Plate and Sheet
AMS-QQ-A-250/11	6061 Aluminum Alloy Plate and Sheet
AMS-QQ-A-250/12	7075 Aluminum Alloy Plate and Sheet
AMS-QQ-A-250/13	Alclad 7075 Aluminum Alloy Plate and Sheet
AMS-QQ-A-250/14	7178 Aluminum Alloy Plate and Sheet
AMS-QQ-A-250/15	Alclad 7178 Aluminum Alloy Plate and Sheet
AMS-QQ-A-250/18	Alclad One Side 7075 Aluminum Alloy Plate and Sheet
AMS-QQ-A-250/19	5086 Aluminum Alloy Plate and Sheet for Seawater Applications
AMS-QQ-A-250/20	5456 Aluminum Alloy Plate and Sheet for Seawater Applications
AMS-QQ-A-250/21	7178-T76 Aluminum Alloy Plate and Sheet (Exfoliation Resistant)
AMS-QQ-A-250/22	Alclad 7178-T76 Aluminum Alloy Plate and Sheet (Exfoliation Resistant)
AMS-QQ-A-250/24	7075 Aluminum Alloy Plate and Sheet (Exfoliation Resistant)
AMS-QQ-A-250/25	Alclad 7075 Aluminum Alloy Plate and Sheet (Exfoliation Resistant)
AMS-QQ-A-250/26	7075, Alclad 7011 Aluminum Alloy Plate and Sheet
AMS-QQ-A-250/28	7178, Alclad 7011 Aluminum Alloy Plate and Sheet
AMS-QQ-A-250/29	2124 Aluminum Alloy Plate
AMS-QQ-A-250/30	2219 Aluminum Alloy Plate and Sheet
AMS-H-6088	Heat Treatment of Wrought Aluminum Alloys
AMS-B-20148	4045 and 4343 Brazing Sheet
AMS-A-22771	Aluminum Alloy Forgings, Heat Treated
AMS-A-81596	2024, 3003, 5052 and 5056 Foil

SAE — AEROSPACE STANDARDS (AS)

7220	1100-H14 Rivets
7222	2117-T4 Rivets

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

C80.5	Aluminum Alloy Rigid Conduit
H35.1	Alloy and Temper Designation Systems for Wrought Aluminum
H35.2	Dimensional Tolerances for Aluminum Mill Products

For all numbered footnotes, see page 1-26.

① The Aluminum Association and its members assume no responsibility for use of this index, for errors, for omissions, or for failure to advise of subsequent revisions or amendments.

② This cross-reference index lists the basic specification or standard number, and no attempt is made to reflect the latest revision or amendment to any particular document. The appropriate specification index published by the specification issuing body should be consulted to determine the latest issue of any particular specification or standard. The aluminum industry generally prefers to use the latest issue of any given specification or standard.

③ Noncurrent specification

2. Typical Properties

The following typical properties are not guaranteed, since in most cases they are averages for various sizes, product forms and methods of manufacture and may not be exactly representative of any particular product or size. These data are intended only as a basis for comparing alloys and tempers and should not be specified as engineering requirements or used for design purposes.

TABLE 2.1 Typical Mechanical Properties ① ②

ALLOY AND TEMPER	TENSION				HARDNESS	SHEAR	FATIGUE	MODULUS
	STRENGTH ksi		ELONGATION percent in 2 in.		BRINNELL NUMBER	ULTIMATE SHEARING STRENGTH	ENDURANCE ③ Limit	MODULUS ④ OF ELASTICITY
	ULTIMATE	YIELD	1⁄16 in. Thick Specimen	½ in. Diameter Specimen	500 kg load 10 mm ball	ksi	ksi	ksi 10^3
1060-O	10	4	43	. .	19	7	3	10.0
1060-H12	12	11	16	. .	23	8	4	10.0
1060-H14	14	13	12	. .	26	9	5	10.0
1060-H16	16	15	8	. .	30	10	6.5	10.0
1060-H18	19	18	6	. .	35	11	6.5	10.0
1100-O	13	5	35	45	23	9	5	10.0
1100-H12	16	15	12	25	28	10	6	10.0
1100-H14	18	17	9	20	32	11	7	10.0
1100-H16	21	20	6	17	38	12	9	10.0
1100-H18	24	22	5	15	44	13	9	10.0
1350-O	12	4	. .	. . ⑤	. .	8	. .	10.0
1350-H12	14	12	. .	. .	. .	9	. .	10.0
1350-H14	16	14	. .	. .	. .	10	. .	10.0
1350-H16	18	16	. .	. .	. .	11	. .	10.0
1350-H19	27	24	. .	. . ⑥	. .	15	7	10.0
2011-T3	55	43	. .	15	95	32	18	10.2
2011-T8	59	45	. .	12	100	35	18	10.2
2014-O	27	14	. .	18	45	18	13	10.6
2014-T4, T451	62	42	. .	20	105	38	20	10.6
2014-T6, T651	70	60	. .	13	135	42	18	10.6
Alclad 2014-O	25	10	21	. .	. .	18	. .	10.5
Alclad 2014-T3	63	40	20	. .	. .	37	. .	10.5
Alclad 2014-T4, T451	61	37	22	. .	. .	37	. .	10.5
Alclad 2014-T6, T651	68	60	10	. .	. .	41	. .	10.5
2017-O	26	10	. .	22	45	18	13	10.5
2017-T4, T451	62	40	. .	22	105	38	18	10.5
2018-T61	61	46	. .	12	120	39	17	10.8
2024-O	27	11	20	22	47	18	13	10.6
2024-T3	70	50	18	. .	120	41	20	10.6
2024-T4, T351	68	47	20	19	120	41	20	10.6
2024-T361 ⑦	72	57	13	. .	130	42	18	10.6
Alclad 2024-O	26	11	20	. .	. .	18	. .	10.6
Alclad 2024-T3	65	45	18	. .	. .	40	. .	10.6
Alclad 2024-T4, T351	64	42	19	. .	. .	40	. .	10.6
Alclad 2024-T361 ⑦	67	63	11	. .	. .	41	. .	10.6
Alclad 2024-T81, T851	65	60	6	. .	. .	40	. .	10.6
Alclad 2024-T861 ⑦	70	66	6	. .	. .	42	. .	10.6
2025-T6	58	37	. .	19	110	35	18	10.4
2036-T4	49	28	24	. .	. .	. .	18 ⑨	10.3
2117-T4	43	24	. .	27	70	28	14	10.3
2124-T851	70	64	. .	8	. .	. .	. .	10.6
2218-T72	48	37	. .	11	95	30	. .	10.8
2219-O	25	11	18	. .	. .	. .	. .	10.6
2219-T42	52	27	20	. .	. .	. .	. .	10.6
2219-T31, T351	52	36	17	. .	. .	. .	. .	10.6
2219-T37	57	46	11	. .	. .	. .	. .	10.6
2219-T62	60	42	10	. .	. .	. .	15	10.6
2219-T81, T851	66	51	10	. .	. .	. .	15	10.6
2219-T87	69	57	10	. .	. .	. .	15	10.6
2618-T61	64	54	. .	10	115	38	18	10.8
3003-O	16	6	30	40	28	11	7	10.0
3003-H12	19	18	10	20	35	12	8	10.0
3003-H14	22	21	8	16	40	14	9	10.0
3003-H16	26	25	5	14	47	15	10	10.0
3003-H18	29	27	4	10	55	16	10	10.0

For all numbered footnotes, see page 2-4.

TABLE 2.1 Typical Mechanical Properties [1] [2] (continued)

The following typical properties are not guaranteed, since in most cases they are averages for various sizes, product forms and methods of manufacture and may not be exactly representative of any particular product or size. These data are intended only as a basis for comparing alloys and tempers and should not be specified as engineering requirements or used for design purposes.

ALLOY AND TEMPER	TENSION				HARDNESS	SHEAR	FATIGUE	MODULUS
	STRENGTH ksi		ELONGATION percent in 2 in.		BRINELL NUMBER	ULTIMATE SHEARING STRENGTH	ENDURANCE [3] Limit	MODULUS [4] OF ELASTICITY
	ULTIMATE	YIELD	1/16 in. Thick Specimen	½ in. Diameter Specimen	500 kg load 10 mm ball	ksi	ksi	ksi · 10³
Alclad 3003-O	16	6	30	40	..	11	..	10.0
Alclad 3003-H12	19	18	10	20	..	12	..	10.0
Alclad 3003-H14	22	21	8	16	..	14	..	10.0
Alclad 3003-H16	26	25	5	14	..	15	..	10.0
Alclad 3003-H18	29	27	4	10	..	16	..	10.0
3004-O	26	10	20	25	45	16	14	10.0
3004-H32	31	25	10	17	52	17	15	10.0
3004-H34	35	29	9	12	63	18	15	10.0
3004-H36	38	33	5	9	70	20	16	10.0
3004-H38	41	36	5	6	77	21	16	10.0
Alclad 3004-O	26	10	20	25	..	16	..	10.0
Alclad 3004-H32	31	25	10	17	..	17	..	10.0
Alclad 3004-H34	35	29	9	12	..	18	..	10.0
Alclad 3004-H36	38	33	5	9	..	20	..	10.0
Alclad 3004-H38	41	36	5	6	..	21	..	10.0
3105-O	17	8	24	..	..	12	..	10.0
3105-H12	22	19	7	..	..	14	..	10.0
3105-H14	25	22	5	..	..	15	..	10.0
3105-H16	28	25	4	..	..	16	..	10.0
3105-H18	31	28	3	..	..	17	..	10.0
3105-H22	22	20	11	..	..	14	..	10.0
3105-H24	25	22	10			15	..	10.0
3105-H25	27	23	9	..	..	15	..	10.0
3105-H26	28	24	9	..	..	16	..	10.0
3105-H28	31	26	8	..	..	17	..	10.0
4032-T6	55	46	..	9	120	38	16	11.4
5005-O	18	6	25	..	28	11	..	10.0
5005-H12	20	19	10	..	..	14	..	10.0
5005-H14	23	22	6	..	..	14	..	10.0
5005-H16	26	25	5	..	..	15	..	10.0
5005-H18	29	28	4	..	..	16	..	10.0
5005-H32	20	17	11	..	36	14	..	10.0
5005-H34	23	20	8	..	41	14	..	10.0
5005-H36	26	24	6	..	46	15	..	10.0
5005-H38	29	27	5	..	51	16	..	10.0
5050-O	21	8	24	..	36	15	12	10.0
5050-H32	25	21	9	..	46	17	13	10.0
5050-H34	28	24	8	..	53	18	13	10.0
5050-H36	30	26	7	..	58	19	14	10.0
5050-H38	32	29	6	..	63	20	14	10.0
5052-O	28	13	25	30	47	18	16	10.2
5052-H32	33	28	12	18	60	20	17	10.2
5052-H34	38	31	10	14	68	21	18	10.2
5052-H36	40	35	8	10	73	23	19	10.2
5052-H38	42	37	7	8	77	24	20	10.2
5056-O	42	22	..	35	65	26	20	10.3
5056-H18	63	59	..	10	105	34	22	10.3
5056-H38	60	50	..	15	100	32	22	10.3
5083-O	42	21	..	22	..	25	..	10.3
5083-H32 [11]	46	33	..	16	..	..	23	10.3
5083-H116 [11]	46	33	..	16	..	..	23	10.3
5083-H321 [11]	46	33	..	16	..	..	23	10.3
5086-O	38	17	22	..	..	23	..	10.3
5086-H32 [11]	42	30	12	..	..	..	..	10.3
5086-H116 [11]	42	30	12	..	..	..	..	10.3
5086-H34	47	37	10	..	..	27	..	10.3
5086-H112	39	19	14	..	..	..	..	10.3

For all numbered footnotes, see page 2-4.

TABLE 2.1 Typical Mechanical Properties [1] [2] (continued)

The following typical properties are not guaranteed, since in most cases they are averages for various sizes, product forms and methods of manufacture and may not be exactly representative of any particular product or size. These data are intended only as a basis for comparing alloys and tempers and should not be specified as engineering requirements or used for design purposes.

ALLOY AND TEMPER	TENSION				HARDNESS	SHEAR	FATIGUE	MODULUS
	STRENGTH ksi		ELONGATION percent in 2 in.		BRINELL NUMBER	ULTIMATE SHEARING STRENGTH	ENDURANCE [3] Limit	MODULUS [4] OF ELASTICITY
	ULTIMATE	YIELD	1/16 in. Thick Specimen	1/2 in. Diameter Specimen	500 kg load 10 mm ball	ksi	ksi	ksi · 10^3
5154-O	35	17	27	..	58	22	17	10.2
5154-H32	39	30	15	..	67	22	18	10.2
5154-H34	42	33	13	..	73	24	19	10.2
5154-H36	45	36	12	..	78	26	20	10.2
5154-H38	48	39	10	..	80	28	21	10.2
5154-H112	35	17	25	..	63	..	17	10.2
5252-H25	34	25	11	..	68	21	..	10.0
5252-H38, H28	41	35	5	..	75	23	..	10.0
5254-O	35	17	27	..	58	22	17	10.2
5254-H32	39	30	15	..	67	22	18	10.2
5254-H34	42	33	13	..	73	24	19	10.2
5254-H36	45	36	12	..	78	26	20	10.2
5254-H38	48	39	10	..	80	28	21	10.2
5254-H112	35	17	25	..	63	..	17	10.2
5454-O	36	17	22	..	62	23	..	10.2
5454-H32	40	30	10	..	73	24	..	10.2
5454-H34	44	35	10	..	81	26	..	10.2
5454-H111	38	26	14	..	70	23	..	10.2
5454-H112	36	18	18	..	62	23	..	10.2
5456-O	45	23	..	24	..	..	..	10.3
5456-H32 [11]	51	37		16	90	30	..	10.3
5456-H25	45	24	..	22	..	..	..	10.3
5456-H116 [11]	51	37	..	16	90	30	..	10.3
5456-H321 [11]	51	37	..	16	90	30	..	10.3
5457-O	19	7	22	..	32	12	..	10.0
5457-H25	26	23	12	..	48	16	..	10.0
5457-H38, H28	30	27	6	..	55	18	..	10.0
5652-O	28	13	25	30	47	18	16	10.2
5652-H32	33	28	12	18	60	20	17	10.2
5652-H34	38	31	10	14	68	21	18	10.2
5652-H36	40	35	8	10	73	23	19	10.2
5652-H38	42	37	7	8	77	24	20	10.2
5657-H25	23	20	12	..	40	12	..	10.0
5657-H38, H28	28	24	7	..	50	15	..	10.0
6005A-T1	..	..	..	..	..	..	..	..
6005A-T5	42	38	10	13	90	..	14	10.0
6005A-T61	45	40	12	17	95	30	14	10.0
6061-O	18	8	25	30	30	12	9	10.0
6061-T4, T451	35	21	22	25	65	24	14	10.0
6061-T6, T651	45	40	12	17	95	30	14	10.0
Alclad 6061-O	17	7	25	..	..	11	..	10.0
Alclad 6061-T4, T451	33	19	22	..	..	22	..	10.0
Alclad 6061-T6, T651	42	37	12	..	..	27	..	10.0
6063-O	13	7	..	..	25	10	8	10.0
6063-T1	22	13	20	..	42	14	9	10.0
6063-T4	25	13	22	..	..	..	..	10.0
6063-T5	27	21	12	..	60	17	10	10.0
6063-T6	35	31	12	..	73	22	10	10.0
6063-T83	37	35	9	..	82	22	..	10.0
6063-T831	30	27	10	..	70	18	..	10.0
6063-T832	42	39	12	..	95	27	..	10.0
6066-O	22	12	..	18	43	14	..	10.0
6066-T4, T451	52	30	..	18	90	29	..	10.0
6066-T6. T651	57	52	..	12	120	34	16	10.0
6070-T6	55	51	10	..	..	34	14	10.0
6082-T6, T6511	49	46	12	14	95	31	14	10.0
6101-H111	14	11	..	..	..	..	..	10.0
6101-T6	32	28	15 [8]	..	71	20	..	10.0
6262-T9	58	55	..	10	120	35	13	10.0
6351-T4	36	22	20	..	..	..	..	10.0
6351-T6	45	41	14	..	95	29	13	10.0

For all numbered footnotes, see page 2-4.

TABLE 2.1 Typical Mechanical Properties ① ② (concluded)

The following typical properties are not guaranteed, since in most cases they are averages for various sizes, product forms and methods of manufacture and may not be exactly representative of any particular product or size. These data are intended only as a basis for comparing alloys and tempers and should not be specified as engineering requirements or used for design purposes.

ALLOY AND TEMPER	TENSION				HARDNESS	SHEAR	FATIGUE	MODULUS
	STRENGTH ksi		ELONGATION percent in 2 in.		BRINNELL NUMBER	ULTIMATE SHEARING STRENGTH	ENDURANCE ③ Limit	MODULUS ④ OF ELASTICITY
	ULTIMATE	YIELD	1/16 in. Thick Specimen	1/2 in. Diameter Specimen	500 kg load 10 mm ball	ksi	ksi	ksi · 10^3
6463-T1	22	13	20	..	42	14	10	10.0
6463-T5	27	21	12	..	60	17	10	10.0
6463-T6	35	31	12	..	74	22	10	10.0
7049-T73	75	65	..	12	135	44	..	10.4
7049-T7352	75	63	..	11	135	43	..	10.4
7050-T73510, T73511	72	63	..	12	..	..	..	10.4
7050-T7451 ⑩	76	68	..	11	..	44	..	10.4
7050-T7651	80	71	..	11	..	47	..	10.4
7075-O	33	15	17	16	60	22	..	10.4
7075-T6, T651	83	73	11	11	150	48	23	10.4
Alclad 7075-O	32	14	17	..	..	22	..	10.4
Alclad 7075-T6, T651	76	67	11	..	..	46	..	10.4
7175-T74	76	66	..	11	135	42	23	10.4
7178-O	33	15	15	16	..	..	..	10.4
7178-T6, T651	88	78	10	11	..	..	..	10.4
7178-T76, T7651	83	73	..	11	..	..	..	10.3
Alclad 7178-O	32	14	16	..	..	..	..	10.4
Alclad 7178-T6, T651	81	71	10	..	..	..	..	10.4
7475-T61	82	71	11	..	..	..	..	10.2
7475-T651	85	74	..	13	..	..	..	10.4
7475-T7351	72	61	..	13	..	..	..	10.4
7475-T761	75	65	12	..	..	..	..	10.2
7475-T7651	77	67	..	12	..	..	..	10.4
Alclad 7475-T61	75	66	11	..	..	..	..	10.2
Alclad 7475-T761	71	61	12	..	..	..	..	10.2
8176-H24	17	14	15	..	..	10	..	10.0

① The mechanical property limits are listed by major product in the “Standards Section” of this manual.
② The indicated typical mechanical properties for all except 0 temper material are higher than the specified minimum properties. For 0 temper products typical ultimate and yield values are slightly lower than specified (maximum) values.
③ Based on 500,000,000 cycles of completely reversed stress using the R.R. Moore type of machine and specimen.
④ Average of tension and compression moduli. Compression modulus is about 2% greater than tension modulus.
⑤ 1350-O wire will have an elongation of approximately 23% in 10 inches.
⑥ 1350-H19 wire will have an elongation of approximately 1½% in 10 inches.
⑦ Tempers T361 and T861 were formerly designated T36 and T86, respectively.
⑧ Based on ¼ in. thick specimen.
⑨ Based on 10^7 cycles using flexural type testing of sheet specimens.
⑩ T7451, although not previously registered, has appeared in literature and in some specifications as T73651.
⑪ 5xxx products in the -H116 and -H32X tempers have similar properties and have the same testing requirements, but are produced by different practices. The -H116 and -H321 tempers are typically used in marine and other applications requiring demonstrations of intergranular and exfoliation corrosion resistance. Products in the -H32 temper have similar tensile properties and while production methods may be similar, corrosion testing requirements are different, therefore, -H32 temper products shall not be substituted for -H116 or -H321 products.

TABLE 2.2 Typical Tensile Properties at Various Temperatures [1]

The following typical properties are not guaranteed, since in most cases they are averages for various sizes, product forms and methods of manufacture and may not be exactly representative of any particular product or size. These data are intended only as a basis for comparing alloys and tempers and should not be specified as engineering requirements or used for design purposes.

ALLOY AND TEMPER	TEMP.	TENSILE STRENGTH, ksi		ELONGATION IN 2 IN., PERCENT
	°F	ULTIMATE	YIELD [2]	
1100-O	–320	25	6	50
	–112	15	5.5	43
	–18	14	5	40
	75	13	5	40
	212	10	4.6	45
	300	8	4.2	55
	400	6	3.5	65
	500	4	2.6	75
	600	2.9	2	80
	700	2.1	1.6	85
1100-H14	–320	30	20	45
	–112	20	18	24
	–18	19	17	20
	75	18	17	20
	212	16	15	20
	300	14	12	23
	400	10	7.5	26
	500	4	2.6	75
	600	2.9	2	80
	700	2.1	1.6	85
1100-H18	–320	34	26	30
	–112	26	23	16
	–118	25	23	15
	75	24	22	15
	212	21	19	15
	300	18	14	20
	400	6	3.5	65
	500	4	2.6	75
	600	2.9	2	80
	700	2.1	1.6	85
2011-T3	75	55	43	15
	212	47	34	16
	300	28	19	25
	400	16	11	35
	500	6.5	3.8	45
	600	3.1	1.8	90
	700	2.3	1.4	125
2014-T6, T651	–320	84	72	14
	–112	74	65	13
	–18	72	62	13
	75	70	60	13
	212	63	57	15
	300	40	35	20
	400	16	13	38
	500	9.5	7.5	52
	600	6.5	5	65
	700	4.3	3.5	72
2017-T4, T451	–320	80	53	28
	–112	65	42	24
	–18	64	41	23
	75	62	40	22
	212	57	39	18
	300	40	30	15
	400	16	13	35
	500	9	7.5	45
	600	6	5	65
	700	4.3	3.5	70

For all numbered footnotes, see page 2-9.

ALLOY AND TEMPER	TEMP.	TENSILE STRENGTH, ksi		ELONGATION IN 2 IN., PERCENT
	°F	ULTIMATE	YIELD [2]	
2024-T3	–320	85	62	18
(Sheet)	–112	73	52	17
	–18	72	51	17
	75	70	50	17
	212	66	48	16
	300	55	45	11
	400	27	20	23
	500	11	9	55
	600	7.5	6	75
	700	5	4	100
2024-T4, T351	–320	84	61	19
(plate)	–112	71	49	19
	–18	69	47	19
	75	68	47	19
	212	63	45	19
	300	45	36	17
	400	26	19	27
	500	11	9	55
	600	7.5	6	75
	700	5	4	100
2024-T6, T651	–320	84	68	11
	–112	72	59	10
	–18	70	58	10
	75	69	57	10
	212	65	54	10
	300	45	36	17
	400	26	19	27
	500	11	9	55
	600	7.5	6	75
	700	5	4	100
2024-T81, T851	–320	85	78	8
	–112	74	69	7
	–18	73	68	7
	75	70	65	7
	212	66	62	8
	300	55	49	11
	400	27	20	23
	500	11	9	55
	600	7.5	6	75
	700	5	4	100
2024-T861	–320	92	85	5
	–112	81	77	5
	–18	78	74	5
	75	75	71	5
	212	70	67	6
	300	54	48	11
	400	21	17	28
	500	11	9	55
	600	7.5	6	75
	700	5	4	100
2117-T4	–320	56	33	30
	–112	45	25	29
	–18	44	24	28
	75	43	24	27
	212	36	21	16
	300	30	17	20
	400	16	12	35
	500	7.5	5.5	55
	600	4.7	3.3	80
	700	2.9	2	110

TABLE 2.2 Typical Tensile Properties at Various Temperatures ① (continued)

The following typical properties are not guaranteed, since in most cases they are averages for various sizes, product forms and methods of manufacture and may not be exactly representative of any particular product or size. These data are intended only as a basis for comparing alloys and tempers and should not be specified as engineering requirements or used for design purposes.

ALLOY AND TEMPER	TEMP.	TENSILE STRENGTH, ksi		ELONGATION IN 2 IN., PERCENT
	°F	ULTIMATE	YIELD ②	
2124-T851	–452	102	90	10
	–320	86	79	9
	–112	76	71	8
	–18	73	68	8
	75	70	64	9
	212	66	61	9
	300	54	49	13
	400	27	20	28
	500	11	8	60
	600	7.5	6	75
	700	5.5	4.1	100
2218-T61	–320	72	52	15
	–112	61	45	14
	–18	59	44	13
	75	59	44	13
	212	56	42	15
	300	41	35	17
	400	22	16	30
	500	10	6	70
	600	5.5	3	85
	700	4	2.5	100
2219-T62	–320	73	49	16
	–112	63	44	13
	–18	60	42	12
	75	58	40	12
	212	54	37	14
	300	45	33	17
	400	34	25	20
	500	27	20	21
	600	10	8	40
	700	4.4	3.7	75
2219-T81, T851	–320	83	61	15
	–112	71	54	13
	–18	69	52	12
	75	66	50	12
	212	60	47	15
	300	49	40	17
	400	36	29	20
	500	29	23	21
	600	7	6	55
	700	4.4	3.7	75
2618-T61	–320	78	61	12
	–12	67	55	11
	–18	64	54	10
	75	64	54	10
	212	62	54	10
	300	50	44	14
	400	32	26	24
	500	13	9	50
	600	7.5	4.5	80
	700	5	3.5	120
3003-O	–320	33	8.5	46
	–112	20	7	42
	–18	17	6.5	41
	75	16	6	40
	212	13	5.5	43
	300	11	5	47
	400	8.5	4.3	60
	500	6	3.4	65
	600	4	2.4	70
	700	2.8	1.8	70

For all numbered footnotes, see page 2-9.

ALLOY AND TEMPER	TEMP.	TENSILE STRENGTH, ksi		ELONGATION IN 2 IN., PERCENT
	°F	ULTIMATE	YIELD ②	
3003-H14	–320	35	25	30
	–112	24	22	18
	–18	22	21	16
	75	22	21	16
	212	21	19	16
	300	18	16	16
	400	14	9	20
	500	7.5	4	60
	600	4	2.4	70
	700	2.8	1.8	70
3003-H18	–320	41	33	23
	–112	32	29	11
	–18	30	28	10
	75	29	27	10
	212	26	21	10
	300	23	16	11
	400	14	9	18
	500	7.5	4	60
	600	4	2.4	70
	700	2.8	1.8	70
3004-O	–320	42	13	38
	–112	28	11	30
	–18	26	10	26
	75	26	10	25
	212	26	10	25
	300	22	10	35
	400	14	9.5	55
	500	10	7.5	70
	600	7.5	5	80
	700	5	3	90
3004-H34	–320	52	34	26
	–112	38	30	16
	–18	36	29	13
	75	35	29	12
	212	34	29	13
	300	28	25	22
	400	21	15	35
	500	14	7.5	55
	600	7.5	5	80
	700	5	3	90
3004-H38	–320	58	43	20
	–112	44	38	10
	–18	42	36	7
	75	41	36	6
	212	40	36	7
	300	31	27	15
	400	22	15	30
	500	12	7.5	50
	600	7.5	5	80
	700	5	3	90
4032-T6	–320	66	48	11
	–112	58	46	10
	–18	56	46	9
	75	55	46	9
	212	50	44	9
	300	37	33	9
	400	13	9	30
	500	8	5.5	50
	600	5	3.2	70
	700	3.4	2	90

TABLE 2.2 Typical Tensile Properties at Various Temperatures ① (continued)

The following typical properties are not guaranteed, since in most cases they are averages for various sizes, product forms and methods of manufacture and may not be exactly representative of any particular product or size. These data are intended only as a basis for comparing alloys and tempers and should not be specified as engineering requirements or used for design purposes.

ALLOY AND TEMPER	TEMP. °F	TENSILE STRENGTH, ksi ULTIMATE	YIELD ②	ELONGATION IN 2 IN., PERCENT
5050-O	–320	37	10	. .
	–112	22	8.5	. .
	–18	21	8	. .
	75	21	8	. .
	212	21	8	. .
	300	19	8	. .
	400	14	7.5	. .
	500	9	6	. .
	600	6	4.2	. .
	700	3.9	2.6	. .
5050-H34	–320	44	30	. .
	–112	30	25	. .
	–18	28	24	. .
	75	28	24	. .
	212	28	24	. .
	300	25	22	. .
	400	14	7.5	. .
	500	9	6	. .
	600	6	4.2	. .
	700	3.9	2.6	. .
5050-H38	–320	46	36	. .
	–112	34	30	. .
	–18	32	29	. .
	75	32	29	. .
	212	31	29	. .
	300	27	25	. .
	400	14	7.5	. .
	500	9	6	. .
	600	6	4.2	. .
	700	3.9	2.6	. .
5052-O	–320	44	16	46
	–112	29	13	35
	–18	28	13	32
	75	28	13	30
	212	28	13	36
	300	23	13	50
	400	17	11	60
	500	12	7.5	80
	600	7.5	5.5	110
	700	5	3.1	130
5052-H34	–320	55	36	28
	–112	40	32	21
	–18	38	31	18
	75	38	31	16
	212	38	31	18
	300	30	27	27
	400	24	15	45
	500	12	7.5	80
	600	7.5	5.5	110
	700	5	3.1	130
5052-H38	–320	60	44	25
	–112	44	38	18
	–18	42	37	15
	75	42	37	14
	212	40	36	16
	300	34	28	24
	400	25	15	45
	500	12	7.5	80
	600	7.5	5.5	110
	700	5	3.1	130

For all numbered footnotes, see page 2-9.

ALLOY AND TEMPER	TEMP. °F	TENSILE STRENGTH, ksi ULTIMATE	YIELD ②	ELONGATION IN 2 IN., PERCENT
5083-O	–320	59	24	36
	–112	43	21	30
	–18	42	21	27
	75	42	21	25
	212	40	21	36
	300	31	19	50
	400	22	17	60
	500	17	11	80
	600	11	7.5	110
	700	6	4.2	130
5083-H32	75	46	33	16
5086-O	–320	55	19	46
	–112	39	17	35
	–18	38	17	32
	75	38	17	30
	212	38	17	36
	300	29	16	50
	400	22	15	60
	500	17	11	80
	600	11	7.5	110
	700	6	4.2	130
5154-O	–320	52	19	46
	–112	36	17	35
	–18	35	17	32
	75	35	17	30
	212	35	17	36
	300	29	16	50
	400	22	15	60
	500	17	11	80
	600	11	7.5	110
	700	6	4.2	130
5254-O	–320	52	19	46
	–112	36	17	35
	–18	35	17	32
	75	35	17	30
	212	35	17	36
	300	29	16	50
	400	22	15	60
	500	17	11	80
	600	11	7.5	110
	700	6	4.2	130
5454-O	–320	54	19	39
	–112	37	17	30
	–18	36	17	27
	75	36	17	25
	212	36	17	31
	300	29	16	50
	400	22	15	60
	500	17	11	80
	600	11	7.5	110
	700	6	4.2	130
5454-H32	–320	59	36	32
	–112	42	31	23
	–18	41	30	20
	75	40	30	18
	212	39	29	20
	300	32	26	37
	400	25	19	45
	500	17	11	80
	600	11	7.5	110
	700	6	4.2	130

TABLE 2.2 Typical Tensile Properties at Various Temperatures [1] (continued)

The following typical properties are not guaranteed, since in most cases they are averages for various sizes, product forms and methods of manufacture and may not be exactly representative of any particular product or size. These data are intended only as a basis for comparing alloys and tempers and should not be specified as engineering requirements or used for design purposes.

ALLOY AND TEMPER	TEMP.	TENSILE STRENGTH, ksi		ELONGATION IN 2 IN., PERCENT
	°F	ULTIMATE	YIELD [2]	
5454-H34	–320	63	41	30
	–112	46	36	21
	–18	44	35	18
	75	44	35	16
	212	43	34	18
	300	34	28	32
	400	26	19	45
	500	17	11	80
	600	11	7.5	110
	700	6	4.2	130
5456-O	–320	62	26	32
	–112	46	23	25
	–18	45	23	22
	75	45	23	20
	212	42	22	31
	300	31	20	50
	400	22	17	60
	500	17	11	80
	600	11	7.5	110
	700	6	4.2	130
5456-H32	75	51	37	16
5652-O	–320	44	16	46
	–112	29	13	35
	–18	28	13	32
	75	28	13	30
	212	28	13	30
	300	23	13	50
	400	17	11	60
	500	12	7.5	80
	600	7.5	5.5	110
	700	5	3.1	130
5652-H34	–320	55	36	28
	–112	40	32	21
	–18	38	31	18
	75	38	31	16
	212	38	31	18
	300	30	27	27
	400	24	15	45
	500	12	7.5	80
	600	7.5	5.5	110
	700	5	3.1	130
5652-H38	–320	60	44	25
	–112	44	38	18
	–18	42	37	15
	75	42	37	14
	212	40	36	16
	300	34	28	24
	400	25	15	45
	500	12	7.5	80
	600	7.5	5.5	110
	700	5	3.1	130
6005A-T5.	75	42	38	10
6005A-T61	75	45	40	12
6053-T6, T651	75	37	32	13
	212	32	28	13
	300	25	24	13
	400	13	12	25
	500	5.5	4	70
	600	4	2.7	80
	700	2.9	2	90

ALLOY AND TEMPER	TEMP.	TENSILE STRENGTH, ksi		ELONGATION IN 2 IN., PERCENT
	°F	ULTIMATE	YIELD [2]	
6061-T6, T651	–320	60	47	22
	–112	49	42	18
	–18	47	41	17
	75	45	40	17
	212	42	38	18
	300	34	31	20
	400	19	15	28
	500	7.5	5	60
	600	4.6	2.7	85
	700	3	1.8	95
6063-T1	–320	34	16	44
	–112	26	15	36
	–18	24	14	34
	75	22	13	33
	212	22	14	18
	300	21	15	20
	400	9	6.5	40
	500	4.5	3.5	75
	600	3.2	2.5	80
	700	2.3	2	105
6063-T5	–320	37	24	28
	–112	29	22	24
	–18	28	22	23
	75	27	21	22
	212	24	20	18
	300	20	18	20
	400	9	6.5	40
	500	4.5	3.5	75
	600	3.2	2.5	80
	700	2.3	2	105
6063-T6	–320	47	36	24
	–112	38	33	20
	–18	36	32	19
	75	35	31	18
	212	31	28	15
	300	21	20	20
	400	9	6.5	40
	500	4.5	3.5	75
	600	3.3	2.5	80
	700	2.3	2	105
6082-T6, T6511	–320	76	62	17
	–112	61	52	13
	–18	51	49	..
	75	49	46	14
	212	48	45	..
	300	48	45	..
	400	15	11	..
	500	..	..	..
	600	..	..	..
	700	..	..	..
6101-T6	–320	43	33	24
	–112	36	30	20
	–18	34	29	19
	75	32	28	19
	212	28	25	20
	300	21	19	20
	400	10	7	40
	500	4.8	3.3	80
	600	3	2.3	100
	700	2.5	1.8	105

For all numbered footnotes, see page 2-9.

TABLE 2.2 Typical Tensile Properties at Various Temperatures ① (concluded)

The following typical properties are not guaranteed, since in most cases they are averages for various sizes, product forms and methods of manufacture and may not be exactly representative of any particular product or size. These data are intended only as a basis for comparing alloys and tempers and should not be specified as engineering requirements or used for design purposes.

ALLOY AND TEMPER	TEMP.	TENSILE STRENGTH, ksi		ELONGATION IN 2 IN., PERCENT
	°F	ULTIMATE	YIELD ②	
6151-T6	–320	57	50	20
	–112	50	46	17
	–18	49	45	17
	75	48	43	17
	212	43	40	17
	300	28	27	20
	400	14	12	30
	500	6.5	5	50
	600	5	3.9	43
	700	4	3.2	35
6262-T651	–320	60	47	22
	–112	49	42	18
	–18	47	41	17
	75	45	40	17
	212	42	38	18
	300	34	31	20
6262-T9	–320	74	67	14
	–112	62	58	10
	–18	60	56	10
	75	58	55	10
	212	53	52	10
	300	38	37	14
	400	15	13	34
	500	8.5	6	48
	600	4.6	2.7	85
	700	3	1.8	95
7075-T6,	–320	102	92	9
T651	–112	90	79	11
	–18	86	75	11
	75	83	73	11
	212	70	65	14
	300	31	27	30
	400	16	13	55
	500	11	9	65
	600	8	6.5	70
	700	6	4.6	70
7075-T73,	–320	92	72	14
T7351	–112	79	67	14
	–18	76	65	13
	75	73	63	13
	212	63	58	15
	300	31	27	30
	400	16	13	55
	500	11	9	65
	600	8	6.5	70
	700	6	4.6	70
7175-T74	–320	106	98	13
	–112	90	83	14
	–18	87	80	16
	75	80	73	14
	212	72	69	17
	300	35	31	30
	400	18	13	65
7178-T6, T651	–320	106	94	5
	–112	94	84	8
	–18	91	81	9
	75	88	78	11
	212	73	68	14
	300	31	27	40
	400	15	12	70
	500	11	9	76
	600	8.5	7	80
	700	6.5	5.5	80
7178-T76,	–320	106	89	10
T7651	–112	91	78	10
	–18	88	76	10
	75	83	73	11
	212	69	64	17
	300	31	27	40
	400	15	12	70
	500	11	9	76
	600	8.5	7	80
	700	6.5	5.5	80
7475-T61 Sheet	–320	99	87	10
	–112	88	79	12
	–18	84	75	12
	75	80	72	12
	212	70	65	14
	300	30	26	28
	400	14	11	55
	500	9.5	7	70
	600	6.5	5.5	80
	700	5	3.8	85
7475-T651 Plate	75	85	74	13
7475-T761	–320	95	82	11
	–112	84	73	12
	–18	80	70	12
	75	76	67	12
	212	64	61	14
	300	30	26	38
	400	14	11	55
	500	9.5	7	70
	600	6.5	5.5	80
	700	5	3.8	85

① These data are based on a limited amount of testing and represent the lowest strength during 10,000 hours of exposure at testing temperature under no load; stress applied at 5,000 psi/min to yield strength and then at strain rate of 0.05 in./in./min to failure. Under some conditions of temperature and time, the application of heat will adversely affect certain other properties of some alloys.

② Offset equals 0.2 percent.

TABLE 2.3 Typical Physical Properties

The following typical properties are not guaranteed, since in most cases they are averages for various sizes, product forms and methods of manufacture and may not be exactly representative of any particular product or size. These data are intended only as a basis for comparing alloys and tempers and should not be specified as engineering requirements or used for design purposes.

ALLOY	AVERAGE [1] COEFFICIENT OF THERMAL EXPANSION	MELTING RANGE [2] [3] APPROX.	TEMPER	THERMAL CONDUCTIVITY AT 77°F	ELECTRICAL CONDUCTIVITY AT 68°F Percent of International Annealed Copper Standard		ELECTRICAL RESISTIVITY AT 68°F
	68° TO 212°F per °F	°F		English Units [4]	Equal Volume	Equal Weight	Ohm—Cir. Mil/Foot
1060	13.1	1195–1215	O	1625	62	204	17
			H18	1600	61	201	17
1100	13.1	1190–1215	O	1540	59	194	18
			H18	1510	57	187	18
1350	13.2	1195–1215	All	1625	62	204	17
2011	12.7	1005–1190 [6]	T3	1050	39	123	27
			T8	1190	45	142	23
2014	12.8	945–1180 [5]	O	1340	50	159	21
			T4	930	34	108	31
			T6	1070	40	127	26
2017	13.1	955–1185 [5]	O	1340	50	159	21
			T4	930	34	108	31
2018	12.4	945–1180 [6]	T61	1070	40	127	26
2024	12.9	935–1180 [5]	O	1340	50	160	21
			T3, T4, T361	840	30	96	35
			T6, T81, T861	1050	38	122	27
2025	12.6	970–1185 [5]	T6	1070	40	128	26
2036	13.0	1030–1200 [6]	T4	1100	41	135	25
2117	13.2	1030–1200 [6]	T4	1070	40	130	26
2124	12.7	935–1180 [5]	T851	1055	38	122	27
2218	12.4	940–1175 [5]	T72	1070	40	126	26
2219	12.4	1010–1190 [5]	O	1190	44	138	24
			T31, T37	780	28	88	37
			T6, T81, T87	840	30	94	35
2618	12.4	1020–1180	T6	1020	37	120	28
3003	12.9	1190–1210	O	1340	50	163	21
			H12	1130	42	137	25
			H14	1100	41	134	25
			H18	1070	40	130	26
3004	13.3	1165–1210	All	1130	42	137	25
3105	13.1	1175–1210	All	1190	45	148	23
4032	10.8	990–1060 [5]	O	1070	40	132	26
			T6	960	35	116	30
4043	12.3	1065–1170	O	1130	42	140	25
4045	11.7	1065–1110	All	1190	45	151	23
4343	12.0	1070–1135	All	1250	47	158	25
5005	13.2	1170–1210	All	1390	52	172	20
5050	13.2	1155–1205	All	1340	50	165	21
5052	13.2	1125–1200	All	960	35	116	30
5056	13.4	1055–1180	O	810	29	98	36
			H38	750	27	91	38
5083	13.2	1095–1180	O	810	29	98	36
5086	13.2	1085–1185	All	870	31	104	33
5154	13.3	1100–1190	All	870	32	107	32
5252	13.2	1125–1200	All	960	35	116	30
5254	13.3	1100–1190	All	870	32	107	32
5356	13.4	1060–1175	O	810	29	98	36
5454	13.1	1115–1195	O	930	34	113	31
			H38	930	34	113	31
5456	13.3	1055–1180	O	810	29	98	36
5457	13.2	1165–1210	All	1220	46	153	23
5652	13.2	1125–1200	All	960	35	116	30
5657	13.2	1180–1215	All	1420	54	180	19
6005	13.0	1125-1210 [6]	T1	1250	47	155	22
			T5	1310	49	161	21
6005A	13.0	1110-1200	T1	1220	47	155	22
6005A	13.0	1110-1200	T5	1340	50	165	21
6005A	13.0	1110-1200	T61	1310	49	161	21

For all numbered footnotes, see page 2-11.

TABLE 2.3 Typical Physical Properties (concluded)

The following typical properties are not guaranteed, since in most cases they are averages for various sizes, product forms and methods of manufacture and may not be exactly representative of any particular product or size. These data are intended only as a basis for comparing alloys and tempers and should not be specified as engineering requirements or used for design purposes.

ALLOY	AVERAGE ① COEFFICIENT OF THERMAL EXPANSION	MELTING RANGE ② ③ APPROX.	TEMPER	THERMAL CONDUCTIVITY AT 77°F	ELECTRICAL CONDUCTIVITY AT 68°F Percent of International Annealed Copper Standard		ELECTRICAL RESISTIVITY AT 68°F
	68° TO 212°F per °F	°F		English Units ④	Equal Volume	Equal Weight	Ohm—Cir. Mil/Foot
6053	12.8	1070–1205 ⑥	O	1190	45	148	23
			T4	1070	40	132	26
			T6	1130	42	139	25
6061	13.1	1080–1205 ⑥	O	1250	47	155	22
			T4	1070	40	132	26
			T6	1160	43	142	24
6063	13.0	1140–1210	O	1510	58	191	18
			T1	1340	50	165	21
			T5	1450	55	181	19
			T6, T83	1390	53	175	20
6066	12.9	1045–1195 ⑤	O	1070	40	132	26
			T6	1020	37	122	28
6070	. .	1050–1200 ⑤	T6	1190	44	145	24
6082	12.8	1070-1200	T6, T6511	1190	44	145	24
6101	13.0	1150–1210	T6	1510	57	188	18
			T61	1540	59	194	18
			T63	1510	58	191	18
			T64	1570	60	198	17
			T65	1510	58	191	18
6105	13.0	1110–1200 ⑥	T1	1220	46	151	23
			T5	1340	50	165	21
6151	12.9	1090–1200 ⑥	O	1420	54	178	19
			T4	1130	42	138	25
			T6	1190	45	148	23
6201	13.0	1125–1210 ⑥	T81	1420	54	180	19
6262	13.0	1080–1205 ⑥	T9	1190	44	145	24
6351	13.0	1030–1200	T6	1220	46	151	23
6463	13.0	1140–1210 ⑥	T1	1340	50	165	21
			T5	1450	55	181	19
			T6	1390	53	175	20
6951	13.0	1140–1210	O	1480	56	186	19
			T6	1370	52	172	20
7049	13.0	890–1175	T73	1070	40	132	26
7050	12.8	910–1165	T74 ⑧	1090	41	135	25
7072	13.1	1185–1215	O	1540	59	193	18
7075	13.1	890–1175 ⑦	T6	900	33	105	31
7175	13.0	890–1175 ⑦	T74	1080	39	124	26
7178	13.0	890–1165 ⑦	T6	870	31	98	33
7475	12.9	890–1175	T61, T651	960	35	116	30
			T76, T761	1020	40	132	26
			T7351	1130	42	139	25
8017	13.1	1190–1215	H12, H22	. .	59	193	18
			H212	. .	61	200	17
8030	13.1	1190–1215	H221	1600	61	201	17
8176	13.1	1190–1215	H24		61	201	17

① Coefficient to be multiplied by 10^6. Example: $12.2 \times 10^6 = 0.0000122$.
② Melting ranges shown apply to wrought products of ¼ inch thickness or greater.
③ Based on typical composition of the indicated alloys.
④ English units = btu-in./ft²hr°F.
⑤ Eutectic melting is not eliminated by homogenization.
⑥ Eutectic melting can be completely eliminated by homogenization.
⑦ Homogenization may raise eutectic melting temperature 20–40°F but usually does not eliminate eutectic melting.
⑧ Although not formerly registered, the literature and some specifications have used T736 as the designation for this temper.

Aluminum and Aluminum Alloy Density Calculation Procedure

The following describes the procedures used to calculate nominal densities of aluminum and aluminum alloys. The densities are determined by computation rather than by a weighing method.

A. For each alloying element, the arithmetic mean of its registered limits is determined. The mean is rounded① to the number of places indicated in Table I.

B. For each impurity element or combination of impurity elements for which a maximum limit is registered, an arithmetic mean is determined using zero as the minimum limit. The mean is rounded to the number of places indicated in Table I.

C. For impurity elements having a combined limit (e.g., Si + Fe), each of the elements is considered to have an equal concentration. The concentrations are calculated by dividing the mean determined for the combined limit in Step B by the number of elements in the combined limit. Each element's concentration is rounded to the number of places indicated in Table I. (See the example calculation for alloy 5254.)

D. The element concentrations in steps A, B and C are totaled and then subtracted from 100 to obtain the concentration of aluminum to be used in the calculation.② The aluminum concentration is rounded to two decimal places.

E. Each element concentration determined in steps A, B, C and D is multiplied by its respective factor given in Table II. Each answer is rounded to three decimal places.

F. The values determined in step E are added together and the number 100 is divided by the total. The answer is rounded to five decimal places.

G. The density in customary units (lbs/cu. in.) is calculated by multiplying the answer obtained in step F by $3.612729 \cdot 10^2$ and rounding the answer as follows:

   1. For aluminum having a specified minimum aluminum content of 99.35 percent or greater the value obtained is rounded to the nearest multiple of 0.0005 and expressed as 0.XXX0 or 0.XXX5.

   2. For aluminum having a specified minimum aluminum content of less than 99.35 percent and aluminum alloys the value obtained is rounded to the nearest multiple of 0.001 and expressed as 0.XXX.

H. The final expression of density in metric units ($kg/m^3 \cdot 10^3$) is obtained by rounding the value determined in step F as follows:

   1. For aluminum having a specified minimum aluminum content of 99.35 percent or greater, the value obtained is rounded to the nearest multiple of 0.005 and expressed as $X.XX0 \cdot 10^3$ or $X.XX5 \cdot 10^3$.

   2. For aluminum having a specified minimum aluminum content of less than 99.35 percent and for aluminum alloys, the value obtained is rounded to the nearest multiple of 0.01 and expressed as $X.XX \cdot 10^3$.

NOTE: Limiting the expression of density to the number of decimal places indicated above is based on the fact that composition variations are discernible from one cast to another for most alloys. The expression of density values to more decimal places than are outlined above implies a higher precision than is justified and should not be used. The values derived by this method are nominal values and as such should not be specified as engineering requirements but, rather, should be used in calculating nominal values for such things as covering area, weight per unit length, weight per unit area, and so on. A density value obtained by this procedure and expressed to the final number of decimal places obtained above should not then be converted to the other system of units.

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① Rounding, except when specified otherwise, shall be in accordance with the rounding-off method of ASTM Recommended Practice E29 (see Table I).

② For 1xxx aluminum the calculated aluminum content may be less than the specified minimum aluminum content. Nevertheless, the calculated aluminum content should be used for purposes of this calculation procedure.

Table I

Less than 0.001 percent	0.000X
0.001 but less than 0.01 percent	0.00X
0.01 but less than 0.10 percent	
Unalloyed aluminum made by a refining process	0.0XX
Alloys and unalloyed aluminum not made by a refining process	0.0X
0.10 through 0.55 percent	0.XX
Over 0.55 percent	0.X, X.X, etc.

Rules for Rounding Off:

Rounding-off method of ASTM Recommended Practices E29, for indicating which places of figures are to be considered significant in specified limiting values:

When the figure next beyond the last place to be retained is less than 5, retain unchanged the figure in the last place retained.

When the figure next beyond the last place to be retained is greater than 5, increase by 1 the figure in the last place retained.

When the figure next beyond the last place to be retained is 5, and there are no figures beyond this 5, or only zeros, increase by 1 the figure in the last place retained if it is odd; leave the figure unchanged if it is even. Increase by 1 the figure in the last place retained, if there are figures beyond this 5.

Table II

Element	Factor
Ag	0.0953
Al	0.3705
B	0.4274
Be	0.5411
Bi	0.1020
Cd	0.1156
Ce	0.1499
Co	0.1130
Cr	0.1391
Cu	0.1116
Fe	0.1271
Ga	0.1693
Li	1.4410
Mg	0.5522
Mn	0.1346
Na	1.0309
Ni	0.1123
O	0.5378
Pb	0.0882
Sc	0.3344
Si	0.4292
Sn	0.1371
Ti	0.2219
V	0.1639
Zn	0.1401
Zr	0.1541

Example (Alloy 5254)

Element	Registered Limits	Calculated Element Concentration	Factor	Element conc. × Factor
Si		0.11*	0.4292	0.047
+	0.45			
Fe		0.11*	0.1271	0.014
Cu	0.05	0.02	0.1116	0.002
Mn	0.01	0.005	0.1346	0.001
Mg	3.1–3.9	3.5	0.5522	1.933
Cr	0.15–0.35	0.25	0.1391	0.035
Zn	0.20	0.10	0.1401	0.014
Ti	0.05	0.02	0.2219	0.004
		4.115		
Al	Remainder (100 4.115 = 95.88)		0.3705	35.524
				37.574

$$\frac{100}{37.574} = 2.6614148\ldots\ldots\text{rounded to } 2.66141$$

Customary density: $(2.66141) \cdot (3.612729 \cdot 10^{2}) = 0.096$ lbs/cu in.

Metric density: $2.66 \cdot 10^{3}$ kg/m^{3}

$$\text{*For Si and Fe: } \frac{0.45 - 0}{2} = 0.225, \text{ rounded to } 0.22$$

$$\frac{0.22}{2} = 0.11 \text{ each for Si and Fe}$$

Example (Alloy 6061)

Element	Registered Limits	Calculated Element Concentration	Factor	Element conc. × Factor
Si	0.40–0.8	0.6	0.4292	0.258
Fe	0.7	0.35	0.1271	0.044
Cu	0.15–0.40	0.28	0.1116	0.031
Mn	0.15	0.08	0.1346	0.011
Mg	0.8–1.2	1.0	0.5522	0.552
Cr	0.04–0.35	0.20	0.1391	0.028
Zn	0.25	0.12	0.1401	0.017
Ti	0.15	0.08	0.2219	0.018
		2.71		
Al	Remainder (100 2.71 = 97.29)		0.3705	36.046
				37.005

$$\frac{100}{37.005} = 2.7023375\ldots\ldots\text{rounded to } 2.70234$$

Customary density: $(2.70234) \cdot (3.612729 \cdot 10^{2}) = .098$ lbs/cu in.

Metric density: $2.70 \cdot 10^{3}$ kg/m^{3}

Example (Aluminum 1145)

Element	Registered Limits	Calculated Element Concentration	Factor	Element conc. × Factor
Si		0.14*	0.4292	0.060
+	0.55			
Fe		0.14*	0.1271	0.018
Cu	0.05	0.02	0.1116	0.002
Mn	0.05	0.02	0.1346	0.003
Mg	0.05	0.02	0.5522	0.011
Zn	0.05	0.02	0.1401	0.003
V	0.05	0.02	0.1639	0.003
Ti	0.03	0.02	0.2219	0.004
		0.40		
Al		99.60	0.3705	36.902
				37.006

* (0.550)/2 = 0.275, rounded to 0.28; or 0.14 each.
100/37.006 = 2.7022644, rounded to 2.70226

Customary density: $(2.70226) \cdot (3.612729 \cdot 10^{2}) = 0.09762533$ rounded to 0.0975 lb/in.^{3}

Metric density: 2.70226, rounded to $2.700 \cdot 10^{3}$kg/m^{3}

TABLE 2.4 Nominal Densities of Aluminum and Aluminum Alloys

Density and specific gravity are dependent upon composition, and variations are discernible from one cast to another for most alloys. The nominal values shown below should not be specified as engineering requirements but are used in calculating typical values for weight per unit length, weight per unit area, covering area, etc. The density values are derived from the metric and subsequently rounded. These values are not to be converted to the metric. X.XXX0 and X.XXX5 density values and X.XX0 and X.XX5 specific gravity values are limited to 99.35 percent or higher purity aluminum.

Alloy	Density (lbs/cu. in.)	Specific Gravity
1050	.0975	2.705
1060	.0975	2.705
1100	.098	2.71
1145	.0975	2.700
1200	.098	2.70
1230	.098	2.70
1235	.0975	2.705
1345	.0975	2.705
1350	.0975	2.705
2011	.102	2.83
2014	.101	2.80
2017	.101	2.79
2018	.102	2.82
2024	.100	2.78
2025	.101	2.81
2036	.100	2.75
2117	.099	2.75
2124	.100	2.78
2218	.101	2.81
2219	.103	2.84
2618	.100	2.76
3003	.099	2.73
3004	.098	2.72
3005	.098	2.73
3105	.098	2.72
4032	.097	2.68
4043	.097	2.69
4045	.096	2.67
4047	.096	2.66
4145	.099	2.74
4343	.097	2.68
4643	.097	2.69
5005	.098	2.70
5050	.097	2.69
5052	.097	2.68
5056	.095	2.64
5083	.096	2.66
5086	.096	2.66
5154	.096	2.66
5183	.096	2.66
5252	.096	2.67
5254	.096	2.66
5356	.096	2.64
5454	.097	2.69
5456	.096	2.66
5457	.097	2.69
5554	.097	2.69
5556	.096	2.66
5652	.097	2.67
5654	.096	2.66
5657	.097	2.69
6003	.097	2.70
6005	.097	2.70
6005A	.098	2.70
6053	.097	2.69
6061	.098	2.70
6063	.097	2.70
6066	.098	2.72
6070	.098	2.71
6082	.098	2.70
6101	.097	2.70
6105	.097	2.69
6151	.098	2.71
6162	.097	2.70
6201	.097	2.69
6262	.098	2.72
6351	.098	2.71
6463	.097	2.69
6951	.098	2.70
7005	.100	2.78
7008	.100	2.78
7049	.103	2.84
7050	.102	2.83
7072	.098	2.72
7075	.101	2.81
7175	.101	2.80
7178	.102	2.83
7475	.101	2.81
8017	.098	2.71
8030	.098	2.71
8176	.098	2.71

3. Application and Fabrication

TABLE 3.1 Wrought Alloy Products and Tempers [3]

ALLOY	SHEET	PLATE	TUBE DRAWN	TUBE EXTRUDED	PIPE	STRUCTURAL PROFILES [1]	EXTRUDED WIRE, ROD, BAR AND PROFILES	ROLLED OR COLD-FINISHED ROD	ROLLED OR COLD-FINISHED BAR	ROLLED OR COLD-FINISHED WIRE	RIVETS	FORGINGS & FORGING STOCK	FOIL	FIN STOCK
1050				H112										
1060	O H12 H14 H16 H18	O H12 H14 H112	O H12 H14 H18 H113	O H112				H14						
1100	O H12 H14 H16 H18	O H12 H14 H112	O H12 H14 H16 H18 H113	O H112			O H112	O H112 F	O H112 F	O H112 H12 H14 H16 H18	O H14	H112 F	O H19	O H14 H18 H19 H25 H111 H113 H211
1145													O H19	O H14 H19 H25 H111 H113 H211
1200				H112										
1235				H112									O H19	
1345										O H12 H14 H16 H18 H19				
1350 [2]	O H12 H14 H16 H18	O H12 H14 H112		H111	H111	H111	H111	O H12 H14 H16 H22 H24 H26	H12 H111	O H12 H14 H16 H19 H22 H24 H26				
2011			T3 T4511 T8					T3 T4 T451 T8	T3 T4 T451 T8	T3 T8				
2014	O T3 T4 T6	O T451 T651	O T4 T6	O T4 T4510 T4511 T6 T6510 T6511			O T4 T4510 T4511 T6 T6510 T6511	O T4 T451 T6 T651	O T4 T451 T6 T651	O T4 T6		F T4 T6 T652		
Alclad 2014	O T3 T4 T6	O T451 T651												
2017								O H13 T4 T451	O T4 T451	O H13 T4	T4			
2018												F T61		

For all numbered footnotes, see page 3-6.

TABLE 3.1 Wrought Alloy Products and Tempers ③ (continued)

ALLOY	SHEET	PLATE	TUBE		PIPE	STRUCTURAL PROFILES ①	EXTRUDED WIRE, ROD, BAR AND PROFILES	ROLLED OR COLD-FINISHED			RIVETS	FORGINGS & FORGING STOCK	FOIL	FIN STOCK
			DRAWN	EXTRUDED				ROD	BAR	WIRE				
2024	O T3 T361 T4 T72 T81 T861	O T351 T361 T851 T861	O T3	O T3 T3510 T3511 T81 T8510 T8511			O T3 T3510 T3511 T81 T8510 T8511	O H13 T351 T4 T6 T851	O T351 T4 T6 T851	O H13 T36 T4 T6	T4			
Alclad 2024	O T3 T361 T4 T81 T861	O T351 T361 T851 T861												
Alclad One Side 2024	O T3 T361 T81 T861	O T351 T361 T851 T861												
1½% Alclad 2024	O T3 T361 T81 T861	O T351 T361 T851 T861												
1½% Alclad One Side 2024	O T3 T361 T81 T861	O T351 T361 T851 T861												
2025												F T6		
2036	T4													
2117								O H13 H15		O H13 H15	T4			
2124		T351												
2218												F T61 T72		
2219	O T31 T37 T81 T87	O T351 T37 T851 T87		O T31 T3510 T3511 T81 T8510 T8511			O T31 T3510 T3511 T81 T8510 T8511	T851	T851		T6	F T6 T852		
Alclad 2219	O T31 T37 T81 T87	O T351 T37 T851 T87												
2618												F T61		
3003	O H12 H14 H16 H18	O H12 H14 H112	O H12 H14 H16 H18 H25 H113	O H112	H18 H112		O H112	O H112 F	O H112 F	O H112 H12 H14 H16 H18	O H14	H112 F	O H19	O H14 H18 H19 H25 H111 H113 H211
Alclad 3003	O H12 H14 H16 H18	O H12 H14 H112	O H14 H18 H25 H113	O H112										

For all numbered footnotes, see page 3-6.

TABLE 3.1 Wrought Alloy Products and Tempers ③ (continued)

ALLOY	SHEET	PLATE	TUBE DRAWN	TUBE EXTRUDED	PIPE	STRUCTURAL PROFILES ①	EXTRUDED WIRE, ROD, BAR AND PROFILES	ROLLED OR COLD-FINISHED ROD	ROLLED OR COLD-FINISHED BAR	ROLLED OR COLD-FINISHED WIRE	RIVETS	FORGINGS & FORGING STOCK	FOIL	FIN STOCK
3004	O H32 H34 H36 H38	O H32 H34 H112	O H34 H36 H38	O										
Alclad 3004	O H32 H34 H36 H38	O H32 H34 H112												
3005	O H12 H14 H16 H18 H19 H26 H28													
3105	O H12 H14 H16 H18 H22 H24 H25 H26 H28													
4032												F T6		
5005	O H12 H14 H16 H18 H32 H34 H36 H38	O H12 H14 H32 H34 H112						O H12 H14 H16 H22 H24 H26 H32		O H19 H32	O H32			
5050	O H32 H34 H36 H38	O H112	O H32 H34 H36 H38					O F	O F	O H32 H34 H36 H38				
5052	O H32 H34 H36 H38	O H32 H34 H112	O H32 H34 H36 H38					O F H32	O F	O H32 H34 H36 H38	O H32		O H19	
5056								O F H32	O F	O H111 H12 H14 H18 H32 H34 H38 H192 H392	O H32		H19	
5083	O H32 H116 H321	O H32 H112 H116 H321		O H111 H112			O H111 H112					H111 H112 F		

For all numbered footnotes, see page 3-6.

TABLE 3.1 Wrought Alloy Products and Tempers ③ (continued)

ALLOY	SHEET	PLATE	TUBE		PIPE	STRUCTURAL PROFILES ①	EXTRUDED WIRE, ROD, BAR AND PROFILES	ROLLED OR COLD-FINISHED			RIVETS	FORGINGS & FORGING STOCK	FOIL	FIN STOCK
			DRAWN	EXTRUDED				ROD	BAR	WIRE				
5086	O H112 H116 H32 H34 H36 H38	O H112 H116 H32 H34	O H32 H34 H36	O H111 H112			O H111 H112							
5154	O H32 H34 H36 H38	O H32 H34 H112	O H34 H38	O H112			O H112	O H112 F	O H112 F	O H112 H32 H34 H36 H38				
5252	H24 H25 H28													
5254	O H32 H34 H36 H38	O H32 H34 H112												
5454	O H32 H34	O H32 H34 H112	H32 H34	O H111 H112			O H111 H112							
5456	O H32 H116 H321	O H32 H112 H116 H321										H112 F		
5457	O													
5652	O H32 H34 H36 H38	O H32 H34 H112												
5657	H241 H25 H26 H28													
6005 6005A				T1 T5 T1 T5 T61			T1 T5 T1 T5 T61							
6053								O H13		O H13	T61	F T6		
6061	O T4 T6	O T451 T651	O T4 T6	O T1 T4 T4510 T4511 T51 T6 T6510 T6511	T6	T6	O T1 T4 T4510 T4511 T51 T6 T6510 T6511	O H13 T4 T451 T6 T651	O T4 T451 T6 T651	O H13 T4 T6 T89 T913 T94	T6	F T6 T652		
Alclad 6061	O T4 T6	O T451 T651												
6063			O T4 T6 T83 T831 T832	O T1 T4 T5 T52 T6	T6		O T1 T4 T5 T52 T6							

For all numbered footnotes, see page 3-6.

TABLE 3.1 Wrought Alloy Products and Tempers [3] (continued)

ALLOY	SHEET	PLATE	TUBE		PIPE	STRUCTURAL PROFILES [1]	EXTRUDED WIRE, ROD, BAR AND PROFILES	ROLLED OR COLD-FINISHED			RIVETS	FORGINGS & FORGING STOCK	FOIL	FIN STOCK
			DRAWN	EXTRUDED				ROD	BAR	WIRE				
6066			O T4 T6	O T4 T4510 T4511 T6 T6510 T6511			O T4 T4510 T4511 T6 T6510 T6511					F T6		
6070				T6			T6							
6082				T6		T6 T6511	T6 T6511							
6101 [2]				T6 T61 T63 T64 T65 H111	T6 T61 T63 T64 T65 H111	T6 T61 T63 T64 T65 H111	T6 T61 T63 T64 T65 H111							
6105				T1 T5			T1 T5							
6151												F T6 T652		
6162							T5 T5510 T5511 T6 T6510 T6511							
6201 [2]										T81				
6262			T6 T9	T6 T6510 T6511			T6 T6510 T6511	T6 T651 T9	T6 T651 T9	T6 T9				
6351				T4 T6	T4 T6		T1 T4 T5 T51 T54 T6							
6463							T1 T5 T6							
6951	T42 T62													
7005							T53							
7049												T73 T7352		
7050		T7451 [4] T7651					T73510 T73511 T74510 [4] T74511 [4] T76510 T76511	H13		H13	T7	T74 [4] T7452 [4] F		
7072														O H14 H18 H19 H23 H24 H241 H25 H111 H113 H211

For all numbered footnotes, see page 3-6.

TABLE 3.1 Wrought Alloy Products and Tempers ③ (concluded)

ALLOY	SHEET	PLATE	TUBE		PIPE	STRUCTURAL PROFILES ①	EXTRUDED WIRE, ROD, BAR AND PROFILES	ROLLED OR COLD-FINISHED			RIVETS	FORGINGS & FORGING STOCK	FOIL	FIN STOCK
			DRAWN	EXTRUDED				ROD	BAR	WIRE				
7075	T6 T73 T76	O T651 T7351 T7651	O T6 T73	O T6 T6510 T6511 T73 T73510 T73511			O T6 T6510 T6511 T73 T73510 T73511 T76 T76510 T76511	O H13 T6 T651 T73 T7351	O T6 T651 T73 T7351	O H13 T6 T73	T6 T73	F T6 T652 T73 T7352		
Alclad 7075	O T6 T73 T76	O T651 T7351 T7651												
Alclad One Side 7075	O T6	O T651												
7008 Alclad 7075	O T6 T76	O T651 T7651												
7175												F T74 T7452 T7454 T66		
7178	O T6 T76	O T651 T7651					O T6 T6510 T6511 T76 T76510 T76511	O H13		O H13	T6			
Alclad 7178	O T6 T76	O T651 T7651												
7475	T61 T761	T651 T7351 T7651						O						
Alclad 7475	T61 T761	T651 T7651												

① Rolled or extruded.
② Products listed for these alloys are for electric conductors only.
③ Suppliers should be consulted for current availability of alloys, tempers and products. Additional alloys, tempers, and products are obtainable from some suppliers. See "Alloys and Temper Designation Systems for Aluminum."
④ T74-type tempers, although not previously registered, have appeared in various literature and specifications as T736-type tempers.

TABLE 3.2 Specialty Mill Products ①

SPECIALTY PRODUCT DESIGNATION	SPECIALTY PRODUCT DESCRIPTION		
	ALLOY	TEMPER	FORM
Brazing sheet			
Nos. 11 and 12	3003 clad with 4343 on one side (No. 11) or both (No. 12)	O H12 H14	Sheet
Nos. 23 and 24	6951 clad with 4045 on one side (No. 23) or both (No. 24)	O	Sheet
Painted sheet	1100 3003	O H12 H14 H16 H18	Coiled sheet
	3105	O H12 H14 H16 H18 H25	Coiled sheet
	5005 5050 5052	O H32 H34 H36 H38	Coiled sheet
Commercial roofing and siding			
Corrugated roofing and siding	3004, Alclad 3004		Sheet
V-beam roofing and siding	3004, Alclad 3004		Sheet
Ribbed roofing	Alclad 3004		Sheet
Ribbed siding	3004, Alclad 3004		Sheet
Duct sheet	Alloy and temper with min. tensile strength of 16.0 ksi		Coiled or flat sheet
Tread plate	6061	O T4 T6	Sheet and plate with raised pattern on one surface
Heat-exchanger tube	1060	H14	Tube
	3003	H14 H25	
	Alclad 3003	H14 H25	
	5052	H32 H34	
	5454	H32 H34	
	6061	T4 T6	
Rigid electrical conduit	3003 6063	H12 T1	Tube

① Other alloys and tempers may be available from individual producers for some of these products.

TABLE 3.3 Comparative Characteristics and Applications

ALLOY AND TEMPER	RESISTANCE TO CORROSION		Workability (Cold) ⑤	Machinability ⑤	Brazeability ⑥	WELDABILITY ⑥			SOME APPLICATIONS OF ALLOYS
	General ①	Stress-Corrosion Cracking ②				Gas	Arc	Resistance Spot and Seam	
1060-O	A	A	A	E	A	A	A	B	Chemical equipment, railroad tank cars
H12	A	A	A	E	A	A	A	A	
H14	A	A	A	D	A	A	A	A	
H16	A	A	B	D	A	A	A	A	
H18	A	A	B	D	A	A	A	A	
1100-O	A	A	A	E	A	A	A	B	Sheet metal work, spun hollowware, fin stock
H12	A	A	A	E	A	A	A	A	
H14	A	A	A	D	A	A	A	A	
H16	A	A	B	D	A	A	A	A	
H18	A	A	C	D	A	A	A	A	
1350-O	A	A	A	E	A	A	A	B	Electrical conductors
H12, H111	A	A	A	E	A	A	A	A	
H14, H24	A	A	A	D	A	A	A	A	
H16, H26	A	A	B	D	A	A	A	A	
H18	A	A	B	D	A	A	A	A	
2011-T3	D ③	D	C	A	D	D	D	D	Screw machine products
T4, T451	D ③	D	B	A	D	D	D	D	
T8	D	B	D	A	D	D	D	D	
2014-O	. .	. .	. .	D	D	D	D	B	Truck frames, aircraft structures
T3, T4, T451	D ③	C	C	B	D	D	B	B	
T6, T651, T6510, T6511	D	C	D	B	D	D	B	B	
2017-T4, T451	D ③	C	C	B	D	D	B	B	Screw machine products, fittings
2018-T61	. .	. .	. .	B	D	D	C	B	Aircraft engine cylinders, heads and pistons
2024-O	. .	. .	. .	D	D	D	D	D	Truck wheels, screw machine products, aircraft structures
T4, T3, T351, T3510, T3511	D ③	C	C	B	D	C	B	B	
T361	D ③	C	D	B	D	D	C	B	
T6	D	B	C	B	D	D	C	B	
T861, T81, T851, T8510, T8511	D	B	D	B	D	D	C	B	
T72	. .	. .	. .	B	D	D	C	B	
2025-T6	D	C	. .	B	D	D	B	B	Forgings, aircraft propellers
2036-T4	C	. .	B	C	D	C	B	B	Auto body panel sheet
2117-T4	C	A	B	C	D	D	B	B	Rivets
2124-T851	D	B	D	B	D	D	C	B	Aircraft structures
2218-T61	D	C	. .	. .	D	D	C	B	Jet engine impellers and rings
T72	D	C	. .	B	D	D	C	B	
2219-O	. .	. .	. .	. .	D	D	A	B	Structural uses at high temperatures (to 600°F) High strength weldments
T31, T351, T3510, T3511	D ③	C	C	B	D	A	A	A	
T37	D ③	C	D	B	D	A	A	A	
T81, T851, T8510, T8511	D	B	D	B	D	A	A	A	
T87	D	B	D	B	D	A	A	A	
2618-T61	D	C	. .	B	D	D	C	B	Aircraft engines
3003-O	A	A	A	E	A	A	A	B	Cooking utensils, chemical equipment, pressure vessels, sheet metal work, builder's hardware, storage tanks
H12	A	A	A	E	A	A	A	A	
H14	A	A	B	D	A	A	A	A	
H16	A	A	C	D	A	A	A	A	
H18	A	A	C	D	A	A	A	A	
H25	A	A	B	D	A	A	A	A	
3004-O	A	A	A	D	B	A	A	B	Sheet metal work, storage tanks
H32	A	A	B	D	B	A	A	A	
H34	A	A	B	C	B	A	A	A	
H36	A	A	C	C	B	A	A	A	
H38	A	A	C	C	B	A	A	A	
3105-O	A	A	A	E	A	A	A	B	Residential siding, mobile homes, rain carrying goods, sheet metal work
H12	A	A	B	E	A	A	A	A	
H14	A	A	B	D	A	A	A	A	
H16	A	A	C	D	A	A	A	A	
H18	A	A	C	D	A	A	A	A	
H25	A	A	B	D	A	A	A	A	

For all numbered footnotes, see page 3-11.

TABLE 3.3 Comparative Characteristics and Applications (continued)

ALLOY AND TEMPER	RESISTANCE TO CORROSION: General ①	RESISTANCE TO CORROSION: Stress-Corrosion Cracking ②	Workability (Cold) ⑤	Machinability ⑤	Brazeability ⑥	WELDABILITY ⑥: Gas	WELDABILITY ⑥: Arc	WELDABILITY ⑥: Resistance Spot and Seam	SOME APPLICATIONS OF ALLOYS
4032-T6	C	B	. .	B	D	D	B	C	Pistons
5005-O	A	A	A	E	B	A	A	B	Appliances, utensils, architectural, electrical conductor
H12	A	A	A	E	B	A	A	A	
H14	A	A	B	D	B	A	A	A	
H16	A	A	C	D	B	A	A	A	
H18	A	A	C	D	B	A	A	A	
H32	A	A	A	E	B	A	A	A	
H34	A	A	B	D	B	A	A	A	
H36	A	A	C	D	B	A	A	A	
H38	A	A	C	D	B	A	A	A	
5050-O	A	A	A	E	B	A	A	B	Builder's hardware, refrigerator trim, coiled tubes
H32	A	A	A	D	B	A	A	A	
H34	A	A	B	D	B	A	A	A	
H36	A	A	C	C	B	A	A	A	
H38	A	A	C	C	B	A	A	A	
5052-O	A	A	A	D	C	A	A	B	Sheet metal work, hydraulic tube, appliances
H32	A	A	B	D	C	A	A	A	
H34	A	A	B	C	C	A	A	A	
H36	A	A	C	C	C	A	A	A	
H38	A	A	C	C	C	A	A	A	
5056-O	A ④	B ④	A	D	D	C	A	B	Cable sheathing, rivets for magnesium, screen wire, zipper
H111	A ④	B ④	A	D	D	C	A	A	
H12, H32	A ④	B ④	B	D	D	C	A	A	
H14, H34	A ④	B ④	B	C	D	C	A	A	
H18, H38	A ④	C ④	C	C	D	C	A	A	
H192	B ④	D ④	D	B	D	C	A	A	
H392	B ④	D ④	D	B	D	C	A	A	
5083-O	A ④	A ④	B	D	D	C	A	B	
H32 ⑧	A ④	A ④	C	D	D	C	A	A	
H321 ⑧	A ④	A ④	C	D	D	C	A	A	
H111	A ④	B ④	C	D	D	C	A	A	Unfired, welded pressure vessels, marine, auto aircraft cryogenics, TV towers, drilling rigs, transportation equipment, missile components
H116 ⑧	A ④	A ④	C	D	D	C	A	A	
5086-O	A ④	A ④	A	D	D	C	A	B	
H32 ⑧	A ④	A ④	B	D	D	C	A	A	
H34	A ④	B ④	B	C	D	C	A	A	
H36	A ④	B ④	C	C	D	C	A	A	
H111	A ④	A ④	B	D	D	C	A	A	
H116 ⑧	A ④	A ④	B	D	D	C	A	A	
5154-O	A ④	A ④	A	D	D	C	A	B	Welded structures, storage tanks, pressure vessels, salt water service
H32	A ④	A ④	B	D	D	C	A	A	
H34	A ④	A ④	B	C	D	C	A	A	
H36	A ④	A ④	C	C	D	C	A	A	
H38	A ④	A ④	C	C	D	C	A	A	
5252-H24	A	A	B	D	C	A	A	A	Automotive and appliance trim
H25	A	A	B	C	C	A	A	A	
H28	A	A	C	C	C	A	A	A	
5254-O	A ④	A ④	A	D	D	C	A	B	Hydrogen peroxide and chemical storage vessels
H32	A ④	A ④	B	D	D	C	A	A	
H34	A ④	A ④	B	C	D	C	A	A	
H36	A ④	A ④	C	C	D	C	A	A	
H38	A ④	A ④	C	C	D	C	A	A	
5454-O	A	A	A	D	D	C	A	B	Welded structures, pressure vessels, marine service
H32	A	A	B	D	D	C	A	A	
H34	A	A	B	C	D	C	A	A	
H111	A	A	B	D	D	C	A	A	
5456-O	A ④	B ④	B	D	D	C	A	B	
H32 ⑧	A ④	B ④	C	D	D	C	A	A	High strength welded structures, pressure vessels, marine applications, storage tanks
H321 ⑧	A ④	B ④	C	D	D	C	A	A	
H116 ⑧	A ④	B ④	C	D	D	C	A	A	
5457-O	A	A	A	E	B	A	A	B	
5652-O	A	A	A	D	C	A	A	B	Hydrogen peroxide and chemical storage vessels
H32	A	A	B	D	C	A	A	A	
H34	A	A	B	C	C	A	A	A	
H36	A	A	C	C	C	A	A	A	
H38	A	A	C	C	C	A	A	A	

For all numbered footnotes, see page 3-11.

TABLE 3.3 Comparative Characteristics and Applications (concluded)

ALLOY AND TEMPER	RESISTANCE TO CORROSION: General ①	RESISTANCE TO CORROSION: Stress-Corrosion Cracking ②	Workability (Cold) ⑤	Machinability ⑤	Brazeability ⑥	WELDABILITY ⑥: Gas	WELDABILITY ⑥: Arc	WELDABILITY ⑥: Resistance Spot and Seam	SOME APPLICATIONS OF ALLOYS
5657-H241	A	A	A	D	B	A	A	A	Anodized auto and appliance trim
H25	A	A	B	D	B	A	A	A	
H26	A	A	B	D	B	A	A	A	
H28	A	A	C	D	B	A	A	A	
6005-T1, T5	B	A	. .	. .	A	A	A	A	
6005A-T1, T5	B	A	B	C	A	A	A	A	Truck, marine, railroad car
6005A-T61	B	A	C	C	A	A	A	A	Extruded profiles, structures, ladders, construction
6053-O	. .	. .	. .	E	B	A	A	B	Wire and rod for rivets
T6, T61	A	A	. .	C	B	A	A	A	
6061-O	B	A	A	D	A	A	A	B	Heavy-duty structures requiring good corrosion resistance, truck and marine, railroad cars, furniture, pipelines
T4, T451, T4510, T4511	B	B	B	C	A	A	A	A	
T6, T651, T652, T6510, T6511	B	A	C	C	A	A	A	A	
6063-T1	A	A	B	D	A	A	A	A	Pipe railing, furniture, architectural extrusions
T4	A	A	B	D	A	A	A	A	
T5, T52	A	A	B	C	A	A	A	A	
T6	A	A	C	C	A	A	A	A	
T83, T831, T832	A	A	C	C	A	A	A	A	
6066-O	C	A	B	D	D	D	B	B	Forgings and extrusion for welded structures
T4, T4510, T4511	C	B	C	C	D	D	B	B	
T6, T6510, T6511	C	B	C	B	D	D	B	B	
6070-T4, T4511	B	B	B	C	D	A	A	A	Heavy duty welded structures, pipelines
T6	B	B	C	C	D	A	A	A	
6082-T6, T6511	B	A	C	C	A	A	A	A	Heavy-duty structures requiring good corrosion resistance, truck and marine, railroad cars, furniture, pipelines
6101-T6, T63	A	A	C	C	A	A	A	A	High strength bus conductors
T61, T64	A	A	B	D	A	A	A	A	
6151-T6, T652	. .	. .	. .	. .	B	. .	. .	. .	Moderate strength, intricate forgings for machine and auto parts
6201-T81	A	A	. .	C	A	A	A	A	High strength electric conductor wire
6262-T6, T651, T6510, T6511	B	A	C	B	B	B	B	A	Screw machine products
T9	B	A	D	B	B	B	B	A	
6351-T1	. .	. .	C	C	C	B	A	B	Extruded profiles, structurals, pipe and tube
T4	A	. .	C	C	C	B	A	B	
T5	A	. .	C	C	C	B	A	A	
T6	A	. .	C	C	C	B	A	A	
6463-T1	A	A	B	D	A	A	A	A	Extruded architectural and trim sections
T5	A	A	B	C	A	A	A	A	
T6	A	A	C	C	A	A	A	A	
6951-T42, T62	. .	. .	. .	. .	A	A	A	A	
7005-T53	. .	. .	. .	. .	B	C	A	A	
7049-T73, T7352	C	B	D	B	D	D	D	B	Aircraft forgings
7050-T73510, T73511, T74 ⑦, T7451 ⑦, T74510 ⑦, T74511 ⑦, T7452 ⑦, T7651, T76510, T76511	C	B	D	B	D	D	D	B	Aircraft and other structures
7075-O	. .	. .	. .	D	D	D	D	B	Aircraft and other structures
T6, T651, T652, T6510, T6511	C ③	C	D	B	D	D	D	B	
T73, T7351	C	B	D	B	D	D	D	B	
7175-T74, T7452, T7454	C	B	D	B	D	D	C	B	
7178-O	. .	. .	. .	. .	D	D	D	B	Aircraft and other structures
T6, T651, T6510, T6511	C ③	C	D	B	D	D	D	B	
7475-O	. .	. .	. .	. .	D	D	D	B	Shell Casings
7475-T61, -T651	C	C	D	B	D	D	B	B	Aircraft & Other
7475-T761, T7351	C	B	D	B	D	D	D	B	Structures
8017-H12, H22, H221	A	A	A	D	A	A	A	A	Electrical conductors
8030-H12, H221	A	A	A	E	A	A	A	A	Electrical conductors
8176-H14, H24	A	A	A	D	A	A	A	A	Electrical conductors

For all numbered footnotes, see page 3-11.

Notes for Table 3.3

① Ratings A through E are relative ratings in decreasing order of merit, based on exposures to sodium chloride solution by intermittent spraying or immersion. Alloys with A and B ratings can be used in industrial and seacoast atmospheres without protection. Alloys with C, D and E ratings generally should be protected at least on faying surfaces.

② Stress-corrosion cracking ratings are based on service experience and on laboratory tests of specimens exposed to the 3.5% sodium chloride alternate immersion test.

A = No known instance of failure in service or in laboratory tests.

B = No known instance of failure in service; limited failures in laboratory tests of short transverse specimens.

C = Service failures with sustained tension stress acting in short transverse direction relative to grain structure; limited failures in laboratory tests of long transverse specimens.

D = Limited service failures with sustained longitudinal or long transverse areas.

These ratings are neither product specific nor test direction specific and therefore indicate only the general level of stress-corrosion cracking resistance. For more specific information on certain alloys, see ASTM G64.

③ In relatively thick sections the rating would be E.

④ This rating may be different for material held at elevated temperature for long periods.

⑤ Ratings A through D for Workability (cold), and A through E for Machinability, are relative ratings in decreasing order of merit.

⑥ Ratings A through D for Weldability and Brazeability are relative ratings defined as follows:

A = Generally weldable by all commercial procedures and methods.

B = Weldable with special techniques or for specific applications that justify preliminary trials or testing to develop welding procedure and weld performance.

C = Limited weldability because of crack sensitivity or loss in resistance to corrosion and mechanical properties.

D = No commonly used welding methods have been developed.

⑦ T74 type tempers, although not previously registered, have appeared in various literature and specifications as T736 type tempers.

⑧ 5xxx products in the -H116 and H32X tempers have similar properties and have the same testing requirements, but are produced by different practices. The -H116 and -H321 tempers are typically used in marine and other applications requiring demonstrations of intergranular and exfoliation corrosion resistance. Products in the -H32 temper have similar tensile properties and while production methods may be similar, corrosion testing requirements are different, therefore, -H32 temper products shall not be substituted for -H116 or -H321 products.

TABLE 3.4 Typical Heat Treatments for Aluminum Alloy Mill Products [1]

The typical treatments listed in this table are for furnaces operating to instructions (mill practices) given in Fahrenheit. For furnaces operating to instructions given in Celsius, see Table 3.4 in the metric unit edition of ALUMINUM STANDARDS AND DATA.

ALLOY	PRODUCT	SOLUTION HEAT TREATMENT [2]		PRECIPITATION HEAT TREATMENT		
		METAL TEMPERATURE [3] °F	TEMPER DESIGNATION	METAL TEMPERATURE [3] °F	APPROX. TIME AT TEMPERATURE [4] Hours	TEMPER DESIGNATION
2011	Rolled or Cold Finished Wire, Rod & Bar	975	T3 [5] T4 T451 [6]	320 — —	14 — —	T8 [5] — —
	Drawn Tube	960	T3 [5] T4511 [6]	310 —	14 —	T8 [5] —
2014 [7]	Flat Sheet	935	T3 [5]	—	—	—
			T42	320	18	T62
	Coiled Sheet	935	T4	320	18	T6
			T42	320	18	T62
	Plate	935	T451 [6]	320	18	T651 [6]
			T42	320	18	T62
	Rolled or Cold Finished Wire, Rod & Bar	935	T4 T451 [6]	320 [8] 320 [8]	18 18	T6 T651 [6]
			T42	320 [8]	18	T62
	Extruded Wire, Rod, Bar, Profiles & Tube	935	T4 T4510 [6] T4511 [6]	320 [8] 320 [8] 320 [8]	18 18 18	T6 T6510 [6] T6511 [6]
			T42	320 [8]	18	T62
	Drawn Tube	935	T4	320 [8]	18	T6
			T42	320 [8]	18	T62
	Die Forgings	935 [9]	T4	340	10	T6
	Hand Forgings and Rolled Rings	935 [9]	T4 [39] T452 [10] [39]	340 340	10 10	T6 T652 [10]
2017	Rolled or Cold Finished Wire, Rod & Bar	935	T4 T451 [6]	— —	— —	— —
			T42	—	—	—
2018	Die Forgings	950 [11]	T4 [39]	340	10	T61
2024 [7]	Flat Sheet	920	T3 [5] T361 [5]	375 375	12 8	T81 [5] T861 [5]
			T42 T42	375 375	9 16	T62 T72
	Coiled Sheet	920	T4	—	—	—
			T42 T42	375 375	9 16	T62 T72
	Plate	920	T351 [6] T361 [5]	375 375	12 8	T851 [6] T861 [5]
			T42	375	9	T62
	Rolled or Cold Finished Wire, Rod & Bar	920	T351 [6] T36 [5] T4	375 — 375	12 — 12	T851 [6] — T6
			T42	375	16	T62
	Extruded Wire, Rod, Bar Profiles & Tube	920	T3 [5] T3510 [6] T3511 [6]	375 375 375	12 12 12	T81 [5] T8510 [6] T8511 [6]
			T42	—	—	—
	Drawn Tube	920	T3 [5]	—	—	—
			T42	—	—	—
2025	Die Forgings	960	T4 [39]	340	10	T6
2036	Sheet	930	T4	—	—	—

For all numbered footnotes, see page 3-16.

TABLE 3.4 Typical Heat Treatments for Aluminum Alloy Mill Products [1] (continued)

ALLOY	PRODUCT	SOLUTION HEAT TREATMENT [2]		PRECIPITATION HEAT TREATMENT		
		METAL TEMPERATURE [3] °F	TEMPER DESIGNATION	METAL TEMPERATURE [3] °F	APPROX. TIME AT TEMPERATURE [4] Hours	TEMPER DESIGNATION
2117	Rolled or Cold Finished	935	T4	—	—	—
	Wire and Rod		T42	—	—	—
2124	Plate	920	T351 [6]	375	12	T851 [6]
2218	Die Forgings	950 [11] 950 [12]	T4 [39] T41 [39]	340 460	10 6	T61 T72
2219 [7]	Flat Sheet	995	T31 [5] T37 [5]	350 325	18 24	T81 [5] T87 [5]
			T42 [39]	375	36	T62
	Plate	995	T37 [5] T351 [6]	350 350	18 18	T87 [5] T851 [6]
			T42 [39]	375	36	T62
	Rolled or Cold Finished Wire, Road & Bar	995	T4 [39] T351 [39]	375 375	36 18	T6 T851 [6]
	Extruded Rod, Bar, Profiles & Tube	995	T31 [5] T3510 [5] T3511 [6]	375 375 375	18 18 18	T81 [5] T8510 [6] T8511 [6]
			T42 [39]	375	36	T62
	Die Forgings and Rolled Rings	995	T4 [39]	375	26	T6
	Hand Forgings	995	T4 [39] T352 [10] [39]	375 350	26 18	T6 T852 [10]
2618	Forgings and Rolled Rings	985 [11]	T4 [39]	390	20	T61
4032	Die Forgings	950 [9]	T4 [39]	340	10	T6
6005	Extruded Rod, Bar, Profiles & Tube	[30]	T1	350	8	T5
6005A	Extruded Rod, Bar	[30]	T1	350	8	T5
	Profiles & Tube	950 [15]	T4 [39]	350	8	T61
6053	Rolled or Cold Finished Wire and Rod	945	T4 [39]	355	8	T61
	Die Forgings	970	T4 [39]	340	10	T6
6061 [7]	Sheet	990	T4	320	18	T6
			T42	320	18	T62
	Plate	990	T4 [21] T451 [6]	320 320	18 18	T6 [21] T651 [6]
			T42	320	18	T62
	Rolled or Cold finished Wire, Rod & Bar	990	T4 T3 [39] T4 T4 T451 [6]	320 [13] 320 [13] 320 [13] 320 [13] 320 [13]	18 18 18 18 18	T6 T89 [5] T913 [14] T94 [14] T651 [6]
			T42	320 [13]	18	T62
	Extruded Rod, Bar, Profiles and Tube	[30]	T1	350	8	T51
		990 [15]	T4 T4510 [6] T4511 [6]	350 350 350	8 8 8	T6 T6510 [6] T6511 [6]
		990	T42	350	8	T62
	Structural Profiles	990 [15]	T4 [39]	350	8	T6
	Pipe	990 [15]	T4 [39]	350	8	T6
	Drawn Pipe	990	T4	320 [13]	18	T6
			T42	320 [13]	18	T62
	Die and Hand Forgings	990	T4 [39]	350	8	T6
	Rolled Rings	990	T4 [39] T452 [10] [39]	350 350	8 8	T6 T652 [10]

For all numbered footnotes, see page 3-16.

TABLE 3.4 Typical Heat Treatments for Aluminum Alloy Mill Products [1] (continued)

ALLOY	PRODUCT	SOLUTION HEAT TREATMENT [2]		PRECIPITATION HEAT TREATMENT		
		METAL TEMPERATURE [3] °F	TEMPER DESIGNATION	METAL TEMPERATURE [3] °F	APPROX. TIME AT TEMPERATURE [4] Hours	TEMPER DESIGNATION
6063	Extruded Rod, Bar, Profiles & Tube	[30]	T1 T1	360 [16] 360	3 3	T5 T52
		950 [13]	T4	350 [17]	8	T6
		970	T42	350 [17]	8	T62
	Drawn Tube	970	T4 T3 [5] [15] [39] T3 [5] [15] [39] T3 [5] [15] [39]	350 350 350 350	8 8 8 8	T6 T83 [5] T831 [5] T832 [5]
			T42	350	8	T62
	Pipe	970 [15]	T4 [39]	350 [17]	8	T6
6066	Extruded Rod, Bar, Profiles & Tube	990	T4 T4510 [6] T4511 [6]	350 350 350	8 8 8	T6 T6510 [6] T6511 [6]
			T42	350	8	T62
	Drawn Tube	990	T4	350	8	T6
			T42	350	8	T62
	Die Forgings	990	T4 [39]	350	8	T6
6070	Extruded Rod, Bar Profiles & Tube	1015 [15]	T4 [39]	320	18	T6
		1015	T42 [39]	320	18	T62
6082	Extrusions	980 980	T4 [39] T4511 [39] [6]	350 350	8 8	T6 [6] T6511 [6]
6101	Extruded Rod, Bar, Tube, Pipe and Structural Profiles	970 [15]	T4 [39] T4 [39] T4 [39] T4 [39] T4 [39]	390 440 410 535 430	10 5 9 7 3	T6 T61 T63 T64 T65
6105	Extruded Rod, Bar Profiles and Tube	[30]	T1	350	8	T5
6151	Die Forgings	960	T4 [39]	340	10	T6
	Rolled Rings	960	T4 [39] T452 [10] [39]	340 340	10 10	T6 T652 [10]
6162	Extruded Rod, Bar, Profiles & Tube	[30]	T1 [39] T1510 [6] [39] T1511 [6] [39]	350 350 350	8 8 8	T5 T5510 [6] T5511 [6]
		980 [15]	T4 [39] T4510 [6] [39] T4511 [6] [39]	350 350 350	8 8 8	T6 T6510 [6] T6511 [6]
6201	Wire	950	T3 [5] [39]	320	4	T81 [5]
6262	Rolled or Cold Finished Wire, Rod and Bar	1000	T4 [39] T4 [39] T451 [6] [39]	340 340 340	8 12 8	T6 T9 [14] T651 [6]
			T42 [39]	340	8	T62
	Extruded Rod, Bar, Profiles and Tube	1000 [15]	T4 [39] T4510 [6] [39] T4511 [6] [39]	350 350 350	12 12 12	T6 T6510 [6] T6511 [6]
		1000	T42 [39]	350	12	T62
	Drawn Tube	1000	T4 [39] T4 [39]	340 340	8 8	T6 T9 [14]
			T42 [39]	340	8	T62
6351	Extruded Rod, Bar and Profiles	[30] [30] 985	T1 T1 T4	250 350 350	10 8 8	T54 T5 T6
6463	Extruded Rod, Bar and Profiles	[30]	T1	400	1	T5
		970 [15]	T4 [39]	350 [17]	8	T6
		970	T42 [39]	350 [17]	8	T62
6951 [29]	Sheet	985	T42	320	18	T62

For all numbered footnotes, see page 3-16.

TABLE 3.4 Typical Heat Treatments for Aluminum Alloy Mill Products ① (continued)

ALLOY	PRODUCT	SOLUTION HEAT TREATMENT ②		PRECIPITATION HEAT TREATMENT		
		METAL TEMPERATURE ③ °F	TEMPER DESIGNATION	METAL TEMPERATURE ③ °F	APPROX. TIME AT TEMPERATURE ④ Hours	TEMPER DESIGNATION
7005	Extruded Rod, Bar and Profiles	㉚	T1 ㊴	㉒	㉒	T53
7049	Die Forgings	875 ⑨	W	㉟	㉟	T73
	Hand Forgings	875 ⑨	W	㉟	㉟	T73
			W52 ⑩	㉟	㉟	T7352 ⑩
7050	Plate	890	W51 ⑥ W51 ⑥	㉛ ㉜	㉛ ㉜	T7451 ⑥ T7651 ⑥
	Rolled or Cold Finished Wire and Rod	890	W	㊳	㊳	T7
	Extruded Rod, Bar and Profiles	890	W510 ⑥ W510 ⑥ W510 ⑥	㊱ ㊲ ㉝	㊱ ㊲ ㉝	T73510 ⑥ T74510 ⑥ T76510 ⑥
			W511 ⑥ W511 ⑥ W511 ⑥	㊱ ㊲ ㉝	㊱ ㊲ ㉝	T73511 ⑥ T74511 ⑥ T76511 ⑥
	Die Forgings	890	W	㉞	㉞	T74
	Hand Forgings	890	W52 ㉞	㉞	㉞	T7452 ⑩
7075 ⑦	Sheet	900 ㉓	W W W	250 ⑱ ⑳ ㉔ ㉘	24 ⑳ ㉔ ㉘	T6 T73 ㉗ T76 ㉗
			W	250 ⑱	24	T62
	Plate	900 ㉓ ㊵	W51 ⑥ W51 ⑥ W51 ⑥	250 ⑱ ⑳ ㉔ ㉘	24 ⑳ ㉔ ㉘	T651 ⑥ T7351 ⑥ ㉗ T7651 ⑥ ㉗
			W	250 ⑱	24	T62
	Rolled or Cold finished Wire, Rod and Bar	915 ㉓ ㊵	W W	250 ⑳ ㉔	24 ⑳ ㉔	T6 T73 ㉗
			W	250	24	T62
			W51 ⑥ W51 ⑥	250 ⑳ ㉔	24 ⑳ ㉔	T651 ⑥ T7351 ⑥ ㉗
	Extruded Rod, Bar and Profiles	870	W W W	250 ⑲ ⑳ ㉔ ㉘	24 ⑳ ㉔ ㉘	T6 T73 ㉗ T76 ㉗
			W	250 ⑲	24	T62
			W510 ⑥ W510 ⑥ W510 ⑥	250 ⑲ ⑳ ㉔ ㉘	24 ⑳ ㉔ ㉘	T6510 ⑥ T73510 ⑥ ㉗ T76510 ⑥ ㉗
			W511 ⑥ W511 ⑥ W511 ⑥	250 ⑲ ⑳ ㉔ ㉘	24 ⑳ ㉔ ㉘	T6511 ⑥ T73511 ⑥ ㉗ T76511 ⑥ ㉗
	Extruded Tube	870	W W	250 ⑲ ⑳ ㉔	24 ⑳ ㉔	T6 T73 ㉗
			W	250 ⑲	24	T62
			W510 ⑥ W510 ⑥	250 ⑲ ⑳ ㉔	24 ⑳ ㉔	T6510 ⑥ T73510 ⑥ ㉗
			W511 ⑥ W511 ⑥	250 ⑲ ⑳ ㉔	24 ⑳ ㉔	T6511 ⑥ T73511 ⑥ ㉗
	Drawn Tube	870	W W	250 ⑳ ㉔	24 ⑳ ㉔	T6 T73 ㉗
			W	250	24	T62
	Die Forgings	880 ⑨	W W	250 ⑳	24 ⑳	T6 T73 ㉗
			W52 ⑩	⑳	⑳	T7352 ⑩ ㉗

For all numbered footnotes, see page 3-16.

TABLE 3.4 Typical Heat Treatments for Aluminum Alloy Mill Products [1] (concluded)

ALLOY	PRODUCT	SOLUTION HEAT TREATMENT [2]		PRECIPITATION HEAT TREATMENT		
		METAL TEMPERATURE [3] °F	TEMPER DESIGNATION	METAL TEMPERATURE [3] °F	APPROX. TIME AT TEMPERATURE [4] Hours	TEMPER DESIGNATION
7075 [7]	Hand Forgings	880 [9]	W W	250 [20]	24 [20]	T6 T73 [27]
			W52 [10] W52 [10]	250 [20]	24 [20]	T652 [10] T7352 [10] [27]
	Rolled Rings	880	W	250	24	T6
7178 [7]	Sheet	875	W W	250 [20]	24 [25]	T6 T76 [27]
			W	250	24	T62
	Plate	875	W51 [6] W51 [6]	250 [25]	24 [25]	T651 [6] T7651 [6] [27]
			W	250	24	T62
	Rolled or Cold Finished Wire and Rod	870	W	250	24	T6
	Extruded Rod, Bar and Profiles	870	W W	250 [26]	24 [26]	T6 T76 [27]
			W	250	24	T62
			W510 [6] W510 [6]	250 [26]	24 [26]	T6510 [6] T76510 [6] [27]
			W511 [6] W511 [6]	250 [26]	24 [26]	T6511 [6] T76511 [6] [27]
7475	Sheet	900 [43]	W W	[45] [46]	[45] [46]	T61 T761
	Plate	900 [43]	W51 [6] W51 [6] W51 [6]	240 [41] [42]	24 [41] [42]	T651 T7351 T7651
	Rod	900	W	[47]	[47]	T62

[1] The times and temperatures shown are typical for various forms, sizes and methods of manufacture and may not exactly describe the optimum treatment for a specific item.

[2] Material should be quenched from the solution heat-treating temperature as rapidly as possible and with minimum delay after removal from the furnace. Unless otherwise indicated, when material is quenched by total immersion in water, the water should be at room temperature and suitably cooled to remain below 100°F during the quenching cycle. The use of high-velocity high-volume jets of cold water is also effective for some materials. For additional details on aluminum alloy heat treatment and for recommendations on such specifics as furnace solution heat treat soak time see specifications AMS 2770 or ASTM B597.

[3] The nominal metal temperatures should be attained as rapidly as possible and maintained ±10°F of nominal during the time at temperature.

[4] The time at temperature will depend on time required for load to reach temperature. The times shown are based on rapid heating, with soaking time measured from the time the load reached within 10°F of the applicable temperature.

[5] Cold work subsequent to solution heat treatment and, where applicable, prior to any precipitation heat treatment is required to attain the specified mechanical properties for these tempers.

[6] Stress-relieved by stretching. Required to produce a specified amount of permanent set subsequent to solution heat treatment and, where applicable, prior to any precipitation heat treatment.

[7] These heat treatments also apply to alclad sheet and plate in these alloys.

[8] An alternative treatment comprised of 8 hours at 350°F also may be used.

[9] Quench after solution treatment in water at 140°F to 180°F.

[10] Stress-relieved by 1–5 percent cold reduction subsequent to solution heat treatment and prior to precipitation heat treatment.

[11] Quench after solution heat treatment in water at 212°F.

[12] Quench after solution heat treatment in air blast at room temperature.

[13] An alternative treatment comprised of 8 hours at 340°F also may be used.

[14] Cold working subsequent to precipitation heat treatment is necessary to secure the specified properties for this temper.

[15] By suitable control of extrusion temperature, product may be quenched directly from extrusion press to provide specified properties for this temper. Some products may be adequately quenched in air blast at room temperature.

[16] An alternate treatment comprised of 1–2 hours at 400°F also may be used.

[17] An alternate treatment comprised of 6 hours at 360°F also may be used.

[18] An alternate two-stage treatment comprised of 4 hours at 205°F followed by 8 hours at 315°F also may be used.

[19] An alternate three-stage treatment comprised of 5 hours at 210°F followed by 4 hours at 250°F followed by 4 hours at 300°F also may be used.

[20] Two-stage treatment comprised of 6 to 8 hours at 225°F followed by a second-stage of:

(a) 24–30 hours at 325°F for sheet and plate
(b) 8–10 hours at 350°F for rolled or cold-finished rod and bar.
(c) 6–8 hours at 350°F for extrusions and tube.
(d) 8–10 hours at 350°F for forgings in T73 temper and 6–8 hours at 350°F for forgings in T7352 temper.

[21] Applies to tread plate only.

[22] Held at room temperature for 72 hours followed by two stage precipitation heat-treatment of 8 hours at 225°F plus 16 hours at 300°F.

[23] With optimum ingot homogenization, heat treating temperatures as high as 928°F are sometimes acceptable.

[24] An alternate two-stage treatment for sheet, plate, tube and extrusions comprised of 6 to 8 hours at 225°F followed by a second stage of 14–18 hours at 335°F may be used providing a heating-up rate of 25°F per hour is used. For rolled or cold-finished rod and bar the alternate treatment is 10 hours at 350°F.

[25] A two-stage treatment comprised of 3–5 hours at 250°F followed by 15–18 hours at 325°F.

[26] A two-stage treatment comprised of 3–5 hours at 250°F followed by 18–21 hours at 320°F.

[27] The aging of aluminum alloys 7075 and 7178 from any temper to the T73 (applicable to alloy 7075 only) or T76 temper series requires closer than normal controls on aging practice variables such as time, temperature, heating-up rates, etc., for any given item. In addition to the above, when reaging material in the T6 temper series to the T73 or T76 temper series, the specific condition of the T6 temper material (such as its property level and other effect of processing variables) is extremely important and will affect the capability of the re-aged material to conform to the requirements specified for the applicable T73 or T76 temper series.

[28] The aging practice will vary with the product, size, nature of equipment, loading procedures and furnace control capabilities. The optimum practice

for a specific item can be ascertained only by actual trial treatment of the item under specific conditions. Typical procedures involve a two-stage treatment comprised of 3–30 hours at 250°F followed by 15–18 hours at 325°F for extrusions. An alternate two-stage treatment of 8 hours at 210°F followed by 24–28 hours at 325°F may be used.

㉙ Core alloy in No. 21, 22, 23 and 24 brazing sheet.

㉚ Quenched directly from the extrusion press. Some extrusions may be adequately quenched using a room temperature air blast.

㉛ A two-stage treatment comprised of 3–6 hours at 250°F followed by 24–30 hours at 330°F.

㉜ A two-stage treatment comprised of 3–6 hours at 255°F followed by 12–15 hours at 330°F.

㉝ A two-stage treatment comprised 4 hours at 250°F followed by 18–22 hours at 320°F.

㉞ A multi-stage treatment comprised of 8 hours at 225°F followed by 8 hours at 250°F followed by 4–10 hours at 350°F.

㉟ Held at room temperature for a minimum of 48 hours followed by a two-stage treatment comprised of 24 hours at 250°F followed by 10–16 hours at 330°F.

㊱ A two-stage treatment comprised of 24 hours at 250°F followed by 10–14 hours at 345°F.

㊲ A two-stage treatment comprised of 24 hours at 250°F followed by 8–10 hours at 345°F.

㊳ A two-stage treatment comprised of 4 hours at 250°F followed by 6–8 hours at 355°F.

㊴ By definition, this temper designation is that which would apply after natural aging even though mechanical properties for this alloy-temper product have not been registered.

㊵ For plate thickness over 4 inches and for rod diameters or bar thicknesses over four inches, a maximum temperature of 910°F is recommended to avoid eutectic melting.

㊶ A two-stage treatment comprised of 4–8 hours at 210°F followed by 24–30 hours at 320°F.

㊷ A two-stage treatment comprised of 4–8 hours at 250°F followed by 26–32 hours at 310°F.

㊸ Without adequate thermal pretreatment, melting may occur at this temperature.

㊺ A two-stage treatment comprises of 250°F for 3 hours plus 320°F for 3 hours.

㊻ A two-stage treatment comprises of 250°F for 3 hours plus 325°F for 10 hours.

㊼ A two-stage treatment comprises of 250°F for 3 hours plus 325°F for 3 hours.

TABLE 3.5 Typical Annealing Treatments for Aluminum Alloy Mill Products

The treatments listed in this table are typical for various sizes and methods of manufacture and may not exactly describe the optimum treatment for a specific item.

ALLOY	METAL TEMPERATURE °F	APPROX. TIME AT TEMPERATURE Hours	TEMPER DESIGNATION
1060	650	①	O
1100	650	①	O
1145	650	①	O
1235	650	①	O
1345	650	①	O
1350	650	①	O
2014	775 ②	2–3	O
2017	775 ②	2–3	O
2024	775 ②	2–3	O
2117	775 ②	2–3	O
2219	775 ②	2–3	O
3003	775	①	O
3004	650	①	O
3005	775	①	O
3105	650	①	O
5005	650	①	O
5050	650	①	O
5052	650	①	O
5056	650	①	O
5083	650	①	O
5086	650	①	O
5154	650	①	O
5254	650	①	O
5454	650	①	O
5456	650	①	O
5457	650	①	O
5652	650	①	O
6005	775 ②	2–3	O ④
6005A	775 ②	2-3	O ④
6053	775 ②	2–3	O
6061	775 ②	2–3	O
6063	775 ②	2–3	O
6066	775 ②	2–3	O
6082	775 ②	2-3	O ④
7072	650	①	O
7075	775 ③	2–3	O
7175	775 ③	2–3	O ④
7178	775 ③	2–3	O
7475	775 ③	2–3	O
Brazing Sheet:			
Nos. 11 & 12	650	①	O
Nos. 23 & 24	650	①	O

① Time in the furnace need not be longer than necessary to bring all parts of load to annealing temperature. Rate of cooling is unimportant.

② These treatments are intended to remove effects of solution heat treatment and include cooling at a rate of about 50°F per hour from the annealing temperature to 500°F. The rate of subsequent cooling is unimportant. Treatment at 650°F, followed by uncontrolled cooling, may be used to remove the effects of cold work, or to partially remove the effects of heat treatment.

③ This treatment is intended to remove the effects of solution heat treatment and includes cooling at an uncontrolled rate to 400°F or less, followed by reheating to 450°F for 4 hours. Treatment at 650°F, followed by uncontrolled cooling, may be used to remove the effects of cold work, or to partially remove the effects of heat treatment.

④ By definition, this temper designation is that which would apply after annealing even though mechanical properties for this alloy-temper product have not been registered.

4. Quality Control

Sampling and Testing

Introduction

The sampling and testing procedures represented in this section are in general use by the aluminum industry for quality control purposes. However, other procedures, whether more rigorous or less vigorous, may also be appropriate for the control of quality. The following sampling and testing procedures are considered suitable for the preparation of specifications.

Reference Documents

chemical analysis

ASTM E34 Chemical Analysis of Aluminum and Aluminum Alloys.

ASTM E55 Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition.

ASTM E607 Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique, Nitrogen Atmosphere.

ASTM E716 Sampling of Aluminum and Its Alloys for Spectrochemical Analysis.

ASTM E1251 Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by Argon Atmosphere, Point-to-Plane, Unipolar Self-Initiating Capacitor Discharge.

tension testing

Products other than foil:

ASTM B557 Tension Testing Wrought and Cast Aluminum and Magnesium Alloy Products.

For foil:

ASTM E345 Tension Testing of Metallic Foil (as modified by procedures shown on page 4-4 and 4-5).

fracture toughness

ASTM E399 Plane-Strain Fracture Toughness of Metallic Materials

ASTM E561 R-Curve Determination

ASTM B645 Plain Strain Fracture Toughness Testing of Aluminum Alloys.

ASTM B646 Fracture Toughness Testing of Aluminum Alloys

bending radius

ASTM E290 Standard Test Method for Semi-Guided Bend Test for Ductility of Metallic Materials.

hardness testing

ASTM E l0 Test for Brinell Hardness of Metallic Materials.

electrical conductivity or resistivity testing

ASTM Bl93 Test for Resistivity of Electrical Conductor Materials.

ASTM E1004 Method for Electromagnetic (Eddy Current) Measurements of Electrical Conductivity.

NOTE: B193 is used in case of dispute.

stress corrosion resistance testing

ASTM G47 Practice for Determining Susceptibility to Stress Corrosion Cracking of High-Strength Aluminum Alloy Products.

exfoliation corrosion resistance testing

ASTM G34 Standard Test Method for Exfoliation Corrosion Susceptibility in 2XXX and 7XXX Series Aluminum Alloys (EXCO Test).

ASTM G66 Test for Visual Assessment of Exfoliation Corrosion Susceptibility of 5XXX Series Alloys (ASSET Test).

intergranular corrosion resistance testing

ASTM G110 Standard Practice for Evaluating Intergranular Corrosion Resistance of Heat Treatable Aluminum Alloys by Immersion in Sodium Chloride and Hydrogen Peroxide Solution.

shear testing

ASTM B565 Shear Testing of Aluminum and Aluminum Alloy Rivets and Cold Heading Wire and Rods.

ASTM B831 Shear Test Method for Shear Testing of Thin Aluminum Alloy Products.

ultrasonic testing

ASTM B594 Standard Method for Ultrasonic Inspection of Aluminum-Alloy-Wrought Products for Aerospace Applications.

ASTM E317 Recommended Practice for Evaluating Performance Characteristics of Pulse-Echo Ultrasonic Testing Systems.

ASTM E127 Recommended Practice for Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks.

SNT-TC-1A ASNT Recommended Practice for “Personnel Qualification and Certification in Nondestructive Testing.”

handling and storing

AA 92 Care of Aluminum

AA TR3 Guidelines for Minimizing Water Staining of Aluminum.

AA TR7 Guidelines for In-Plant Handling of Aluminum Sheet and Plate.

Sampling for Chemical Analysis

Common practice for semi-continuously cast products is to take one or more control samples before and one or more during the casting of each cast unit (units, if cast simultaneously) and to analyze the samples spectrochemically.

Continuously cast products may contain metal from two or more molten metal sources each of which has been sampled and analyzed for conformance to composition limits. During casting, at least one sample is taken to represent each cut length of ingot (group of cut lengths, if cast simultaneously), for each 50,000 pound increment or one sample per hour of casting. If the cast product is either slab/coil or rod/bar, the molten metal batch composition represents the product.

Cast units that conform to established chemical composition limits are so identified and either then undergo fabrication or are placed in stock for subsequent fabrication into wrought products.

For finished product not analyzed as stated above, one sample is taken for each 4,000 pounds, or fraction thereof, of each alloy in an inspection lot to determine conformance to established chemical composition limits. Forgings are sampled as follows: One sample per 2,000 lb. or fraction thereof for forgings having a nominal weight of 5 lb. or less, or one sample per 6,000 lb. or fraction thereof for forgings having a nominal weight greater than 5 lb.

Sampling for Mechanical Tests

Samples shall be in the temper supplied to the customer. The number of samples commonly taken varies with product type and inspection lot size.

Coiled Sheet. One (1) sample from each end of each parent coil but no more than one sample per 2,000 pounds or part thereof in a lot.

Flat Sheet. One (1) sample from each end of each parent coil. Where parent coil end identity is not available, one sample for each 2,000 pounds or part thereof in a lot.

Non-recoiled Hot Mill Coil. One (1) sample from the outside end of each coil.

Plate. One (1) sample from each end of each parent plate but no more than one sample per 4,000 pounds, or part thereof, in a lot.

Wire, Rod, Bar, Profiles, Tube, Pipe. Nominal weight less than one (1) pound per linear foot: one (1) sample for each 1,000 pounds, or fraction thereof, in a lot. Nominal weight of one (1) pound or greater per linear foot: one (1) sample for each 1,000 feet, or part thereof, in a lot.

Die Forgings. Nominal weight up to and including five (5) pounds: one (1) sample for each 2,000 pounds, or part thereof, in a lot. Nominal weight greater than five (5) pounds: one (1) sample for each 6,000 pounds, or part thereof, in a lot.

Hand Forgings. One (1) sample for each 6,000 pounds, or part thereof, in a lot.

Tension Test Specimens

Tension test specimens may be machined or they may be substantially the full cross section of the material being tested.

full-section specimens. Tension test specimens of substantially the full cross section of the material may be used for wire, rod, bar and profiles. It is permissible to reduce the section slightly throughout the test section to ensure fracture within the gauge marks. The gauge length should be four times the diameter for round specimens other than electric conductor wire, and 2 in. for other sections. For electric conductor wire the gauge length is 10 in.

Full-section tension test specimens having a 2-in. gauge length may be used for round tubular products. Snug-fitting metal plugs are inserted into the ends of the specimen to permit the testing machine jaws to grip the specimen properly.

machined specimens. Standard machined specimens for tension testing of wrought aluminum mill products are of two types: round and rectangular, with a gauge length of 2 in. and a width or diameter of ½ in. They are shown in ASTM B 557.

Smaller round specimens proportional to the standard ½ in. diameter round specimen are used when a standard specimen cannot be prepared. Examples are shown in ASTM B 557. Other sizes of small round specimens may be used if the gauge length for measurement of elongation is four times the diameter of the reduced section of the specimen. Tension test specimens are normally taken as follows:

Sheet and Plate. For non-heat-treatable alloy sheet and plate, tension test specimens are taken in the longitudinal direction. For heat-treatable alloy sheet, tension test specimens are taken in the long transverse direction for widths 9 in. and greater, and in the longitudinal direction for widths less than 9 in. For heat-treatable alloy plate, tension test specimens are taken in the long transverse direction, and, when specified, in the longitudinal and short transverse directions. Long transverse and longitudinal tension test specimens are taken midway between the two plate surfaces for plate 0.500 in. through 1.500 in. in thickness, and midway between the center and surface of plate over 1.500 in. in thickness. Short transverse tension test specimens are taken so that the mid-point of their axes lies on the plate's mid-thickness. Short transverse testing is only applicable to plate 1.500 in. and greater in thickness. The standard rectangular tension test specimen is used for sheet and for plate less than 0.500 in. in thickness. For plate 0.500 in. and greater in thickness, the standard ½ in. round tension test specimen or a smaller round specimen proportional to it is used. Material less than ¾ in. in width is tested in full section when the standard ½ in. round tension test specimen or a smaller round specimen proportional to it cannot be used, in which case elongation is not determined.

Wire, Rod and Bar. Tension test specimens are taken in the longitudinal direction. If the size or shape makes it impractical to use full-section tension test specimens, the standard ½ in. round specimen or a smaller round specimen proportional to it is used, except that for rectangular bar less than ½ in. in thickness the standard rectangular tension test specimen may be used. For material 1½ in. and less in diameter or thickness, when not tested in full section, the tension test specimen is taken from the center of the section. For material greater than 1½ in. in diameter or thickness, the specimen is taken midway between the center and surface of the section. For rectangles greater than 1½ in. in thickness, the specimen is also located midway between the center and edge. Elongation is not determined for wire, other than electric conductor wire, less than 0.125 in. in diameter or thickness.

Profiles. Tension test specimens are taken in the longitudinal direction only, unless additional test ori-entations are agreed between supplier and purchaser. If the size or profile makes it impractical to use full-section tension test specimens, the standard ½ in. round specimen or a smaller round specimen proportional to it is used, except that for profiles less than ½ in. in thickness having parallel surfaces the standard rectangular tension test specimen may be used. For profiles from which these machined specimens cannot be obtained, and which cannot be tested in full section, a rectangular or round specimen of the largest possible dimensions is used, and elongation is not determined. For profiles 1½ in. and less in thickness, when not tested in full section, the tension test specimen is taken- from the center of the predominant or thickest part of the profile. For profiles greater than 1½ in. in thickness, the specimen is taken midway between the center and surface and midway between the center and edge of the predominant or thickest part of the profile. When the predominant or thickest part of the profile cannot be determined by visual inspection, use the procedure described in the appendix beginning on page 4-14. Elongation is not determined for profiles less than 0.062 in. in thickness.

Tubular Products. Tension test specimens are taken in the longitudinal direction. If the size or shape makes it impractical to use full-section tension test specimens, the standard rectangular specimen is used for tubular products having a flat wall and a similar curved specimen for products having a curved wall, or the standard ½ in. round specimen or a smaller round specimen proportional to it is used.

Die Forgings. Tension test specimens are taken from the center of the predominant or thickest part of die forgings from which a coupon can be obtained, from a prolongation of the forging, or from coupons separately forged from the same stock used to produce the forgings. The following test orientation definitions have been adopted by MMPDS (MIL-5) Coordination Committee for test data submitted after 1996 October:

Longitudinal	Specimen orientation is parallel, within ±15°, to the predominant grain flow.
Long Transverse	Specimen orientation is perpendicular, within ±15°, to the longitudinal (predominant) grain direction <u>and</u> parallel, within ±15°, to the parting plane. (Both conditions must be met.)
Short Transverse	Specimen orientation is perpendicular, within ±15°, to the longitudinal (predominant) grain direction <u>and</u> perpendicular, within ±15°, to the parting plane. (Both conditions must be met.) When possible, short transverse specimens shall be taken across the parting plane.
Off Axis	Any specimen orientation or test direction that does not fit any of the above three definitions. These orientations will not be used in material specifications.

Note: In cases where the grain flow is difficult to define, microstructural analysis must be performed to define the grain flow. This can be done on the first cut-up forging.

Testing is applicable to a direction only if the corresponding dimension is over 2.000 in. in thickness. For forgings 0.500 in. and greater in thickness, the standard ½ in. round specimen or a smaller round specimen proportional to it is used. For forgings 0.312 through 0.499 in. in thickness, either a round specimen proportional to the standard ½ in. round specimen or a rectangular specimen is used. For forgings less than 0.312 in. in thickness, a rectangular specimen is used.

Hand Forgings. Tension test specimens are taken in the long transverse and short transverse directions, and, when specified, in the longitudinal direction. The longitudinal specimen is taken so that its axis coincides with the longitudinal centerline of the forging. The transverse specimens are taken so that the mid-point of their axes lies on the longitudinal centerline of the forging. Each specimen is so chosen that the distance from the mid-point of its axis to the end of the forging is at least half the thickness of the forging. Testing is applicable to a direction only if the corresponding dimension is over 2.000 in. in thickness. The standard ½ in. round specimen or a smaller round specimen proportional to it is used.

shear test specimens. Shear test specimens of the full cross section of the wire are used for wire up through 0.372 in. in diameter. Wire over 0.372 in. in diameter and rod are machined down to 0.372 in. in diameter for testing. Wire in diameters other than those for which a standard shear jig size is available are machined down to the next smaller jig size.

measurement of specimens. Before testing, the tension test specimens are measured.

Cross-Sectional Dimensions. The dimensions used for determining the cross-sectional area of tension test specimens are measured at the center of the gauge length and recorded as follows:

Nominal Dimensions	*Measured to at least the nearest:*
less than 0.100	0.0001
0.100 to 0.200	0.0005
0.200 and over	0.001

Gauge Length. When longitudinal or transverse elongation is to be determined, a gauge mark is placed at each end of the gauge length and the distance between them is measured and recorded to the nearest 0.01 in. For short transverse specimens the distance is measured to the nearest 0.002 in.

Tensile Properties

The mechanical properties normally obtained from tension test specimens, and the methods used, are as follows:

yield strength (0.2 percent offset), determined by the "offset method."

Offset method. Yield strength by the "offset method" is computed from a load-strain curve obtained by means of an extensometer. A straight line is drawn parallel to the initial straight line portion of the load-strain curve and at a distance to the right corresponding to 0.2 percent offset (0.002 in. per in. of gauge length). The load reached at the point where this straight line intersects the curve divided by the original cross-sectional area (sq. in.) of the tension test specimen is the yield strength.

ultimate or tensile strength. Ultimate strength is determined by dividing the maximum load carried by the specimen during a tension test by the original cross- sectional area of the specimen.

elongation. After completion of the tension test, the ends of the fractured specimen are fitted together carefully and the distance between the gauge marks is measured to the nearest 0.01 in. A percentage scale reading to 0.5 percent of the gauge length may be used. The elongation is the increase in gauge length, expressed as a percentage of the original gauge length. If the percentage elongation of a tension test specimen is less than that specified, and if any part of the fracture is outside of the middle half of the gauge length or in a punched or scribed mark within the reduced section, the test may be discarded.

For specimens taken in the short transverse direction the following procedure applies:

a. Any partly torn fragments that might influence the final measurement are removed.
b. The broken ends are matched together to obtain an integral fit and an end load of about 2 ksi is applied. The load may then be removed, provided the specimen remains intact.
c. The final gauge length is measured to the nearest 0.002 in.

Tension Testing of Foil

Tension testing of foil must be carefully controlled because test results can be materially affected by rough specimen edges, the presence of even slight scratches or fold marks on the surface, speed of testing, improper alignment in the testing machine, and other variables inherent in the testing of thin material. Testing of foil thinner than about 0.0007 inch usually is subject to special agreement between vendor and purchaser.

tension test specimens. Tension test specimens for foil may be machined (Type A) or they may be sheared (Type B). Either type specimen should be examined under 20 · magnification to determine that the edges are smooth and that there are no surface irregularities.

Machined Specimens—Type A. These specimens are in dimensional conformance with the ½ in. sheet type specimen in ASTM E 345, Tension Testing of Metallic Foil. They are machined in packs by use of a milling type cutter which should be kept very sharp. For satisfactory results it is helpful to interleave some thicknesses and tempers with Mylar or other suitable material when machining them.

Sheared Specimens—Type B. These specimens are prepared individually to the following dimensions and tolerances:

Width	0.500 or 1.000 ± 0.001 in.
Length	10.00 in. ± 0.002 in①
Thickness	Same as material thickness

They are sheared by use of a double bladed cutter such as the Thwing-Albert JDC Precision Cutter or equal. The cutter may be designed so that the specimen will have a gradual decrease in its width from the ends to the center, but the width at the center will not be more than 0.001 in. less than at the ends.

specimen thickness. Thickness of specimens taken from soft foils or from foils 0.002 in. and thinner is determined to an accuracy of 2% of the thickness by weighing in accordance with ASTM Test Method E 252 or by measuring devices. When using method E 252, the specimens themselves are weighed when it is practical. At least two specimens are weighed together. When Type B specimens are not used for weighing, a sample in accordance with Method E 252 may be used when taken from an area adjacent to that from which the test specimens were taken.

When specimens or samples are weighed, the thickness is computed to the nearest 0.0001 in. and preferably to the nearest 0.00001 in. by use of the formula:

$$T = \frac{W}{AD}$$

Where: T = Specimen thickness, in.
W = Specimen or sample weight, g
A = Specimen area, sq. in.
D = Alloy density, g/cu. in.

The following densities calculated in accordance with the

① Tolerance is applicable only when specimen is weighed for thickness determination procedure on page 2-12 may be used for D:

Alloy	Density, g/in.[3]
99.80 purity and over	44.25
1145	44.33
1235	44.33
1100	44.41
3003	44.74
5050	44.08
5052	43.92
5056	43.26

Thickness of specimens taken from hard materials or materials greater than 0.002 in. in thickness may be determined by use of an optimeter, an electrical-type measuring device, vernier micrometer or mechanical comparator, provided that the thickness is measured to at least the nearest 2%.

specimen width. Measure and record the specimen width dimension to the nearest 0.001 in.

testing machines. The tensile test machines may be of the pendulum or the positive head speed type and conform to the requirements of ASTM Methods E 4, Standard Methods of Verification of Testing Machines. The loads used in determining tensile strength or yield strength are within the loading range of the machine as defined in Method E 4.

test procedure. The test procedure is in accordance with ASTM Method E 345, Tension Testing of Metallic Foil, with provisions as follows:

When only the ultimate tensile strength is determined the rate of strain is between 0.06 and 0.5 in/in. of gauge length/minute.

When the yield strength is also determined the rate of strain is 0.002 to 0.010 in./in. of gauge length/minute until above the yield strength.

When Type B specimens are used the minimum distance between grips is 5 in.

When elongation is determined for Type B specimens the difference in distance between the grips before testing and after fracture is used, or if it is tested using a positive head speed type machine the elongation may be taken from the load-deformation graph and computed by the formula:

$$\text{Elongation, \%} = \frac{\text{Head speed x inches of chart}}{\text{Chart speed x gauge length}} \times 100$$

Two tests are made from each sample taken and the average of the two tests is reported.

If results for tensile strength are reported in pounds per inch of width, they are reported to three significant figures.

If there is reason to believe that test results are not accurate because of conditions such as rough edges, surface scratches or creases on the original specimen, incorrect testing procedure or a significant difference in the two results, one or more tests are made as appear necessary. When three or more tests are made from a sample, the average of the two closest values is reported.

Visual Inspection of Aluminum Mill Products

Including parts manufactured from such products

The following criteria are generally recognized as applicable for visual inspection for discontinuities in aluminum mill products, and parts manufactured from these products, with or without the aid of liquid penetrant methods.[2] It is generally recognized that the various liquid penetrant methods of inspection of metal products for surface discontinuities are useful aids to visual inspection. However, it should be recognized also that these inspection methods frequently develop extraneous indications that are not indicative of defective material or parts.

1. Any discontinuity that can be completely removed with reasonable facility, within the applicable dimensional tolerances for the material or part being inspected, is not considered as a reason for rejection of the part or material, unless the removal of the discontinuity makes the surface unsuitable for applications where surface appearance is important and where surface considerations were made known to the seller at the time the order was placed.
2. Verifiable indications of the following discontinuities that cannot be completely removed with reasonable facility, within the applicable dimensional tolerances for the material or part being inspected, are considered reasons for rejection, regardless of the use to which the material or part is being put:
   (a) Cracks
   (b) Laps
   (c) Seam defects
   (d) Flow through (forgings)
3. Verifiable indications of the following discontinuities that cannot be completely removed with reasonable facility, within the applicable dimensional tolerances for the material or parts being inspected, may be considered as reasons for rejection of the material or part subject to mutual agreement between the purchaser and vendor with due consideration being given to the alloy and application of the part or material.
   (a) Blisters
   (b) Slivers
   (c) Cold shuts
   (d) Inclusions
   (e) Scratches
   (f) Gouges

② Liquid penetrant methods of inspection should not be used in lieu of pressure tests when material or parts are used in applications requiring pressure and/or leak tightness unless such substitution is negotiated between purchaser and vendor. If penetrant inspection is used in lieu of pressure testing, the acceptance or rejection of material or parts shall be judged on the basis of the ability of representative material to withstand an application pressure or leak test.

(g) Nicks
(h) Corrosion
(i) Voids resulting from selective etch attack
(j) Metal pickup
(k) Fins
(l) Pin holes
(m) Die lines
(n) Abrasions
(o) Streaks
(p) Non-uniform surface appearance (see "Water Stain," "Oil Stain," "Heat Treat Stain," and "Oxide Discoloration").
(q) Kinks

Ultrasonic Testing

1. Scope

Equipment, test procedures, descriptions of discontinuity classes and other general requirements are contained in the following paragraphs. For standard discontinuity limits applicable to specific alloy-product combinations, see Table 6.3.

This standard is not applicable if, subsequent to ultrasonic inspection, the material is plastically deformed or exposed to a temperature in excess of that used to attain the temper existing at inspection.

2. Ultrasonic Discontinuity Class Descriptions

Material furnished in any temper shall conform to the requirements of Table 6.3 when inspected in accordance with Section 4. The discontinuity class limits are described as follows:

Class AA Areas:

a. Indications from a single discontinuity do not exceed the response for a 3⁄64 inch diameter flat bottomed hole at the estimated discontinuity depth.
b. Multiple indications in excess of the response from 2/64 inch diameter flat bottomed hole at the estimated discontinuity depth do not have their indicated centers closer than 1 inch.
c. Indications from a single discontinuity equal to or greater than the response from 2⁄64 inch diameter flat bottomed hole at the estimated discontinuity depth are not more than ½ inch in length.
d. Multiple discontinuities are not of such size or frequency as to reduce the back reflection pattern to 50% or less of the back reflection pattern of normal material of the same geometry when associated with the doubling of the normal noise level with the ultrasonic beam perpendicular to the front and back surfaces to ensure that the loss of back reflection is not caused by surface roughness or part geometry variation.

Class A Areas:

a. Indications from a single discontinuity do not exceed the response for a 5⁄64 in. diameter flat-bottomed hole at the estimated discontinuity depth.
b. Multiple indications in excess of the response from a 3⁄64 in. diameter flat-bottomed hole at the estimated discontinuity depth do not have their indicated centers closer than 1 in.
c. Indications from a single discontinuity equal to or greater than the response from a 3⁄64 in. diameter flat-bottomed hole at the estimated discontinuity depth are not more than 1 in. in length.
d. Multiple discontinuities are not of such size or frequency as to reduce the back reflection pattern to 50 percent or less of the back reflection pattern of normal material of the same geometry when associated with a doubling of the normal noise level with the ultrasonic beam perpendicular to the front and back surfaces to ensure that the loss of back reflection is not caused by surface roughness or part geometry variation.

Class B Areas:

a. Indications from a single discontinuity do not exceed the response from an 8⁄64 in. diameter flat-bottomed hole at the estimated discontinuity depth.
b. Multiple indications in excess of the response from a 5⁄64 in. diameter flat-bottomed hole at the estimated discontinuity depth do not have their indicated centers closer than 1 in.
c. Indications from a single discontinuity equal to or greater than the response from a 5⁄64 in. diameter flat-bottomed hole at the estimated discontinuity depth are not more than 1 in. in length.
d. Multiple discontinuities are not of such size or frequency as to reduce the back reflection pattern to 50 percent or less of the back reflection pattern of normal material of the same geometry when associated with a doubling of the normal noise level with the ultrasonic beam perpendicular to the front and back surfaces to ensure that the loss of back reflection is not caused by surface roughness or part geometry variation.

Class C Areas:

(May apply to noncritical areas and to some areas not covered by Table 6.3)
Indications from a single discontinuity do not exceed the response from an 8⁄64 in. diameter flat-bottomed hole at the estimated discontinuity depth.

3. Equipment

The ultrasonic testing equipment includes a test system comprising a basic ultrasonic test instrument, a search unit, an interconnecting apparatus, a suitable tank containing liquid couplant, a bridge/head and manipulator, and appropriate standard reference blocks. The test system is capable of meeting or exceeding the following requirements as determined by the procedures outlined in ASTM E 317 Recommended Practice for Evaluating Performance Characteristics of Pulse-Echo Ultrasonic Testing Systems. The requirements shown in this table are applicable as indicated only for the selected frequencies used for the inspection. The test system is required to meet the limits only for the test frequencies actually used.

Standard reference blocks used to establish test sensitivity and to evaluate discontinuities are flat entry-surface blocks that are manufactured and checked in accordance with procedures outlined in ASTM E 127 Recommended Practice for Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks.

Test Frequency	*2.25 MHz*	*5.0 MHz*	*10.0 MHz*	*15.0 MHz*
Vertical Limit, Min	2.5" tp ①	2.5" tp	2.5" tp	2.5" tp
Upper Linearity Limit, Min. ②	95%	95%	95%	95%
Lower Linearity Limit, Max. ②	10%	10%	10%	10%
Ultrasonic Sensitivity, Min. ②	50%④	100% ④	80% ④	50% ④
Signal to Noise Ratio, Min.	65④	100 ④	100 ④	100 ④
Entry Surface Resolution Max.	0.7"	0.5"	0.3"	0.2"
Back Surface Resolution Max.	0.3"	0.2"	0.1"	0.1"
Horizontal Limit, Min.	3.5"	3.5"	3.5"	3.5"
Horizontal Linearity, Min. ③	85%	85%	85%	85%

① tp=Trace to Peak
② Percentage of Vertical Limit
③ Percentage of Horizontal Limit
④ ASTM Reference Block 1-0300

4. Inspection Technique

When ultrasonic inspection is specified, conformance with the requirements of Section 2 is determined by the immersion method using pulsed longitudinal waves, unless otherwise negotiated. Initial scanning is performed perpendicularly to the inspection surface, except for die forgings on which initial scanning is performed perpendicularly to the parting plane whenever possible. Angular manipulation is used to obtain maximum response from individual discontinuities. The amount of scanning overlap is determined at the time of inspection to assure that all areas are effectively covered.

The test frequency and sensitivity standardization used for this inspection are selected to ensure the most effective detection and evaluation of discontinuities in the parts being inspected. (See Section 3 for Entry Surface and Back Surface Resolution Limits.) Any differences in the finish between the inspection surface and the standard reference blocks are not to be of such magnitude as to significantly affect the calibrated test sensitivity.

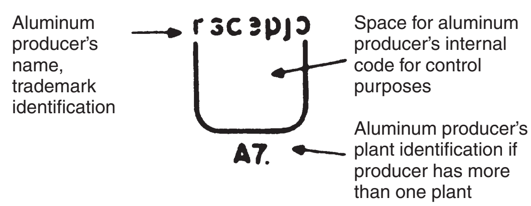
When ultrasonic inspection is specified for section thicknesses and weights outside the limits shown in Table 6.3, the discontinuity limits to be observed are as negotiated at the time of quotation and/or order acceptance and will be shown on zoned engineering drawings of the material to be inspected. The drawings will indicate areas on the material that are non-critical and/or that are to be removed by machining. Cylindrical parts or areas of sections containing fillets may require inspection by special ultrasonic tests such as shear waves, but in such cases the techniques will be as agreed upon by the purchaser and vendor at time of quotation and/or order acceptance.

5. Personnel Qualification

When inspection of material is specified in accordance with the requirements of this standard, personnel performing the inspection will be qualified and certified to Level I or higher as prescribed in the ASNT Recommended Practice SNT-TC-1A, “Personnel Qualification and Certification in Nondestructive Testing.”

6. Marking

When ultrasonic inspection by the vendor is specified, aluminum mill products so inspected and accepted will be stamped as follows:



Identification Marking

When required, wrought aluminum mill products are marked only for identification purposes with the following information on the product or on tags attached to the product.

1. Name or registered trademark of the company that performs the final processing or finishing operation prior to marketing the product.

   Note: The company that performs nothing more than a simple shearing or sawing operation of non-coiled products may be excluded from marking the products with its name.

2. Alloy and temper of the product. Aluminum Association designations are used when applicable.
3. When required, the basic number of the specification to which the product was produced. The basic number does not include the suffix, which indicates a revision, amendment, or date of issue.
4. Specified (ordered) thickness or diameter of the following products:

   Sheet and plate. . . . . Thickness (in)
   Coiled wire and
   spooled wire . . . . Diameter (in)

Tube
  Straight lengths . . . . Outside diameter and wall thickness (in)
  Coiled . . . . Wall thickness (in)
  Pipe . . . . Nominal pipe size and ANSI schedule number

Note: When the specified (ordered) thickness or diameter is subject to special tolerances that differ from those appearing in the specification to which the product was produced, marking with specified (ordered) thickness or diameter is appropriate, providing the range permitted by the special tolerances does not fall outside the applicable specification limits for that specified (ordered) thickness or diameter.

5. When required by the material specification, the appropriate identification is added for seamless pipe or tube.
6. When required by the detailed specification for heat treatable material, spot marking of lot number.

Marking on the product is with ink applied by printing, stamping, or stenciling. The ink will not rub off or be otherwise effaced by contact incidental to normal handling, exposure to the elements, shipment and storage. The height of the characters is commensurate with the size of the product; for example, not less than ⅜ inch for flat sheet and plate.

Straight lengths of products that are of sufficient size to be marked may be spot marked or continuously marked. Coiled products and short lengths can be spot marked or tagged.

Spot Marking. Consists of marking the identification at least once on the product.

Continuous Marking. Consists of recurring marking of the identification in intervals not greater than 40 inches throughout the length of the product per ASTM B666/B666M.

Standard identification marking of wrought aluminum mill products is as follows:

Flat sheet less than 0.012 in. in thickness (for O temper, less than 0.020 in. in thickness). Spot marking near one end.

Plate and Flat sheet 0.012 in. and over (for O temper 0.020 in. and over) in thickness and less than 6 in. wide. Continuous marking in one row.

Plate up through 0.375 in. and flat sheet 0.012 in. and over (for O temper, 0.020 in. and over) in thickness, 6 through 60 in. in width, and 36 through 200 in. in length. Continuous marking in rows running the direction of rolling on 6 in. centers across the width on one surface. Every third row contains the producer's name or trademark and the specified (ordered) thickness. The other two rows each contain the alloy and temper and the specification number, and are staggered.

Plate over 0.375 in. in thickness, flat sheet and plate over 60 in. in width or over 200 in. in length. Same marking as plate and flat sheet shown above or perimeter marking on one surface. When perimeter marking of two rows is chosen, one row contains the producer's name or trademark and the specified (ordered) thickness, and the second row contains the alloy and temper, and the specification number.

Coiled sheet. Spot marking in one or more rows near the outside end.

Sheet and plate circles 24 in. and over in diameter. Spot marking unless cut from sheet or plate having continuous marking.

Sheet and plate circles less than 24 in. in diameter. Tagging or marking of shipping container.

Note: Alclad one side flat sheet, plate, circles and coiled sheet are marked on the bare side.

Rod, bar and extruded profiles. Continuous marking of straight lengths of sizes having an accessible flat surface ½ in. or more in width and being indented less than ⅛ in., or a diameter of ½ in. or more, and tagging of smaller sizes and coils.

Structural profiles. Spot marking near one end.

Bus bar. Spot marking near one end, except that specification number is omitted.

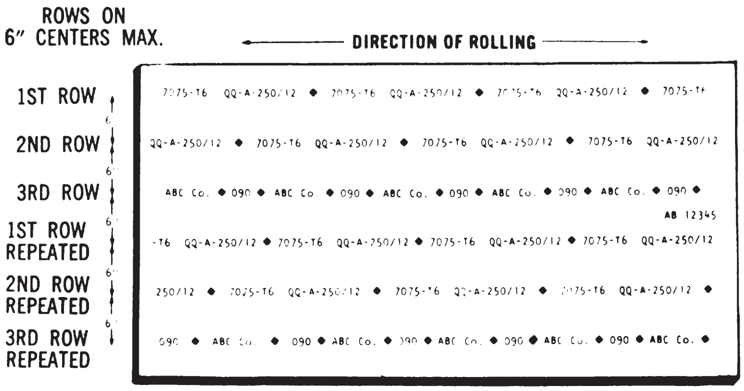
Tube and pipe. Continuous marking of straight lengths in a single row of sizes having wall thickness of 0.029 in. and greater and a flat surface of ½ in. or more in width, or a diameter of ½ in. or more, and tagging of smaller sizes and coils.

Wire. Tagging of coils or straight lengths, and spot markings on one flange of spools.

Forgings.
  Hand forging—Spot marking on one place of each piece.
  Die forging—Marking as required by the forging drawing.

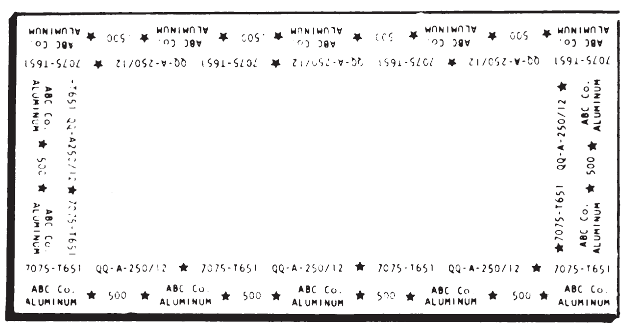
The standard identification marking for wrought aluminum mill products conforms to ASTM B666/B666M, Identification Marking of Aluminum Products, which specifies the marking required by government specification for the products.

FIGURE 4.1 Typical Identification Marking



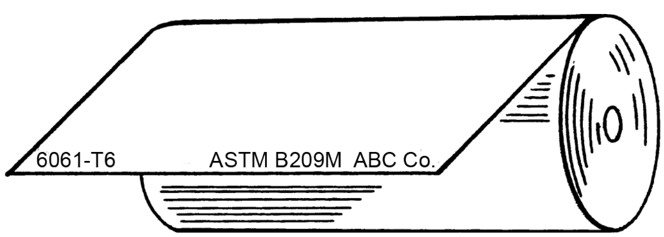
CONTINUOUS MARKINGS

Continuous Marking for Plate Through 0.375 in. and Flat Sheet 0.012 in. and over (for O Temper, 0.020 in. and over) in Thickness, 6 Through 60 in. in Width, and 36 Through 200 in. in Length.

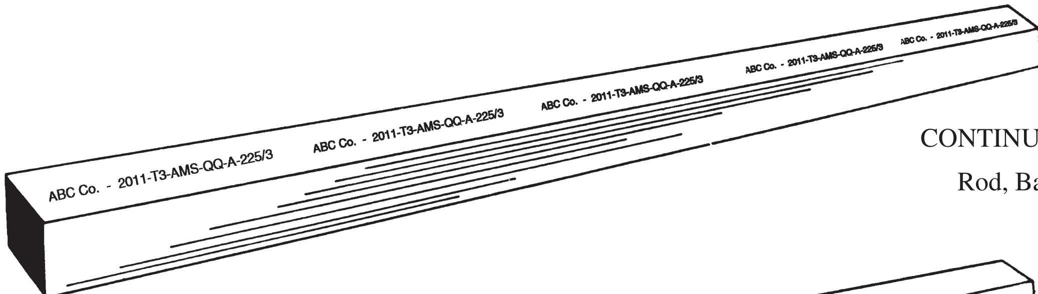


PERIMETER MARKING

Perimeter Marking for Plate over 0.375 in. in Thickness, Flat Sheet and Plate over 60 in. in Width or over 200 in. in Length.

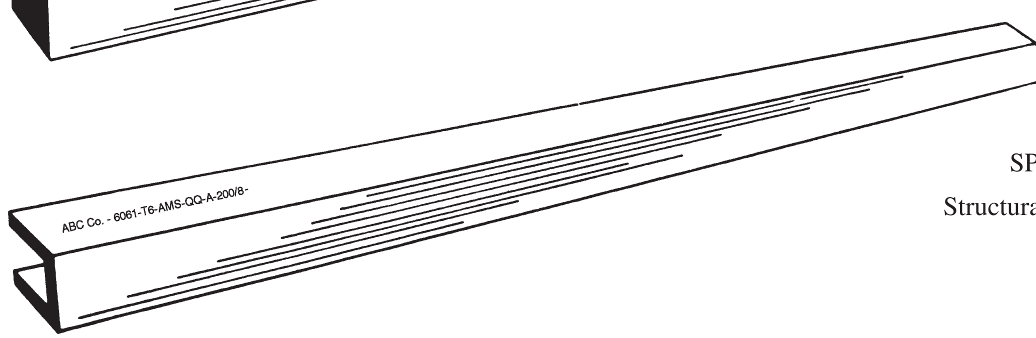


SPOT MARKING, Coiled Sheet



CONTINUOUS MARKING

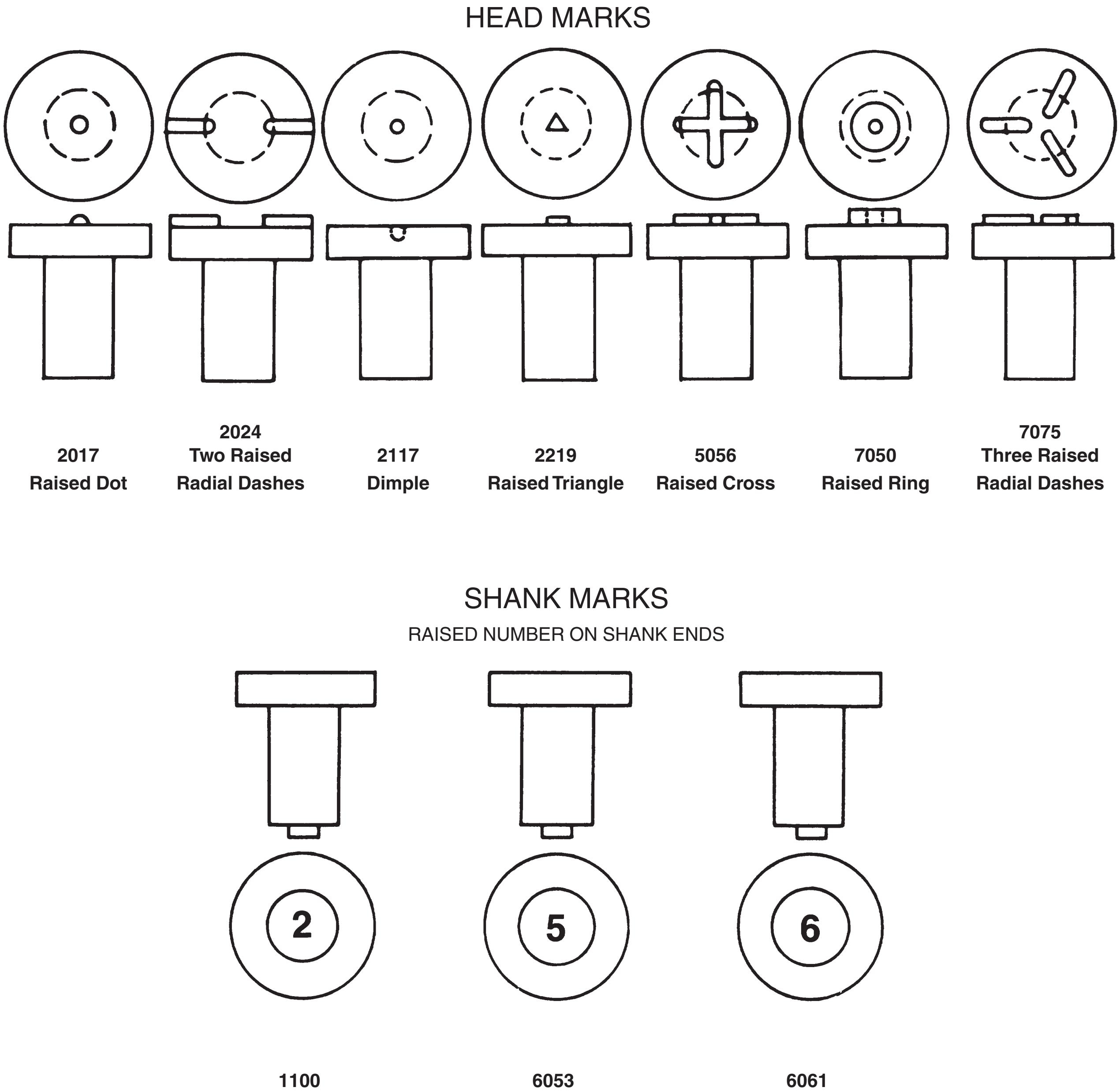
Rod, Bar, Profiles and Tube



SPOT MARKING

Structural Profiles and Bus Bar

FIGURE 4.2 Rivet Identification Markings



Color Code

Wrought aluminum mill products are sometimes identified as to alloy by the use of a color code; for example, tags or paint on the end of rod and bar. Colors have been established for the alloys listed in the following table and graph. *NOTE: These colors do not apply to ink used for identification marking.*

ALLOY	COLOR
1100	White
1350	Unmarked
2011	Brown
2012*	Yellow and White
2014	Gray
2017	Yellow
2018	White and Green
2024	Red
2025	White and Red
2111*	Black and Green
2117	Yellow and Black
2214*	White and Gray
2218	White and Purple
2219	Yellow and Blue
2618	Brown and Black
3003	Green
4032	White and Orange
4043	White and Brown
5052	Purple
5056	Yellow and Brown
5083	Red and Gray
5086	Red and Orange

ALLOY	COLOR
5154	Blue and Green
5183	Orange and Brown
5356	Blue and Brown
5456	Gray and Purple
5554	Red and Brown
5556	Black and Gray
6013*	Red and Blue
6020*	Red and Yellow
6053	Purple and Black
6061	Blue
6063	Yellow and Green
6066	Red and Green
6070	Blue and Gray
6101	Red and Black
6151	White and Blue
6262	Orange
6351	Purple and Orange
7005	Brown and Purple
7049	Blue and Purple
7050	Yellow and Orange
7068*	Green and Gray
7075	Black
7076*	White and Black
7149*	Orange and Black
7150	Yellow and Purple
7175	Green and Brown
7178	Orange and Blue

COLOR	Orange	Gray	Purple	Brown	Green	Blue	Yellow	Red	Black	White
White	4032	2214*	2218	4043	2018	6151	2012*	2025	7076*	1100
Black	7149*	5556	6053	2618	2111*	. .	2117	6101	7075	
Red	5086	5083	. .	5554	6066	6013*	6020*	2024		
Yellow	7050	. .	7150	5056	6063	2219	2017			
Blue	7178	6070	7049	5356	5154	6061				
Green	. .	7068*	. .	7175	3003					
Brown	5183	. .	7005	2011						
Purple	6351	5456	5052							
Gray		2014								
Orange	6262									

*Included for completeness of table; alloy not listed elsewhere in this manual.

Handling and Storing Aluminum

Aluminum is one of the easiest materials to keep in good condition. It has a high natural resistance to corrosive conditions normally encountered during shipment and storage, and a little care will maintain its original appearance for a long time. The principal things to guard against are conditions that might cause surface abrasions or water stains.

Suppliers make every effort to pack aluminum so that "traffic marks" or "rub marks" do not occur during shipment and so that the product remains dry. All incoming shipments should be inspected promptly, however, since both transportation lines and suppliers have a time limit in which damage claims will be honored.

Traffic marks may appear as scratches, surface abrasions or a condition resembling cinders embedded in the metal. They result from mechanical abrasion and subsequent oxidation of the abraded areas. Their principal disadvantage lies in their unsightliness and their effect on finishing operations.

To avoid traffic marks suppliers pack the metal so that it is not subjected to undue flexing or twisting and so that the units within a package do not rub against one another. Products subject to damage by flexing or bending usually are packed on skids or in lumber boxes. Paper or chipboard is used where necessary for cushioning thin or soft metal. Strapping is used to reinforce skids and boxes and to bind wrapped bundles.

Water stains are nonmetallic in appearance and, while usually whitish, may appear iridescent, depending upon the alloy or degree of oxidation. They are caused by the entrapment of moisture between the adjacent surfaces of closely packed material. The purer aluminum alloys are more resistant to water stain, while the condition seems most pronounced on those alloys having high magnesium content. Water stain is a superficial condition, and the mechanical properties of the metal having such stain are not affected.

Condensation is perhaps the most troublesome cause of water stains. It may be prevented by avoiding conditions where the temperature of the metal drops below the dew point of the surrounding air; or, conversely, conditions where the moisture of the air increases enough to carry the dew point above the metal temperature. It is thus important to ensure that a sudden fall in temperature or increase in humidity does not occur in the places of storage.

If possible, cold metal should be placed in a dry storage place until its temperature has increased substantially before it is brought into a heated room with a higher humidity. This may be accomplished by placing a new shipment in temporary storage where its temperature is raised slowly to that of the permanent storage room.

If a shipment of aluminum arrives in a wet condition, it should be thoroughly dried before storing. This may be done by evaporation in air or by means of dry air currents. When the moisture is removed in this manner within a short period after the metal becomes wet, stain is usually prevented. If stain has occurred, and the moist condition causing it is removed, the stain will not develop further. Once safely dry, the metal should not be stored near such obvious water sources as steam and water pipes, and it should be kept at a reasonable distance from open doors and windows.

Where water stains have occurred, the degree of staining may be judged fairly accurately by the relative roughness of the stained area. If the surface is reasonably smooth, the stain is merely superficial, and its appearance may be improved by mechanical or chemical treatments. Scratch brushing or the use of steel wool and oil is effective in removing water stain.

Aluminum packed in original boxes should never be left in the open, because the greater variations in temperature and humidity outdoors increase the possibility of condensation. Even if the package is wrapped with "water-proof" paper, the impossibility of obtaining a perfect seal makes outdoor storage highly undesirable. So-called waterproof packages are designed solely for the protection of the metal during shipment and are not meant to withstand any extended exposure to the weather.

In the continuous use of large quantities of metal, the oldest stock should be used first. Occasional checking of the stock on hand will help to prevent any serious corrosion.

In storing aluminum it is desirable to avoid contact between it and other metals, since this sometimes results in scratches or other marks. The use of woodfaced shelving racks and bins is recommended. It is also good practice to keep aluminum away from caustics, nitrates, phosphates, and some acids.

Additional information relating to handling and storage of aluminum may be found in the Aluminum Association publications referenced earlier in this Section.

Protective Oil for Aluminum

Water stain on aluminum may be prevented by exclusion of moisture-laden air and water from contact with the metal. The recommended method of attaining this is through the use of a protective oil of such nature that it will not react with aluminum. Oils that meet the following tests have been found to be generally adequate for use as a preservative.

Requirements

material. The oil is a fraction of petroleum containing additives, if necessary, to meet the following requirements.

procedure. Viscosity, flash point, pour point, and protection tests are performed after storage stability test. Oil samples for these tests are taken from the top one-third of the stored oil. Tentative approval is given on oil complying with all requirements after fourteen days of storage. Final approval is given on oil complying with all requirements after six months of storage.

storage stability. The oil shows no evidence of separation after storage as follows: Two samples are placed in storage. One sample is examined after 14 days of storage for tentative approval. The other sample is examined after six months of storage for final approval. Each sample consists of one gallon of oil. Each sample is stored at a temperature of 77 ± 10°F in the absence of light in a clean widemouth glass container of one gallon capacity.

color and appearance. The oil is clear, transparent, and uniform in appearance after application to the metal surface.

viscosity. The kinematic viscosity at 100°F is not less than 4.27 and not more than 54.0 centistokes (40.1-251 SUS) when tested in accordance with ASTM D445.

flash point. The flash point is not below 175°F when tested in accordance with ASTM D92.

pour point. The pour point is not above 30°F when tested in accordance with ASTM D97.

protection. Not more than two surfaces out of the ten panels fail after being coated with protective oil and tested as follows: Ten clean, dry flat panels of alloy 3003 sheet in H series tempers (size 0.064 by 3 by 5 in.) are coated with the oil by the immersion method, utilizing a Fisher-Payne Dip Coater operating at a withdrawal rate of 3 in. per minute. Prior to coating, the panels are cleaned by first wiping with cheesecloth soaked in acetone followed by immersion in trichloroethylene vapor. Ten drops of distilled water are applied on each coated panel. The ten panels are assembled into a package and are placed horizontally in a humidity chamber. A ten pound weight, enclosed in plastic, is placed on the package and the packages are exposed for two weeks to 100 percent relative humidity at 90°F. The presence of discoloration or etching due to corrosion on either surface of any panel is sufficient cause to consider that particular panel failed. There are eighteen test surfaces in each package; the two outside exposed surfaces are not considered.

removability. The oil is of such character that it can be removed by normal means such as those described in the Aluminum Association publication, "Care of Aluminum."

marking ink. Protective oils used do not obliterate or hide identification marking on the sheet.

workmanship. The workmanship is in accordance with high-grade commercial practice covering this class of material. Oil is free from suspended matter, grit, water, or any other adulteration.

Certification Documentation

When required by the purchaser, the supplier of mill products or fabricating ingot will issue documentation to the purchaser certifying that the material supplied has been inspected and tested and has been found to meet the requirements of the material ordered, including any specification(s) referenced on the order or contract and that supporting test results are on file.

Depending upon the purchaser's requirements, certification documentation may be in different forms. The following types of certifications are those most commonly required.

Certificate of Compliance: This document is the only one that is issued to cover shipments over an extended period rather than on a shipment by shipment basis. The period covered usually is one year and no test results are included with this certificate.

Certificate of Ingot Analysis: This document quotes the analysis of metal shipped in ingot form.

Certificate of Inspection: This document includes no composition limits or test results.

Certificate of Inspection and Test Results: This document lists applicable chemical composition limits and quotes minimum and maximum mechanical property values obtained from testing each lot. If applicable, test results for physical or other properties (e.g. electrical conductivity) will be included.

Certificate of Inspection and Test Results including Chemical Analysis: This document shows specific results from cast or product chemical analysis and also shows minimum and maximum mechanical property values obtained from testing each lot. If applicable, test results for physical or other properties will be included.

Certification of mechanical properties, as issued by the producer, may not be applicable to coil products that have been flattened, leveled or straightened subsequent to shipment by the producer, as these operations may alter the mechanical properties of the product.

It is important to realize that, although all portions of the lot are expected to conform to the required chemical composition limits, chemical composition is not precisely identical at all locations throughout any ingot, billet or wrought product. Also, the analytical equipment used may produce values of greater precision than can be justified by the sampling or the analysis techniques. To avoid misunderstanding, such values should be rounded to match the precision of the registered limits.

For inspection lots that contain material from more than one cast, a single cast analysis may not fully represent all of the material in the lot. In such instances, a clear statement from the supplier of what the analysis represents would be helpful to the purchaser.

The above forms will fill most needs of purchasers. The need for other types of certification would be subject to special request to the supplier. The above forms are certified by authorized company personnel.

Appendix 1

Determination of Predominant Area and Location of Test Specimens in Profiles

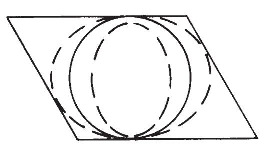
I. Determination of Predominant Area of Profiles

A. General Inspection Method

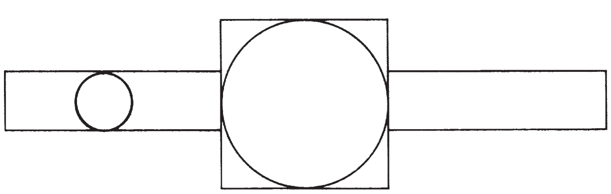
1. A cross-section drawing of the profile is required.
2. Areas for consideration shall be rectangular or circular portions of the cross section. A curved area of constant thickness shall be treated as a rectangle.
3. The rectangle or circle of greatest area is the predominant area, with the thickness of that area defined as the diameter of the largest circle that can be drawn within the area. Where the greatest area cannot be determined by visual inspection, the areas in question shall be calculated.

B. Construction Method

1. Construct the largest diameter circle in the cross-section. In cases where the largest circle can be constructed at the junction of a projection, the circle shall be constructed there only if the thickness of the projection is greater than 20 percent of the thickness of the main body at that location and if the circle is at least 1" in diameter.
2. Construct the largest rectangle about the circle.
   a. If no rectangle can be drawn, as in the case of a parallelogram, the circle is the area for consideration. In cases where overlapping circles of equal size can be drawn, the circle with a center halfway between the centers of the circles farthest apart is the area for consideration.



   b. When rounded corners are involved, the rectangle shall assume square corners if the radius of the rounded corner is not greater than 25 percent of the rectangle thickness.
3. Next consider the area included in a rectangle determined by the next largest diameter circle in the cross-section, and repeat as many times as necessary to determine the rectangle or circle of greatest area, excluding any area previously considered.



II. Location of Longitudinal Test Specimens in Predominant Area

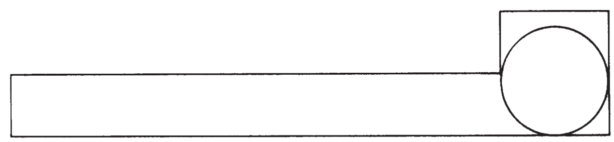
A. Tensile and Compression Specimens

I. Rectangular Areas
The specimen shall have its axis parallel to the direction of extrusion and be located as follows:
   a. Sections of uniform thickness:

Location of Specimen Axis

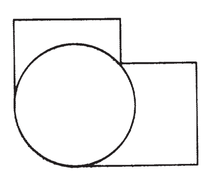
Section Thickness	With Respect to Thickness	With Respect to Width: 1.500" & Less Wide	With Respect to Width: 1.501" & Over Wide
Up thru 1.500"	T/2	W/2	W/4
1.501" & Over	T/4	—	W/4

   b. Sections of non-uniform thickness:



Construct the largest circle whose center falls within the predominant area. In cases where the largest circle can be constructed at the junction of a projection, the circle shall be constructed there only if the thickness of the projection is greater than 20 percent of the thickness of the main body at that location and if the circle is at least 1" in diameter. If overlapping circles of equal size can be drawn, the circle with center midway between the centers of the circles farthest apart is the one for consideration. Determine location of specimen using rules for circular areas in II.A.2.

2. Circular Areas
The specimen shall have its axis parallel to the direction of extrusion and be located:
   a. In the center of the circle when diameter is 1.500" or less.



   b. Halfway between the center of the circle and the perimeter, on the radius that touches the surface of the cross-section, and that when extended in the opposite direction produces the longest line when the diameter is 1.501" or more.

III. Location of Long Transverse Test Specimens in Predominant Area

A. Tensile and Compression Specimens

1. Rectangular Areas
   The axis of the specimen shall be parallel to the long direction of the rectangle and through the center of the rectangle. If the configuration of an extrusion with a predominant area less than 3" length permits, a standard sub-size specimen from a ⅜" square · 3" long blank shall be taken, provided the specimen gage length is entirely within the rectangle, and the midpoints of the specimen and the rectangle coincide.
2. Circular Areas
   a. When the predominant area occurs at the junction of a projection, the axis of the specimen shall be parallel to the side opposite the projection if the sides are parallel, or along the midline if the sides are not parallel. If the configuration of an extrusion with a predominant area less than 3" diameter permits, a standard sub-size specimen from a ⅜" square · 3" long blank shall be taken, provided the specimen gage length is entirely within the circle and the midpoints of the specimen and the circle coincide.
   b. In all other cases, the axis of the specimen shall be along the diameter that when extended produces the longest line. If the configuration of an extrusion with a predominant area less than 3" diameter permits, a standard subsize specimen from a ⅜" square · 3" long blank shall be taken, provided the specimen gage length is entirely within the circle and the midpoints of the specimen and the circle coincide.
   c. Even though a circle at the heavy end of a tapered extrusion precludes a transverse test, a test shall be made along the midline of the tapered area and extending as far outside the circle as necessary.

IV. Location of Short Transverse Test Specimens in Predominant Area

Tensile and Compression Specimens, Rectangular and Circular Areas.

The axis of the specimen shall be perpendicular to the axis of the long transverse specimen, and the midpoint of the short transverse specimen shall correspond with the midpoint of the long transverse specimen. Other details regarding long transverse test specimens apply.

V. Special Tests

Any testing in positions other than described above or involving transverse specimens smaller than those produced from a ⅜" · 3" blank is subject to special consideration.

Appendix 2

Dimensional Tolerances for Aluminum Alloy Products

Dimensional tolerance limits, like mechanical property limits, are developed as industry consensus standards, and thus represent dimensional tolerances that may be met by all members of the industry. These dimensional tolerance limits would be applicable in instances where no specific tolerance limits are agreed upon between the purchaser and vendor at the time the contract or order is entered.

Dimensional tolerance limits vary by aluminum alloy product and product dimensions, and so reference is made to the appropriate section of the Standards for the specific product involved.

Applicability—The tolerances published in Aluminum Standards and Data are applicable to products supplied by producers of those products. They are not applicable to products that are slit, sheared, sawed or blanked by the distributors and/or purchasers of those products.

Cut-to-length: When coiled or flat sheet is cut up in smaller sheets, the applicable tolerances are those for the original wider or longer sheets.

Sheared-to-size: When sheet is sheared to size from larger sheets by distributors and/or purchasers, size tolerances publication are no longer applicable because of the uncontrolled distortion introduced by the shearing process and its variability with different shear tools.

Dimensional Tolerance Measurement—Tolerances are expressed as inch fractions or decimals, or as percentages of base vales. The choice of tolerance depends on the dimension being measured and the precision of the measuring instrument. Where instruments permitting a high degree of precision are acceptable, standard dimensional tolerances are expressed in decimals, except for foil:

Tolerance less than 0.005 in. . . . . multiple of 0.0005

Tolerance of 0.005 or greater 0.XXX

For measurements commonly made with instruments not permitting such a high degree of precision, standard dimensional tolerances are expressed as inch fractions.

Conformance to Limits—For purposes of determining conformance to the dimensional tolerances, a measured value is not rounded off.

Negotiated Dimensional Tolerance Limits—In some specific instances, purchasers requiring dimensional tolerances tighter than the standard tolerance limits shown in the product-specific sections of this publication negotiate such limits directly with their suppliers. This is an accepted practice in the industry, and in any specific instance, the tolerance limits applicable to a specific order or contract are those negotiated between purchaser and supplier.

As a representative indication of this practice, it is fairly routine for suppliers to agree under specific conditions to purchasers' requests for dimensional tolerance limits that are one-half the published standards. Thus, as an illustrative example, dimensional tolerance limits for specific orders of aluminum alloy sheet and plate might be agreed to at one-half the levels in Table 7.7a, or as shown in Table 4.1.

TABLE 4.1 Example of Alternative Sheet and Plate Thickness Tolerances at One-half Published Tolerance Limits ①

SPECIFIED THICKNESS, in.		SPECIFIED WIDTH—in.							
		Up thru 39.37	Over 39.37 Thru 59.06	Over 59.06 Thru 78.74	Over 78.74 Thru 98.43	Over 98.43 Thru 118.11	Over 118.11 Thru 137.80	Over 137.80 Thru 157.48	Over 157.48 Thru 177.17
Over	Thru	TOLERANCES—in. plus and minus							
0.0059	0.01	0.0005	0.0008	. .	. .	. .	. .	. .	. .
0.010	0.016	0.0005	0.0008	. .	. .	. .	. .	. .	. .
0.016	0.025	0.0008	0.0010	0.0015	0.0018	. .	. .	. .	. .
0.025	0.032	0.0010	0.0013	0.0018	0.0020	. .	. .	. .	. .
0.032	0.039	0.0010	0.0015	0.0018	0.0023	0.003	. .	. .	. .
0.039	0.047	0.0013	0.0018	0.0023	0.003	0.004	0.004	. .	. .
0.047	0.063	0.0015	0.0018	0.0025	0.003	0.004	0.005	. .	. .
0.063	0.079	0.0018	0.0020	0.003	0.004	0.004	0.005	. .	. .
0.079	0.098	0.0018	0.0023	0.003	0.004	0.005	0.006	. .	. .
0.098	0.126	0.0023	0.003	0.004	0.005	0.006	0.007	. .	. .
0.126	0.158	0.003	0.004	0.005	0.006	0.007	0.008	. .	. .
0.158	0.197	0.004	0.005	0.006	0.007	0.008	0.009	. .	. .
0.197	0.248	0.005	0.006	0.007	0.008	0.009	0.011	0.014	. .
0.248	0.315	0.006	0.007	0.008	0.009	0.011	0.014	0.018	0.022
0.315	0.394	0.008	0.009	0.010	0.012	0.014	0.017	0.021	0.026
0.394	0.630	0.012	0.012	0.014	0.016	0.018	0.022	0.027	0.033
0.630	0.984	0.016	0.016	0.019	0.022	0.024	0.029	0.035	0.043
0.984	1.575	0.020	0.020	0.024	0.028	0.033	0.038	0.045	0.053
1.575	2.362	0.028	0.028	0.030	0.035	0.043	0.050	0.058	. .
2.362	3.150	0.038	0.038	0.043	0.050	0.053	0.063	. .	. .
3.150	3.937	0.050	0.050	0.058	0.063	0.065	0.080	. .	. .
3.937	6.299	0.065	0.065	0.073	0.083	. .	. .	. .	. .

① From Table 7.7a

As another example, solely for illustrative purposes, purchasers of extruded profiles may negotiate with producers for specific profiles with one-half the standard length, straightness or twist limits shown in Tables 11.5, 11.6 or 11.7, respectively.

Examples of Use of Tolerance Tables—The following examples are provided as basic illustrations of the application of the dimensional tolerance limit tables to representative aluminum alloy products. For more detail, consult the following Aluminum Association publication:

"Understanding Aluminum Extrusion Tolerances", The Aluminum Association.

Twist Limits

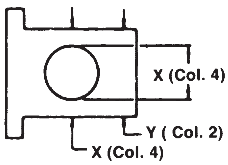
Twist is normally measured by placing the product on a flat surface and at any point along its length measuring the maximum distance between the bottom surface of the section and the flat surface. From this measurement, the actual deviation from straightness† of the section at that point is subtracted. The remainder is the twist. To convert the standard twist tolerance (degrees) to an equivalent linear value, the sine of the standard tolerance is multiplied by the width of the surface of the section that is on the flat surface. The following values are used to convert angular tolerances to linear deviation:

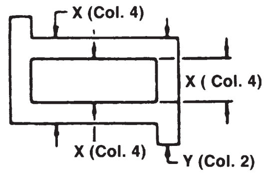
Tolerance, degrees	*Maximum allowable linear deviation inch per inch of width*
¼	0.004
½	0.009
1	0.017
1½	0.026
3	0.052
5	0.087
7	0.122
9	0.156
15	0.259
21	0.358

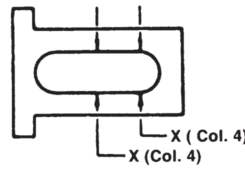
†See Table of Straightness Limits for product of interest to determine actual deviation from straightness.

Examples of Use of Dimensional Tolerances for Extruded Profiles (Table 11.2)

Closed-Space Dimensions

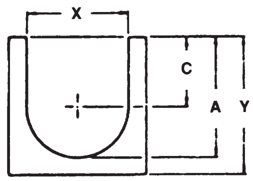


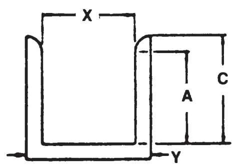


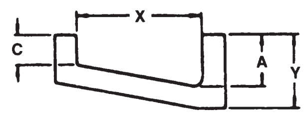


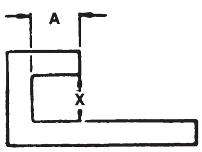
All dimensions designated "Y" are classed as "metal dimensions," and tolerances are determined from column 2.
Dimensions designated "X" are classed as "space dimensions through an enclosed void," and the tolerances applicable are determined from column 4 unless 75 percent or more of the dimension is metal, in which case column 2 applies.

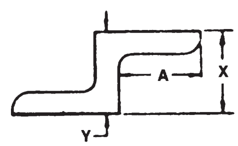
Open-Space Dimensions





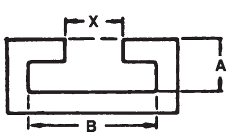


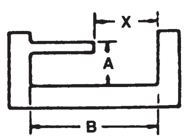


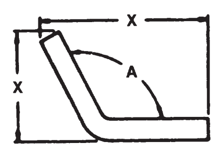


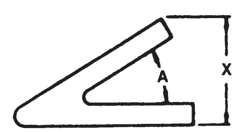
Tolerances applicable to dimensions "X" are determined as follows:
1. Locate dimension "X" in column 1.
2. Determine which of columns 49 is applicable, dependent on distance "A."
3. Locate proper tolerance in column 4, 5, 6, 7, 8 or 9 in the same line as dimension "X."

Dimensions "Y" are "metal dimensions"; tolerances are determined from column 2.
Distances "C" are shown merely to indicate incorrect values for determining which of columns 49 apply.







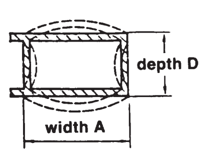


Tolerances applicable to dimensions "X" are determined as follows:
1. Locate distance "B" in column 1.
2. Determine which of columns 49 is applicable, dependent on distance "A."
3. Locate proper tolerance in column 4, 5, 6, 7, 8 or 9 in the same line as value chosen in column 1.

Tolerances applicable to dimensions "X" are not determined from Table 11.2; tolerances are determined by standard tolerances applicable to angles "A."

Completely Enclosed Hollow Profiles

The following tolerances apply where the space is completely enclosed (hollow profiles): For the width (A), the balance is the value shown in Col. 4 for the depth dimension (D); For the depth (D), the tolerance is the value shown in Col. 4 for the width dimension (A). In no case is the tolerance for either width or depth less than the metal dimensions (Col. 2) at the corners.



Example—Alloy 6061 hollow profile having 1 3 rectangular outside dimensions; width tolerance is ±0.021 inch and depth tolerance ±.034 inch. (Tolerances at corners, Col. 2, metal dimensions, are ±0.024 inch for the width and ±0.012 inch for the depth.) Note that the Col. 4 tolerance of 0.021 inch must be adjusted to 0.024 inch so that it is not less than the Col. 2 tolerance.

5. Terminology

SCOPE: The following list of terms is associated primarily with wrought aluminum products (and their production) which form the basis of most of the information found in Aluminum Standards and Data. The list is not intended to include every term likely to be used within the aluminum industry.

—A—

AMS—Abbreviation for Aerospace Material Specification.

ANSI—Abbreviation for American National Standards Institute.

ASME—Abbreviation for American Society of Mechanical Engineers.

ASTM—Abbreviation for American Society for Testing and Materials.

AWS—Abbreviation for American Welding Society.

Abrasion—See "Mark, Traffic."

Aging—Treatment of metal aiming at a change in its properties by precipitation of intermetallic phases from supersaturated solid solution. Additional terms referencing "Aging" include:

Age Hardening—See "Aging"—Precipitation Hardening."

Age Softening—Decrease in strength and hardness at room temperature in certain strain hardened alloys containing magnesium.

Artificial—Treatment at temperature above room temperature.

Delayed—A process where an ally is kept below room temperature in order to prevent or delay precipitation from supersaturated solid solution. After returning to room temperature precipitation process will continue normally.

Natural—Treatment at room temperature.

Over—Artificial aging beyond peak aging temperature-time conditions, in order to improve selected metallurgical characteristics of the metal, e.g. resistance ot stress corrosion or intergranular corrosion. OVer-aging results in reduced tensile properties compared with peak aged metal.

Peak—Artificial aging under temperature-time conditions that result in maximum tensile strength.

Pre-Aging—Short thermal treatment applied after quenching, but before significant precipitation hardening occurs.

Precipitation Hardening—An increase in strength and hardness caused by precipitation of intermetallic phases from supersaturated solid solution; also termed "Age Hardening."

Ramp—Step aging involving a time-controlled increase or decrease in temperature between the specified temperatures, either in steps of continuously.

Step—Artificial aging typically carried out in two successive stages at different specified temperatures.

Under—Artifical aging below peak aging temperature-time conditions resulting in slightly reduced tensile strength and improved ductility, compared with peak aged metal.

Alclad—Clad sheet/plate having on one or both surfaces a metallurgically bonded aluminum coating that is anodic to the core, thus electrolytically protecting the core against corrosion. If on one side only is clad, the product is oftem baned "Alclad One Side SHeet/Plate". For Alclad products, see specific product such as "Plate," "Sheet," "Rod", "Tube," or "Wire."

Alligatoring; Crocodiling—Longitudinal doubling and/or splitting at both ends of a slab in a plane parallel to the rolled surface occuring during the first passes of the reversing hot mill.

Alloy—A substance having metallic properties and composed of two or more elements, so combined that they cannot readily be separated by physical means. Additional terms referencing "Alloy" include:

Aluminum—Aluminum which contains alloying elements, whrer aluminum predominates by mass over each of the other elements and where the aluminum content is not greater than 99.00%.

Free Machining—An alloy that, virtue of its chemical composition and temper, is designed to give, on machining, small broken chips, typically by adding alloying elements with low melting point.

Heat -Treatable—An alloy which can be strengthened by suitable thermal treatment.

Non-Heat-Treatable—An alloy which is primarily strengthened only by working and not by thermal treatment.

Refined Aluminum—A casting alloy obtained after metallurgical treatment of molten metal obtained from aluminum scrap.

Wrought—An alloy primarily intended for the production of wrought products by hot and/or cold working.

Alloying Element—Metallic or non-metallic element which is controlled within specific upper and lower limits for the purpose of giving the aluminum alloy certain special properties.

Aluminum—Unalloyed aluminum or aluminum alloy. Additional terms referencing "Aluminum" include:

Unalloyed—Aluminum without alloying elements where the minimum aluminum content is specified to be greater than 99.00%. Unalloyed aluminum is often called "Aluminum", i.e. the term "Aluminum" then does not include aluminum alloys. See "Alloy—Aluminum."

Angularity—Conformity to, or deviation from, specified angular dimensions in the cross section of a shape or bar.

Angulation—The deliberate departure from a horizontal passline on the entry side of a rolling mill used for one-side bright rolling.

Annealing—A thermal treatment to soften metal by reduction or removal of strain hardening resulting from cold working and/or by coalescing precipitates from the solid solution. Additional terms referencing "Annealing" include:

Flash—Annealing carried out by heating quickly and, if necessary, holding for a short time at an appropriate temperature, typically in continuous furnaces.

Partial—Annealing of a cold worked metal to reduce the strength to a controlled but not fully softened level.

Recrystallization—Annealing to obtain complete recrystallization of the metal.

Super—Annealing of a heat treatable alloy, followed by a slow, controlled rate of cooling to produce a condition of maximum ductility with a minimum tendency to natural aging.

Anodized Metal—Metal with an anodic layer, produced by an electrolytic oxidation process in which a metal surface layer is converted to an oxide layer having protective, decorative or functional properties. These properties are obtained by various anodized processes which include the following:

> **Architectural—**Anodizing to produce an architectural finish to be used in permanent, exterior and static situations where both appearance and long life are important.
>
> **Bright—**Anodized metal with a high specular reflectance as the primary characteristic.
>
> **Clear—**Metal with a substantially colorless, translucent anodic oxidation finish.
>
> **Color—**Anodized metal colored either during anodizing or by subsequent coloring processes.
>
> **Combination—**Metal with an anodic oxidation layer that is colored by electrolytic coloring or produced by integral color anodizing followed by absorption dyeing.
>
> **Decorative—**Anodizing where a decorative finish with a uniform or aesthetically pleasing appearance is the primary characteristic.
>
> **Dyed—**Metal with an anodic oxidation layer colored by absorption of dye-stuff or pigments into the pore structure.
>
> **Electrolytically Colored—**Metal with an anodic oxidation layer that has been colored by the electrolytic deposition of a metal or metal oxide into the pore structure.
>
> **Hard—**Anodized metal on which the anodic oxidation finish has been produced with wear and/or abrasion resistance as the primary characteristic.
>
> **Integral Color—**Metal that has been anodized using an appropriate (typically organic acid based) electrolyte which produces a colored finish during the anodizing process itself.
>
> **Interference Color—**Metal with an anodic oxidation layer colored by means of optical interference effects, as intended.

Anodizing Sheet—See "Sheet—Anodizing."

Arbor Break—See "Buckle—Arbor."

Arbor Mark—See "Mark—Arbor."

Artificial Aging—See "Aging."

—B—

Back End Condition—A condition occurring in the last metal to be extruded. It is a result of the oxidized surface of the billet feeding into the extrusion.

Backup Roll—Nongrooved roll which stiffen or strengthen a work roll.

Bar—A solid wrought product that is long in relation to its cross section which is square or rectangular (excluding plate and flattened wire) with sharp or rounded corners or edges, or is a regular hexagon or octagon, that is typically supplied in straight lengths and in which at least one perpendicular distance between parallel faces is 0.375 inch or greater. In North America, below this limit the product is called "Wire" In Europe, a bar is supplied in straight length; if supplied in coiled form, the product is called "Wire." Additional terms referencing "Bar" include:

> **Bus—**A rigid electric conductor in the form of a bar. A rigid electric conductor of any cross section is often called "Bus Conductor."
>
> **Cold-Finished—**Bar brought to final dimensions by cold work (typically performed by drawing) to obtain improved surface finish and dimensional tolerances.
>
> **Cold-Finished Extruded—**Cold finished bar produced from extruded bar.
>
> **Cold-Finished Rolled—**Cold-finished bar produced from rolled bar.
>
> **Extruded—**Bar brought to final dimensions by hot extruding.
>
> **Rolled—**Bar brought to final dimensions by hot rolling.
>
> **Saw Plate—**Bar brought to final thickness by hot or cold rolling and to final width by sawing.

Base Box—General—An agreed-upon unit of area used primarily in packaging applications. One common base box for aluminum is 31,360 square inches, originally composed of 112 rectangular sheets each 14 by 20 inches.

Belled Edge—See "Edge—Belled."

Belly—A loose center buckle extending to near the edges of a sheet See "Buckle—Center."

Bend Test—See "Test—Bend."

Billet—A hot worked semifinished product suitable for subsequent working by such methods as rolling, forging, extruding, etc.

Blank— A piece of metal of uniform thickness and of regular or irregular shape taken from a wrought or unwrought product. If taken from a wrought product, it is intended for subsequent processing such as bending, stamping or deep drawing.

Blanking—Production of blanks by stamping on a blanking press with closed cut.

Bleed Out—See "Two-Tone."

Blister—A raised spot, inside hollow, on the surface of products caused by the penetration of a gas into a subsurface zone typically during thermal treatment. A void resulting from blister that has ruptured is often termed “Blow Hole”. Additional terms referencing “Blister” include:

Bond—A raised spot on only one surface of the metal whose origin is a blister between the cladding and core in a clad product.

Coating—A blister in the coating of an Alclad or a clad product.

Core—A blister resulting from a gas-filled hole in the core of the metal. In thin-walled products, core blisters are visible on both opposite surfaces.

Block Mark—See “Scratch—Tension.”

Blow Hole—See “Blister.”

Bolt Stock—Bar or wire suitable and intended for the manufacture of bolts. See also “Cold Heading Bar” and “Cold Heading Rod” and “Cold Heading Wire.”

Bore Test—See “Test—Bore.”

Boss—A knoblike projection on the main body of a forging or casting.

Bottom Draft—Taper or slope in the bottom of a forged depression to assist the flow of metal toward the sides of the depressed area.

Bow—Several types exist including:

Lateral—Deviation of a longitudinal edge from a straight line. Also called “Lateral Curvature.”

Longitudinal—Deviation from straightness in the plane of a flat product along the main axis, as measured by use of a baseplate on which the product is positioned so that its own weight minimizes the curvature. Also called “Longitudinal Arch” and “Longitudinal Curvature.”

Transverse—Curvature in the plane of a flat product perpendicular to the main axis. Also called “Transverse Arch.”

Brazing—Joining metals by fusion of nonferrous alloys that have melting points above 800F (425C) but lower than those of the metals being joined.

Brazing Rod—See “Rod—Brazing.” .

Brazing Sheet—See “Sheet—Brazing.”

Brazing Wire—See “Wire—Brazing.”

Bright Sheet—See “Sheet, One Side Bright Mill Finish.”

Brinell Hardness—See “Hardness—Brinell.”

Bristle Mark—See “Mark, Bristle.”

Broken Die—A deviation from the desired cross section due to the absence of a certain portion of the die used to extrude the profile.

Broken Edge—See “Edge—Broken.”

Broken Matte Finish—Non-uniform surface on the matte side of packed rolled foil, caused by bright spots.See “Broken Surface.”

Broken Surface— Surface having multiple minute cracks running transverse to the direction of working. In packed rolled foil it is called “Broken Matte Finish” or “bright spots” if on the matte side.

Bruise—See “Mark— Roll Bruise.”

Brushing—Mechanical roughening of a surface, typically with rotating brushes.

Buckle—A departure from flatness represented by alternate bulges and hollows or waves along the length of a product. Additional terms referencing “Buckle” include:

Arbor—Bend, crease, wrinkle, or departure from flat, occurring perpendicular to the slit edge of a coil and which are repetitive in nature, with severity decreasing as the distance increases in the coil from the original source. Normally, it is found on the ID of a coil but can appear on the coil OD as a result of a prior winding operation.

Center—A departure from flatness represented by alternate bulges and hollows along the length and in the center across the width of a product, the edges of which remain comparatively straight. Center buckles are also termed “Center Waves” or “Pockets.”

Edge—A departure from flatness represented by a corrugated or wave-like formation of the edges of a product in which the center area remains comparatively flat. Edge buckles are also termed “Edge Waves” or “Wavy Edges.”

Quarter—A departure from flatness represented by alternate bulges and hollows along the length and is approximately at both quarter points across the width of a product, the edges of which remain comparatively straight.

Buff Streak—See “Streak —Buff.”

Buffing—A mechanical finishing operation in which fine abrasives are applied to a metal surface by rotating fabric wheels for the purpose of developing a lustrous finish.

Burnish Streak—See “Streak—Burnish.”

Burnishing—See “Two-Tone.”

Burr—A thin ridge of roughness on an edge left by a cutting operation such as slitting, trimming, shearing, blanking, sawing, etc.

Bursting Strength—See “Test—Mullen.”

Bus Bar—See “Bar—Bus.”

—C—

Camber—This term not recommended. See “Bow—Lateral.”

Can Stock—Sheet or strip used for the fabrication of rigid cans including ends (lids) and tabs by drawing/ironing, pressing or forming operations. Can stock covers can body stock, end (lid) stock and tab stock.

Carbon Mark—See “Mark—Carbon.”

Cast—The quantity of products cast simultaneously from the same melt. The different ingots of a cast can have different dimensions. This term is not used for castings. In North America, multiple “drops” are made with one cast number.

Center Buckle—See "Buckle—Center."

Center Set—The difference in thickness between the middle and edges (average) of a sheet.

Chafing—See "Mark—Traffic."

Chatter Mark—See "Mark—Chatter."

Chemical Brightening—A chemical treatment to improve the reflectivity of a surface.

Chemical Polishing—The polishing of a metal surface by immersion in a solution of chemical reagents.

Chip Mark—See "Dent—Repeating."

Chop—Metal sheared from a vertical surface of a die forging which is spread by the die over an adjoining horizontal surface.

Chucking Lug—A lug or boss added to a forging so that "on center" machining and forming may be performed with one setup or checking. This lug is finally machined or cut away.

Cinching—See "Scratch—Tension."

Circle—A circular blank fabricated from plate, sheet or foil.

Circumscribing Circle—A circle that will just contain the cross-section of a profile, typically designated by its diameter.

Clad Sheet—See "Sheet—Clad."

Closed Die—Forging die, typically in pairs, into which impressions have been cut to impart the required shape.

Coating (Organic)—A process in which a coating material is applied on a metallic substrate, including cleaning and chemical pre-treatment. This term covers a one-side or two-side, single or multiple application of liquid or powder coating materials which are subsequently cured. This term also covers laminating with plastic films. Additional terms referencing "Coating" include:

> **Blister—**See "Blister—Coating."
>
> **Build-Up—**A coating thickness greater than nominal in localized area of sheet, typically along edges, due to uneven application techniques.
>
> **Coil—**Continuous coating of a coiled metal sheet.
>
> **Conversion—**An inorganic pre-treatment applied to a metal surface by dipping or spraying or the use of a roll-coater to build up a stable oxide film to enhance coating adhesion and to retard corrosion. Liquids containing chromates or phosphates are often used for conversion coating. For many applications, chromate pre-treatments have been replaced by non-chromate pre-treatments.Drip—A non-uniform extraneous deposit of coating on the coated sheet.
>
> **Film—**An organic film applied to a substrate to which an adhesive and, as appropriate, a primer has been applied beforehand.
>
> **High or Low—**Failure of the coating to meet the agreed upon thickness limits measured in weight per unit area.
>
> **Organic—**Paint or lacquer film on a coated product produced from wet paint or from powder coating, or the laminated organic film.Oven Trash—See "Dirt."

Streak—See "Streak—Coating."

Cobble—(1) A jamming of the mill by aluminum product while being rolled. (2) A piece of aluminum which for any reason has become so bent or twisted that it must be withdrawn from the rolling operation and scrapped.

Coil Curvature—See "Coil Set."

Coil Orientation—Clockwise Coil: With the coil core vertical ("eye to the sky") and viewed from above, a trace of the metal edge from the ID to the OD involves clockwise movement. Counter-Clockwise (Anti-Clockwise) Coil: With the coil core vertical ("eye to the sky") and viewed from above, a trace of the metal edge from the ID to the OD involves counter-clockwise (anti-clockwise) movement.

Coil Set—Longitudinal bow in an unwound coil in the same direction as curvature of the wound coil.

> **Coil Set Differential—**The difference in coil set from edge to edge of a coiled sheet sample. It is measured with the sample on a flat table, concave side up, and is the difference in elevation of the corners on one end.
>
> **Coil Set, Reversed—**Longitudinal bow in an unwound coil in the direction opposite to the curvature of the wound coil.

Coiled Sheet—See "Sheet—Coiled."

Coining (of forged material)—Final cold forging operation applied to obtain close tolerances.

Cold Crack—A crack in cast metal initiated by mechanical stresses at temperatures significantly below the solidus temperature.

Cold Heading Bar—Bar suitable for the manufacture of bolts and rivets.

Cold Heading Rod—Rod suitable for the manufacture of bolts and rivets.

Cold Heading Wire—Wire suitable for the manufacture of bolts and rivets.

Cold Shut—(1) A linear discontinuity in a cast surface caused by freezing of the melt meniscus in contact with the mould and the liquid metal flowing over the solidified metal. (2) A discontinuity (lap) in a forging caused by metal flowing into a section from two directions. See also "Lap."

Cold Working— Forming of a solid metal without preheating.

Collapse—Out-of-round condition of coil often due to inappropriate tension during rewinding operations.

Coloring—See "Anodized Metal."

Concavity—Inward curvature across the width of a flat product. See also "Convexity."

Concentricity— The extent to which the inner and outer walls of round tube have a common center of curvature.

Condensation Stain—See "Corrosion—Water Stain."

Condenser Tube—The term "Heat-Exchanger Tube" is preferred, unless specific reference to a condenser application is intended.

Conduit—A tube used to protect electric wiring.

Conduit, Rigid—Conduit having dimensions of ANSI Schedule 40 pipe in standardized length with threaded ends.

Container—See "Extrusion—Container."

Contour—That portion of the outline of a transverse cross section of an extruded shape that is represented by a curved line or curved lines.

Controlled Atmosphere—Atmosphere in which the partial pressures of the gases and the temperature are maintained within specified limits so as to minimize (or more rarely induce) certain reactions between the atmosphere and the product treated, e. g. oxidation.

Controlled Compression—The working of forged metal at room temperature immediately after quenching and under compression through the thickness in the solution treated condition to relieve internal stresses caused by quenching, and to minimize distortion during machining.

Conversion Coating—See "Coating, Conversion."

Conversion of Units

Conversion, Hard—Hard conversion rationalizes a mathematically converted number to a commonly accepted value that is easier to work with and remember. A hard conversion may impart a greater change in the magnitude of the value than allowed by conventional rounding and may result in a value that is physically different.

Conversion,Soft—Soft conversion is a mathematical conversion from one set of units to another without changing the magnitude of the quantity beyond conventional rounding.

Convexity—Outward curvature across the width of a flat product. See also "Concavity."

Core—A hollow cylinder on which a coiled product may be wound that forms the inside diameter of a coil.

Core Blister—See "Blister.—Core."

Coring—See "Back End Condition."

Corner—Convex junction between two surfaces.

Corner Turn-up—Deviation of the corner(s) of a sheet from a perfectly flat plane on which it rests, often caused by distortion, buckle or twist condition.

Corrosion—The deterioration of a metal by chemical or electrochemical reaction with its environment. Additional terms referencing "Corrosion" include:Exfoliation—Corrosion that progresses approximately parallel to the metal surface, causing layers of the metal to be elevated by the formation of corrosion product.

Filiform—Corrosion in the form of irregularly distributed thread-like filaments that can occur under certain conditions under coatings.

Galvanic—Corrosion associated with the current of galvanic cell consisting of two dissimilar conductors in an electrolyte or two similar conductors in dissimilar electrolytes. Aluminum will corrode if it is anodic to the dissimilar metal.

Intercrystalline (Intergranular)—Corrosion occurring preferentially at grain boundaries of a metal.

Pitting—Localized corrosion resulting in small pits or craters in a metal surface.

Stress Cracking—Failure by cracking resulting from selective directional attack caused by the simultaneous interaction of sustained tensile stress at an exposed surface with the chemical or electro-chemical effects of the surface environment.

Water Stain— Superficial surface oxidation due to the reaction of water films held between closely adjacent metal surfaces such as between wraps of a coil or sheets in a stack. The appearance of a water stain varies from iridescent in mild cases to white, gray, or black in more severe instances.

Corrugating—Forming rolled metal into a series of straight parallel regular alternate grooves and ridges. See "Sheet—Corrugated."

Coupon—A piece taken from a sample or a specimen which is suitably prepared for test. In Europe the term "Test Piece" is used. See also "Specimen."

Covering Area—Yield expressed in terms of a given number of square inches in a pound. For metric units, use square meters per kilogram.

Crease—A sharp deviation from flat in the sheet which is transferred from processing equipment subsequent to the roll bite. See "Kink."

Creep Rupture Strength—Maximum gross stress which the material withstands when submitted to sustained loading at a defined temperature, typically above 100°C (212°F).

Critical Strain—See "Recrystallization."

Crown—The difference in thickness between one of the edges and the center of a rolled product.

Curl—An undesirable condition caused by uneven rates of absorption or evaporation of moisture, uneven rates of contraction or expansion, or internal stresses in the material. Curl is most prevalent in laminated structures where the components have differing physical properties.

Cut-Up Test (of forging)—See "Test—Cut-Up."

—D—

Deep Drawing—Forming a deeply recessed part by forcing sheet metal to undergo plastic flow between dies, usually without substantial thinning of the sheet.

Defect—A defect is anything that renders the aluminum unfit for the specific use for which it was ordered.

Degreasing—The removal of substances from the surface of a product which may negatively affect the subsequent surface treatment, e. g. oil or grease, typically by a suitable organic solvent or an aqueous detergent.

Density—The mass per unit volume.

Dent—A sharply delimitated surface impression on the metal, often caused by a blow from another object. Typical sources include:

Expansion—Localized surface deviation from flat generated by expansion of vapor during thermal treatment of cold rolled coiled sheet.

Repeating—Dent appearing periodically, often caused by a particle adhering to a rotating roll over which the metal has passed.

Die Line—Continuous longitudinal line formed on an extruded or drawn product caused by minor irregularities and/or the built-up of aluminum or non-metallic inclusions, on the bearing surfaces of the die.

Diffusion Streak—See “Streak—Diffusion”

Direction—Orientation of metal object. These include:

> **Longitudinal**—The direction of the major metal flow in a working operation.
>
> **Long Transverse—**The transverse direction parallel to the major sectional dimension of the product.
>
> **Short Transverse—**The transverse direction parallel to the minor sectional dimension of the product. For hand forgings, this direction is typically the direction of forging. For rolled or extruded products the (wall) thickness is measured in the short transverse direction.
>
> **Transverse—**Any direction perpendicular to the longitudinal direction.

Dirt—Particle as dust or dirt entrapped between the rolling cylinder and the rolled product. See also “Streak.”

Disc—Circle from which a central concentric area has been removed.

Draft—Taper on the sides of a die or mold impression to facilitate removal of forgings, castings or patterns from dies or molds.

Drag Mark—See “Rub, Tool.”

“Draw and Iron”—Can Bodies—Term which refers to a method of fabricating a can body in which a cup is drawn from flat sheet, redrawn to the final diameter and then wall ironed to reduce the wall thickness and to achieve the required height.

Drawing—Pulling metal through a die in order to reduce or change the cross-section or to work harden the metal. In forging, this term describes the process of working metal between flat dies to reduce the cross section and increase length.

Drawing and Ironing—Deep drawing followed by substantial thinning of the sheet in the gap between a cylinder and a ring.

Drawing Stock—Semi-finished solid wrought product of uniform cross section along its whole length, supplied in coils and of a quality intended and suitable for drawing into wire.

Drawn Product—A product formed by pulling material through a die.

Drawn-In Scratch—See “Scratch—Drawn In.”

Drift Expanding Test—See “Test—Flare.”

Dropped Edge—See “Edge—Dropped.”

Dry Sheet—See “Lube—Low.”

Dry Surface—A foil surface substantially free from oily film, and suitable for lacquering, printing, or coating with water-dispersed adhesives.

Ductility—Ability of a material to deform plastically before fracturing.

Dye Penetrant—Test/Liquid Penetrant Inspection—See “Test—Dye Penetrant.”

—E—

Earing—Wavy projections spaced symmetrically around the rim of a deep drawn product due to non-uniform directional properties in the aluminum and/or by improperly adjusted tooling.

> **Earing Test—**See “Test—Earing.”
>
> **Ears—**Wavy symmetrical projections formed in the course of deep drawing or spinning as a result of directional properties or anisotropy in sheet.

Eccentricity—Deviation between the centers of curvature of the inner and outer walls of round tube. Eccentricity is typically determined as the difference between the mean wall thickness and minimum or maximum wall thickness at any one cross-section. The permissible degree of eccentricity can be expressed by a plus and minus wall-thickness tolerance.

Eddy Current Test—See “Test—Eddy Current.”

Edge (of a Rolling Ingot) — One of the narrow faces (plane or of a specific geometry) of a rolling ingot parallel to the casting axis. Other terms referring to “Edge” include:

Band—See “Two-Tone.”

Belled—Excessive buildup of material on edge(s) during a rewinding operation. Typical causes include excessive edge burr, turned edge, and “dog bone” shaped cross sectional profiles.

Broken (Cracked)—Edge of a rolled product containing cracks, splits, or tears, caused by inability to be formed without fracturing.

Buckle—See “Buckle—Edge.”

Buildup—See “Belled” above.

Damaged—Edge of a coil that has been bent, torn or scraped by an object.

Dropped—A continuous, downward edge deflection.

Liquated—Surface condition remaining after portions of a side of an as-cast rolling ingot deforms enough during hot rolling to become top and/or bottom surface(s) of the rolled product at an edge.

Rippled—See “Buckle.”

Wavy—See “Buckle.”

Electrical Conductivity—The reciprocal of electrical resistivity.

Electrical Resistivity**—**Electrical resistance of a given material related to unit length and unit cross- section area.

Electrochemical Brightening—An electrochemical treatment to improve the reflectivity of a surface.

Electropolishing—The polishing of a metal surface by making it anodic in an appropriate electrolyte.

Elongation—The percentage increase in distance between two marks on a test piece, termed “gauge marks”, that results from straining the test piece in tension to fracture between these gauge marks. The elongation depends on the distance between the gauge mark. The elongation depends on the cross-sectional dimensions of the test piece. For example, the values obtained from sheet specimens will be lower for thin sheet than for thicker sheet. The same is true for extrusions. Elongation is the simplest and most common representation of the ductility of the material.

Embossing—A pattern mechanically impressed on a surface by rolling or pressure.

Endurance Limit—The limiting stress below which a material will withstand a specified large number of cycles of stress.

Erichsen Test—See “Test—Erichsen.”

Etching**—**Selective dissolution of the surface of a metal in a liquid, typically caustic soda, with the intention to improve the surface aspect or to prepare the surface for further treatment or for inspection. Etching can also be performed by an electrochemical process. Caustic etching is important to produce the required product appearance in architectural and decorative anodizing. The term “pickling” for this concept is not a preferred term within the aluminium industry.

Extrudate—Material exiting an extrusion die subject to further processing (quenching, stretching, cutting), to become an extruded profile.

Extrusion—A process in which a billet in a container is forced under pressure through an aperture of a die. Additional terms referencing “Extrusion” include:

Extrusion—A process in which a billet in a container is forced under pressure through an aperture of a die. Additional terms referencing “Extrusion” include:

Billet—Extrusion ingot cut to length.

Butt—That portion of an extrusion billet that is left unextruded.

Container—Hollow cylinder in an extrusion press from which the billet is extruded.

Contour—That portion of the outline of a transverse cross section of an extruded shape that is represented by a curved line or curved lines.

Die—A block of steel having one or more holes of the required contour through which a billet is forced. A “Porthole Die” is an extrusion die that incorporates a mandrel as an integral part of the die assembly. “Bridge”, “Spider” and “Self-Stripping” dies are special forms of porthole die. Hollow profiles or tubes extruded by a porthole die are characterized by one or more longitudinal extrusion seams.

Direct—Extrusion process with relative movement between billet and container.

Effect—Increased tensile properties in the longitudinal direction of an extruded product caused by a characteristic non-recrystallized structure in certain alloys.

Impact—A process in which an unheated slug is extruded through a die by a single blow in the direction of the blow, or in the space between the punch and the closed die in the direction counter to the blow.

Indirect—Extrusion process without relative movement between billet and container.

Ingot—Ingot, intended and suitable for extruding, typically of solid circular cross-section, sometimes with a central hollow or a flattened cross-section.

Log—Extrusion ingot not cut to length.

Press—Machine consisting essentially of a container, a ram or other pressure-applying device, and a die, used for extrusion.

Ratio—The ratio of the cross-sectional area of the extrusion container to that of the extruded product.

Seam—Region in an extruded product where metal has been welded together in the extrusion die because of high pressure and elevated temperature. The extrusion seam is not visible on the extruded product unless an appropriate surface treatment, e. g. etching and anodizing, has been made. A longitudinal extrusion seam is one in a hollow profile or a tube, parallel to the extrusion direction, which has been formed after creating two or more streams of metal and rejoining them around the mandrel of a porthole or bridge die. Extrusion seams are naturally occurring in porthole/bridge dies. This concept is sometimes termed “charge weld.” A transverse extrusion seam is one which is formed when two subsequent billets are welded together in the extrusion die.

Tool—Term typically referring to the dies, mandrels, etc., used in the production of extruded or drawn shapes or tube.

Eyehole—See "Holiday."

—F—

Fabricating Ingot—A cast product intended and suitable for forming by hot or cold working. See also "Extrusion", "Forging" and "Rolling."

Fatigue—The tendency for a metal to break under conditions of repeated cyclic stressing considerably below the tensile strength. Fatigue fractures begin as minute cracks that grow under the action of the fluctuating stress.

Fatigue Strength—Maximum stress amplitude that can be sustained by a product for a specified number of cycles generally expressed as the stress amplitude giving a 50 % probability of fracture after a given number of load cycles.

Feed Line—See "Streak—Grinding."

Fillet—A concave junction between two surfaces.

Fin—A thin projection on a forging resulting from trimming or from the metal under pressure being forced into hairline cracks in the die or around die inserts.

Fin Stock—Coiled sheet or foil suitable and intended for manufacture of fins for heat-exchanger applications.

Finish—The characteristics of the surface of a product. Additional terms referencing "Finish" include:

Embossed—A pattern mechanically impressed on a surface by rolling or pressure.

Matte—A diffuse finish typically produced by rolling, etching, brushing or blast cleaning.

Mill—A finish naturally occurring after rolling.

Mirror—A finish after rolling or polishing with high specular reflectivity.

Satin—A fine-textured matte finish produced mainly by special roll grinding.

Scratch-Brushed—A matte or satin finish produced by abrasion with rotating wire brushes.

Finned Tube—See "Tube—Finned."

Fir-Tree Structure—Macrostructure of an etched and/or anodized metal, characterized by areas of different gloss with sharp boundaries between these areas caused by different types of intermetallic phases. Fir-tree structure originates in the macrostructure of the ingot. It can be found in sections of the ingot after appropriate mechanical pre-treatment and subsequent etching or anodizing.

Fish Mouthing—See "Lamination."

Flaking—A condition in coated sheet where portions of the coating become loosened due to inadequate adhesion.

Flanging Test (of tube)—See "Test—Flanging."

Flash—A thin protrusion at the parting line of a forging which forms when metal, in excess of that required to fill the impressions, is forced between the die interfaces.

Flash Line—A line left on a forging where flash has been removed.

Flat Sheet—See "Sheet—Flat."

Flatness—The extent to which the surface of a product approaches a plane.

Flattening Test (of tube)—See "Test—Flattening."

Flow Lines—See "Line— Flow."

Fluted Tube—See "Tube—Fluted."

Foil—Generally, a rolled product rectangular in cross section of thickness equal to or less than 0.0079 inch (Formerly 0.006 inch, changed to 0.0079 inch for international harmonization). There is an overlap in the thickness range 0.006-0.0079 inch defined for foil and sheet. Foil products in this gage range are supplied to foil product specifications.

Annealed—Foil completely softened by thermal treatment.

Bright—Foil having a uniform bright specular finish on both sides.

Chemically Cleaned—Foil washed in a chemical solution to remove lubricants and other foreign material.

Consumer (Household)—Foil intended for public use, principally for use in culinary applications such as cooking and storage.

Container—Single rolled foil with a gauge above approximately 0.0014 inch (35 µm), produced at soft or intermediate temper and often involving alloys of the 3xxx and 8xxx series intended for press forming into smooth or wrinkled walled containers for foodstuffs and the like.

Converter—Foil, typically soft annealed, supplied for further processing such as coloring, printing, embossing or laminating.

Embossed (Patterned)—Foil on which a pattern has been impressed or embossed on either one or both faces.

Etched—Foil roughened chemically or electrochemically to provide an increased surface area.

Hard—Foil fully work-hardened by rolling.

Intermediate Temper—Foil intermediate in temper between "Annealed" and "Hard".

Matte One Side (M1S)—Foil with a diffuse reflecting finish on one side and a bright specular finish on the other.

Mechanically Grained—Foil mechanically roughened for such applications as lithography.

Mill Finish (MF)—Foil having a non-uniform finish which may vary from coil to coil and within a coil.

Printed—Foil printed with a design or on all-over color.

Scratch Brushed—Foil abraded, usually with wire brushes, to produce a roughened surface.

Stock—Sheet suitable for further rolling to foil. See also "Reroll Stock."

Fold—See "Lap."

Forgeability—The term used to describe the relative workability of forging material.

Forging—Wrought product formed by hammering or pressing, typically when hot, between open dies (hand forging) or closed dies (drop or die forging). Additional terms referencing "Forging" include:

Blocker-type—A forging made in a single set of impressions to the general contour of a finished part.

Cold-coined—A forging that has been restruck cold in order to obtain closer dimensions, to sharpen corners or outlines and in non-heat-treatable alloys, to increase hardness.

Die—A forging shaped by working in closed dies.

Drop—A forging formed by a heavy die which drops on the metal.

Hammer—A forging produced by repeated blows of a forging hammer.

Hand—A forging worked between flat or simply shaped dies by repeated strokes or blows and manipulation of the piece, intending to convert the metallurgical structure from cast to wrought prior to machining into a final part.

Impact—A part formed in a confining die from a metal slug, typically cold, by rapid single stroke application of force through a punch, causing the metal to flow around the punch and/or through an opening in the punch or die.

Ingot—An ingot intended and suitable for forging.

Plane—A reference plane or planes normal to the direction of applied force from which all draft angles are measured.

Precision—A forging produced to tolerances closer than standard.

Rolled Ring—A cylindrical product of relatively short height, circumferentially rolled from a hollow section.

Stock—A solid product, typically ingot, rod, bar of profile, intended and suitable for forging. Forging stock is typically a cast product or an extruded product.

Upset—A forging having part or all of its cross section greater than that of the stock.

Formability—The relative ease with which a metal can be formed by rolling, extruding, drawing, deep drawing, forging, etc.

Fracture Test—See "Test—Fracture."

Fracture Toughness—A parameter indicating the resistance of a material to crack extension.

Fretting—See "Mark—Traffic."

Friction Scratch—See "Scratch—Friction."

Full Center—See "Buckle—Center."

Furnace Solution Heat Treatment—Heating an alloy to a suitable temperature in a furnace and holding for a sufficient time to allow one or more soluble constituents to enter into solid solution, where they are retained in a supersaturated state after quenching.

—G—

Galling—See "Pickup."

Gauge Length—The distance between two gauge marks on a test piece between which the test piece ruptures during a tensile test. The gauge length before applying the load is termed "Original Gauge Length." Sometimes the spelling "gage" is used.

Grain (Metal)—Crystal of uniform grid orientation within a metal. Addition terms referencing "Grain" include:

Equiaxed—Grains or crystals that have approximately the same dimensions in three axial directions.

Flow—Change of the shape of metal grains under the influence of hot or cold working.

Growth—Growth of larger metal grains at the expense of smaller ones.

Peripheral Coarse—An area of recrystallized grains at the periphery of an extruded product (or forged product if made from extruded stock), which has sometimes lower properties than the non-recrystallized core.

Size—Mean size of metal grains expressed in terms of the number of grains per unit area or unit volume, as the mean grain diameter or an appropriate index.

Twin Columnar Grains (TCG)—Macrostructure of rapidly solidified cast metal characterized by a twin plane in the centre of each dendrite stem parallel to the direction of crystal growth. Twin columnar grains are often termed "feather crystals."

Grinding—Removal of material by means of abrasives contained in, or bonded to, a rigid or flexible holder. See also "Linishing."

Grease Streak—See "Streak—Grease."

—H—

Hair, Slitter—Minute hair-like sliver along edge(s) due to shearing or slitting operation.

Handling Mark—See "Mark —Handling."

Hard Conversion—See "Conversion, Hard."

Hardener—An alloy containing at least some aluminum and one or more additional elements intended to be added to molten aluminum to adjust the chemical composition and /or to control the as cast structure. The term "Master Alloy" is used for different concepts in different regions and should be avoided. In Europe the term refers to hardeners obtained from melting and in the US the term refers to a hardener which combines several metallic elements in a fixed ratio and which is intended to be added to pure aluminum to provide a finished alloy composition. Hardeners can have various forms including waffles (obtained by casting the melt into an adequate mold), briquettes (obtained by compacting a powder), granules and wire.

Hardness—Resistance of a metal to plastic deformation, typically measured by indentation. Two common methods to determine hardness are:

> **Brinell, HB—**Resistance to penetration of a spherical indentor under standardized conditions. HB is approximately equal to 0.3 * Rm when Rm is the tensile strength, expressed in MPa. If tungsten carbide as indentor material is specified, e.g. ISO 6506-1, then the designation HBW is used.
>
> **Vickers, HV—**Resistance to penetration of a square-based pyramidal diamond indentor under standardized conditions. HV is approximately equal to 1.10 * HB.

Hardness Test—See "Test—Hardness."

Heat Streak—See "Streak —Heat."

Heat Treat Lot—See "Lot —Heat Treatment."

Heat Treat Stain—A discoloration due to non-uniform oxidation of the metal surface during solution heat treatment.

Heat Treatment—Heating, holding at elevated temperature and cooling of the solid metal in such a way as to obtain desired metallurgical structure or properties. Heating for the sole purpose of hot working (see "Preheating") is excluded from the meaning of this term. The term "Thermal Treatment" is used for the same concept as a synonym. See also "Solution Heat Treatment" and "Aging."

Heat-Treatable Alloy— See "Alloy—Heat-Treatable."

Helical-Welded Tube—See "Tube—Helical-Welded."

Herringbone—See "Streak—Herringbone."

High Lube—See "Lube—High."

Hole—Void in rolled product. See also "Mark—Inclusion."

Holiday—An uncoated area of a coated product due to non-wetting of the metal surface by the coating.

Homogenizing—A process whereby metal is heated to temperatures near the solidus temperature and held at that temperature for varying lengths of time in order to reduce microsegregation and to modify the form and composition of intermetallic phases, which typically results in an improved formability by hot and/or cold working.

Hook—See "Kink."

Hot Crack—A crack formed in a cast metal or in a welding because of internal stress developed on cooling at the solidus temperature or slightly above. For castings (only) the term "Hot Tear" is also used.

Hot Mill Pickup—See "Streak—Coating."

Hot Shortness—A condition of the metal at excessively high working temperatures characterized by low mechanical strength and a tendency for the metal to crack rather than deform.

Hot Spot—A dark grey or black surface patch on anodized extruded products caused by non-uniform cooling after extrusion. Hot spots are typically associated with lower hardness and coarse magnesium silicide precipitates.

Hot Tear—See "Tear, Speed."

Hot Working—Forming of a solid metal after preheating. Strain hardening may or may not occur during hot working.

Hydroforming—Forming of a hollow profile or a tube in a die by use of a liquid under high pressure.

—I—

Impact—A forged part formed in a confining die from a metal slug, typically cold, by rapid single stroke application of force through a punch, causing the metal to flow around the punch and/or through an opening in the punch or die. See also "Extrusion—Impact."

Impurity—Metallic or non-metallic element present in a metal, the minimum content of which is not controlled. Typically, the maximum concentration of an impurity in aluminum is controlled.

Inclusion—Extraneous material accidentally entrapped into the liquid metal during melting or melt treatment or entrapped into the metal surface during hot or cold working.

Inclusion, Stringer—See "Streak—Razor."

Incomplete Seam—See "Extrusion—Seam."

Indentation—Small hollow mark on the surface of the metal. An indentation is also termed "Pit."

Ingot—A cast product intended and suitable for remelting or forming by hot or cold working. See "Extrusion—Ingot," "Fabricating Ingot," "Forging—Ingot," "Remelt Ingot," "Reroll Stock," and "Rolling—Ingot."

Inspection Lot—See "Lot—Inspection."

Interleaving—The insertion of paper or application of suitable strippable coatings between layers of metal to protect from damage.

—K—

Kink—An abrupt deviation from straightness. The term "Hook" is sometimes used for this concept. For rolled products, this term is also used for an abrupt bend or deviation from flatness which is caused by localized bending during handling. See "Crease."

Knife Mark—See "Mark—Knife."

Knock-Out Mark—See "Mark—Knock Out."

Laminated Material—Composite material obtained by joining layers of different materials together by means other than metallic bonding, typically by gluing them together. Examples of laminated materials are paper on aluminum foil, extruded plastics films on aluminum foil, etc. Laminated material with a plastic core and aluminum skin on both sides is called "Aluminum Composite Material (ACM)."

Lamination—An internal crack or separation aligned parallel to the principal surfaces of a rolled product. See also "Back End Condition."

Lap—A discontinuity in a forging caused by metal flowing into a section from two directions. Also called a "Cold Shut."

Lap-Welded Tube—See "Tube—Lap-Welded."

Lateral Bow—See "Bow—Lateral."

Leveling—The mechanical flattening of plate, sheet or foil. The operation is carried out by stretching, local reverse bending, and other methods. These include:

> **Roller**—Flattening of plate or sheet by passing it between a series of staggered rolls.
>
> **Stretcher**—Leveling carried out by uniaxial tension.
>
> **Tension**—Flattening of a strip continuously on a series of staggered rolls with applied tension, thus stretching the strip while bending it.
>
> **Thermal**—Leveling carried out at an elevated temperature under an applied load normal to the surface to be flattened.

Leveler Chatter—See "Mark—Chatter."

Leveler Mark—See "Dent—Repeating."

Leveler Streak—See "Streak—Leveler."

Line—Several varieties include:Flow—The line pattern which shows the direction of flow on the surface.

Looper—Closely spaced symmetrical lines on the surface of a formed product, typically occurring after a deep drawing operation.

Lüders—Strain marks which appear between 45° and 55° to the straining direction are often termed "strain marks type B" or "Lüders lines." See also "Mark—Strain."

Line, Weld—See "Extrusion —Seam."

Liner—The slab of coating metal that is placed on the core alloy and is subsequently rolled down to clad sheet as composite.

Linishing—Grinding with a coarse abrasive to remove superficial defects, either to produce a decorative finish or preparatory to further processing. See also "Grinding."

Liquated Edge—See "Edge, Liquated."

Liquation—See "Segregation—Surface."

Liquidus Temperature—The temperature at which total melting of the solid is achieved upon heating from the solid state, or at which solid first appears upon cooling from the liquid state.

Lock Seam Tube—See "Tube—Lock Seam."

Log—See "Extrusion—Log."

Long Transverse Direction—See "Direction—Long Transverse."

Longitudinal Bow—See "Bow—Longitudinal."

Longitudinal Direction—See "Direction—Longitudinal."

Looper Line—See "Line—Looper."

Loose Wrap—See "Wrap, Loose."

Lot—Two types are:

Lot, Cast—A quantity of products cast from the same molten metal furnace charge. All of the ingots, strip, billets, or castings from the same molten metal charge are then considered to comprise a Cast Lot.

Lot, Continuous Casting—In the case of continuous casting, the producer can define a Cast Lot in different ways. If able to accurately relate ingots, etc. to a specific molten metal charge, then the definition is the same as "Lot, Cast". If not, a reasonable alternative would be to relate an individual Continuous Cast Lot to a period of time, for example, 4 hours.

Heat Treatment—Quantity of products of the same grade or alloy, form, thickness or cross-section and produced in the same way, heat-treated in one furnace load, or such products solution treated and subsequently precipitation treated in one furnace load. More than one solution-treatment batch can be included in one aging furnace load. For heat-treatment in a continuous furnace (vertical or horizontal), the products continuously heat-treated during a specified time (e. g. 8 hours) can be considered as one heat-treatment lot.

Inspection—Consignment or part thereof submitted for inspection or sampling, characterized by a set of identical criteria, e. g. grade or alloy, temper, size, shape, thickness or cross-section or fabrication batch.

Low Lube—See "Lube—Low."

Lube—Three terms are:

High—Nonconformity, when lubricant limit exceeds the maximum agreed upon limit measured in weight per unit area.

Low—Nonconformity, when the lubricant does not meet the minimum agreed upon limit measured in weight per unit area.

—M—

Spot—See “Spot, Lube.”

Lüders Line—See “Line—Lueders.”

Machining Stock—Bar or wire typically supplied to close tolerances and suitable for repetition machining operations. This product is sometimes referred to as “Screw Machine Stock” (SMS). See also “Screw Stock.”

Macrostructure—Structure of a metal as revealed by visual examination of a surface without any enhanced magnification, typically after mechanical and/or chemical preparation, e. g. machining and macro-etching. See also “Microstructure.”

Macro-Etching Test—See “Test—Macro-Etching.”

Mark—Damage in the surface of the product, e. g. indentations or raised surface If the source of the mark is known, a more precise composite term is used as follows:

Arbor—Surface damage in the vicinity of a coil ID caused by contact with a roughened, damaged or non-circular arbor.

Bearing—A depression in the extruded surface caused by a change in bearing length in the extrusion die.

Bite—Periodical imperfection on the surface of a rolled product, generally perpendicular to the rolling direction, because of a mark on a roll coating caused by the initial feeding of the ingot.

Block—See “Scratch—Tension.”

Bristle—Raised surface about one inch long, crimped wire shaped and oriented in any direction.

Carbon—Gray or black surface marking caused by contact with carbon runout blocks.

Chatter—Regularly spaced superficial marks, transverse to the rolling or extrusion direction, produced by vibration between the metal and the working surface during fabrication.

Drag—See “Rub, Tool.”

Edge Follower—Faint intermittent marks at the edge of a cold rolled product which are usually perpendicular to the rolling direction. This mark is caused by action of devices designed to rewind coils without weave.

Handling—See “Mark—Rub.”

Heat Treat Contact—Brownish, iridescent, irregularly shaped stain with a slight abrasion located somewhere within the boundary of the stain resulting from metal-to-metal contact during the quenching of solution heat-treated flat sheet or plate.

Herring Bone—Superficial markings taking the form of alternate light and dark bands forming a V or W pattern across the width of rolled metal. See also “Mark—Strain.”

Inclusion—A mark in a metal surface resulting from an inclusion. The term includes marks with still visible inclusions or voids from which the inclusions have left.

Knife—A continuous scratch (which may also be creased) near a slit edge of a rolled product, caused by sheet contacting the slitter knife.

Knock-Out—A small solid protrusion or circular fin on a forging or a casting, resulting from the depression of a knock-out pin under pressure or inflow of metal between the knock-out pin and the die or mold.

Metal-on-Roll—See “Dent—Repeating.”

Mike—Narrow continuous line near the rolled edge caused by a contacting micrometer.

Pinch—Pressed-in folds in rolled products, generally running parallel to the direction of rolling.

Reeling—Superficial spiral markings present on round extruded or drawn products that have been straightened by reeling.

Ripple—Optical surface effect in the form of a very slight repeated transverse wave or shadow mark, sometimes encountered with rolled or drawn products.

Roll Periodic—Raised or depressed area on a rolled product formed during rolling by the imprint of a damage on the roll. The repeat distance is a function of the offending roll diameter.

Roll Bruise—A greatly enlarged roll mark whose height or depth is very shallow. See also “Mark—Roll.”

Roll Skid—A full width line perpendicular to the rolling direction and repeating as a function of a work roll diameter.

Rub—A mark consisting of a large number of very fine scratches or abrasions. A rub mark can occur by metal-to-metal contact, movement in handling and movement in transit. Rub marks are often termed “Friction Scratches”. More severe forms of rub marks, caused by handling are often termed “Handling Marks” or “Handling Scratches.” See “Mark—Handling” and “Scratch—Handling.”

Snap—A band-like pattern around the full perimeter of an extruded section and perpendicular to its length caused by an abrupt change of an extrusion parameter during the process. If the extrusion process is abruptly suspended, then the term “Stop Mark” is used. See also “Mark—Stop.”

Stop—A transverse peripheral ridge on a product arising from a stoppage during rolling, extrusion or drawing. See also “Mark—Snap.”

Strain—Surface patterns on formed products of some alloys after straining. Stochastical flamboyant strain marks which can appear at low strain levels are often termed “Strain Marks of Type A”. Strain marks which appear between 45° and 55° to the straining direction are often termed “Strain Marks of Type B” or “Lueders Lines.”

Stretcher Grip—Transverse indentation at the ends of a product impressed by the grips of a stretching machine. See also "Mark—Stretcher Jaw."

Stretcher Jaw—A cross hatched appearance left by jaws at the end(s) of metal that has been stretched if insufficient metal has been removed after the stretching operation.

Stretcher Strain—A permanent surface distortion in the form of either flamboyant patterns or Lueders lines that can appear under certain conditions on stretched extruded products. The onset of these markings varies according to the type of metal and the degree of stretching.

Tab—See "Buckle—Arbor."

Tail—See "Mark—Roll Bruise."

Take Up—See "Scratch—Tension."

Traffic—Abrasions, typically dark in color, resulting from relative movement between metal surfaces during handling and transit, e. g. during the cooling of profiles on the run-out table. A mirror image of a traffic mark is observed on the adjacent contacting surface.

Vent—A small protrusion on a forging resulting from the entrance of metal into a die vent hole.

Whip—Surface abrasion on a rolled product, generally diagonal to the rolling direction, caused by a fluttering action of the metal as it enters the rolling mill.

Master Alloy—This term should be avoided. See "Hardener."

Master Coil—A coil processed to final temper as a single unit, intended to be slit and/or cut into smaller coils or into individual sheets or plates. In North America, the preferred term is "Parent Coil" for this concept. See also "Plate—Master (Parent)."

Mean Diameter (of round rod/bar or tube)—Average of any two diameters measured at right angles in the same cross-sectional area.

Mean Wall Thickness (of tube)—Average of the largest and the smallest wall thickness of tube measured in the same plane perpendicular to the axis of the tube.

Mechanical Properties—Properties of a material that are associated with elastic and inelastic reaction when force is applied, or that involve the relationship between stress and strain; for example, modulus of elasticity, tensile strength, endurance limit. These properties are often incorrectly referred to as "Physical Properties." The mechanical properties obtained by a tensile test, e.g. modulus of elasticity in tension, tensile strength and elongation are often termed "Tensile Properties."

Mechanical Polishing—Polishing with a flexible rotating mop carrying an abrasive compound.

Melt—Quantity of molten metal that has simultaneously undergone the same preparatory treatment in the furnace before the casting operation.

Microstructure—Structure of a metal as revealed by microscopic examination of a surface, typically after mechanical and/or chemical preparation, e. g. polishing and micro-etching. See also "Macrostructure."

Mike Mark—See "Mark, Mike."

Mismatch—Deviation of a die forging from the specified form caused by opposing die halves not being in perfect alignment.

Modulus of Elasticity (Young's Modulus)—The ratio of stress applied to a material to corresponding strain throughout the range where they are proportional. As there are three kinds of stresses, so there are three kinds of moduli of elasticity for any material—modulus of elasticity in tension, modulus of elasticity in compression, and modulus of elasticity in shear (shear modulus).

Mottling, Pressure—Non-uniform surface appearance of a laminated product resulting from uneven pressure distribution between adjacent layers of the product.

Mullen Test—See "Test—Mullen."

—N—

Natural Aging—See "Aging—Natural."

Nick—Rolled products, see "Scratch." Extrusions, see "Mark, Handling."

Non-Heat-Treatable Alloy—See "Alloy—Non-Heat-Treatable."

Nonfill—Deviation of a die forging from the specified form caused by failure of metal to fill a forging die impression.

Notch, Double Shear—An abrupt deviation from straight on a sheared edge. This offset may occur if the flat sheet or plate product is longer than the blade for the final shearing operation.

—O—

Off Gauge—Deviation of a dimension of a product, e. g. width or wall thickness, from the specified tolerances.

Offset—Yield strength by the "offset method" is computed from a load-strain curve obtained by means of an extensometer.

Oil Stain—See "Stain—Oil."

Orange Peel—A surface pattern on formed products that occurs when a coarse grain structure is present in the formed surface of the metal.

Oscillation—Uneven wrap in coiling and lateral travel during winding. Improper alignment of rolls over which the metal passes before rewinding and insufficient rewind tension are typical causes. See also "Telescoping."

Out-of-Register—An embossed pattern distortion due to misalignment of the male and female embossing rolls.

Ovality—Departure of the cross-section of a round tube, rod or bar or wire from a true circle.

Overheating—Heating a product, beyond the intended temperature, which may result in the melting of certain constituents and a reduction in mechanical properties. Typically, overheated metal cannot be reclaimed by thermal or mechanical treatment.

Oxide Discoloration—See "Stain—Heat Treat."

—P—

Pack Rolling—A term sometimes used for the concept of double rolling. See "Rolling—Double".

Painted Sheet—See "Sheet—Painted."

Parent Coil—A coil processed to final temper as a single unit, intended to be slit and/or cut into smaller coils or into individual sheets or plates. See "Master Coil", the preferred term outside of North America.

Parent Plate—A plate processed to final temper as a single unit, intended to be cut into smaller plates.

Partial Annealing—See "Annealing—Partial."

Parting Line—A condition unique to stepped extrusions where more than one cross section exists in the same extruded shape. A stepped shape uses a split die for the minor or small cross section and after its removal, another die behind it for the major configuration. Slightly raised fins can appear on that portion of the shape where the two dies meet. See also "Profile—Stepped Extruded."

Patterned Sheet—See "Foil—Embossed" and "Sheet—Embossed."

Perforation—Hole in foil with a maximum diameter >0.008 inch (> 0.2 mm) which occurs randomly throughout the rolled coil length. See also "Pinhole" and "Roll Hole."

Physical Properties—The properties, other than mechanical properties, that pertain to the physics of a material; for example, density, electrical conductivity, heat conductivity, thermal expansion.

Pick-Off—The transfer of portions of the coating from one surface of the sheet to an adjacent surface due to poor adhesion of the coating.

Pickup—Irregular surface appearance caused by intermittent adhesion between the forming tools and the metal. The condition of excessive friction between the forming tool and the metal is often termed "Galling."

Pickup, Repeating—See "Dent—Repeating."

Pickup, Roll—See "Streak— Coating."

Pick-Ups—Torn, comma-like spots on the surface of extruded products caused by a local material deposition on the surface of the die.

Pinch Mark—See "Mark—Pinch."

PinholeVoid(s) in foil of gauge below 0.001 inch (20 µm) of normally round or oval shape with a maximum diameter <0.008 inch (< 0.2 mm), randomly distributed. See also "Perforation" and "Roll Hole."

Pipe—Tube in standardized combinations of outside diameter and wall thickness.Pipe is commonly designated by "Nominal Pipe Sizes" and "ANSI Schedule Numbers."Additional terms referencing "pipe" include:

Drawn—Pipe brought to the final dimensions by drawing through a die.

Extruded—Pipe formed by hot extruding.

Seamless—Pipe which does not contain any line junctures (metallurgical welds) resulting from the method of manufacture. (Note: This product may be produced by extruding or by drawing using either die-and-mandrel or hot piercer processes.)

Structural—Pipe commonly used for structural purposes.

Piping—See "Back End Condition."

Pit—See "Indentation."

Pitting—See "Corrosion—Pitting."

Plate—A rolled product that is rectangular in cross section and with thickness not less than 0.250 inch (6 mm) with sheared or sawn edges. Additional terms referencing "Plate" include:

Alclad—Clad plate having on one or both surfaces a metallurgically bonded aluminum coating that is anodic to the core, thus electrolytically protecting the core against corrosion. If one side only is clad, the product is often named "Alclad One Side Plate."

Baseplate—Thick, stable plate having a horizontal surface of a very high, controlled flatness, mainly used for controlling the straightness, flatness, twist, etc., of rolled and extruded products.

Clad—Plate consisting of an aluminum core to which a thin layer of aluminum or another metal is metallurgically bonded on one side or on both sides, typically by rolling.

Circle Stock—Plate intended to be sawn, sheared or blanked into circles to be subsequently formed, drawn, etc.

Cold Rolled—Plate the final thickness of which is obtained by cold rolling.

Hot Rolled—Plate the final thickness of which is obtained by hot rolling. A reroll plate is often called "Slab."

Machined—Semi-finished product produced from a plate completely machined over one or two sides.

Master (Parent)—Plate processed to final temper as a single unit, intended to be cut into smaller plates.

Mill Finish—Plate having a finish defined by the actual roll grinding and rolling conditions, without further specification from a customer or a standard. The appearance of mill finish plate can vary from plate to plate or within one plate.

Milling—Machining process in which metal is removed by a revolving multi-edged cutter to provide flat or profile surfaces. Removal of metal by etching is often termed "chemical milling."

Tooling—Cast or rolled product of rectangular cross-section not less than 0.250 inch (6 mm) in thickness, and with edges either as-cast, sheared or sawn, with internal stress levels controlled to achieve maximum stability for machining purposes in tool and jig applications.

Tread—Plate (or sheet) upon which a pattern has been impressed on one side by rolling using a specially prepared roll with an appropriate pattern, to provide improved traction.

Pop, Solvent—Blister and/or void in the coating resulting from trapped solvents released during curing process.

Porosity—Fine holes or pores within a cast metal. Additional terms referencing "Porosity" include:

Gas—Porosity caused by entrapped gas or by evolution of dissolved hydrogen during solidification.

Precipitation Hardening**—**See "Aging—Precipitation Hardening."

Preheating—A process in which the material is raised to an elevated temperature for the start of the first operation of forming solid metal. In some cases preheating can be combined with homogenization.

Pressure Mottling—See "Mottling, Pressure."

Pressure Test—See "Test—Pressure."

Profile—A wrought product that is long in relation to its cross-sectional dimensions which is of a form other than that of sheet, plate, rod, bar, tube, wire or foil. For profiles sometimes the term "Shape" or "Section" is used. Additional terms referencing "Profile" include:

Cold-Finished—A profile brought to final dimensions by cold-working to obtain improved surface finish and dimensional tolerances.

Drawn—A cold finished profile brought to final dimensions by drawing through a die.

Extruded—A profile brought to final dimensions by extruding.

Hollow—A profile in which the cross section completely encloses one or more voids.

Precision—A profile which fulfils special requirements concerning tolerances on form and dimensions.

Seamless—A hollow profile which does not contain any line junctures resulting from method of manufacture.

Semi-Hollow—A solid profile any part of whose cross section is a partially enclosed void, the area of which is substantially greater than the square of the width of the gap. The ratio of the area of the void to the square of the gap is dependent on the class of semi-hollow profile, the alloy and the gap width.

Solid—A profile in which the cross-section does not include any enclosed void.

Stepped Extruded—An extruded profile whose cross section changes abruptly in area at intervals along its length.

Structural—A profile, rolled or extruded, commonly used for structural purposes such as angles, channels, H-beams, I-beams, tees, and zees.

Proof Strength—See "Yield Strength."

—Q—

A characteristic assigned to a product, process or system (e.g. the price of a product, the owner of a product) is not a quality characteristic of that product, process or system. For aluminum products a quality characteristic can be a dimension, a mechanical property, a physical property, a functional characteristic, or the appearance.

See also "Structural Quality Characteristic" and "Visual Quality Characteristic."

Quarter Buckle—See "Buckle—Quarter."

Quenching—Cooling a metal from an elevated temperature by contact with a solid, a liquid or a gas, at a rate rapid. Additional terms referencing "Quenching" include:

Air—Quenching of a product by forced air, e. g. ventilators.

As-Quenched Condition—Condition of an alloy during the time immediately following quenching and before the mechanical properties have been significantly altered by precipitation hardening.

Critical Quenching Rate—Minimum mean cooling rate from solution treatment temperature necessary to enable an alloy to possess certain mechanical properties in the precipitation hardened condition.

Hot Line Quenching—Quenching of a rolled product on its exit from hot mill.

Incubation Period—The interval between the quenching operation and the start of a significant change in properties produced by precipitation hardening.

Press Quenching—Quenching of an extruded product on its exit from the extrusion press.

Transfer Period (Quenching)—The time between removing the metal from the solution treatment furnace and contact with the quenching medium.

Quenching Stress—Non-uniform stress retained within the metal after quenching. See also "Residual Stress."

—R—

Razor Streak—See "Streak—Razor."

Rear End Condition—See "Back End Condition."

Recrystallization—Nucleation and growth of new undeformed metal grains in a deformed metal. Deformed metal grains are characterized by a tight network of dislocations. "Critical Strain" is the minimum amount of cold work or cold deformation necessary to initiate recrystallization during subsequent annealing or solution heat treatment. One can distinguish between the lower critical strain corresponding to the onset of the recrystallization, which typically causes coarse grain, and the somewhat higher upper critical strain which produces a fine recrystallized grain.

Redraw Rod—This term is not recommended. The term "Drawing Stock" is preferred.

Refined Aluminum—See "Aluminum—Refined.

Reeling—Winding of a wire onto a reel, bobbin or drum. See also "Straightening—Roller."

Reflector Sheet—See "Sheet—Reflector." Reheating—Heating metal again to hot-working temperature. In general no structural changes are intended.

Remelt Ingot—Ingot intended and suitable for remelting. Large ingots for remelting, typically having a mass of about 1000 pounds, are often called "sows." Small ingots for remelting typically having a mass of about 50 pounds are often called "pigs."

Re-Oil—Oil put on the sheet after cleaning and before coiling for shipment to prevent water stain.

Reroll Stock—Coiled sheet suitable and intended for further rolling. See also "Can Stock", "Fin Stock", "Foil— Stock" and "Sheet Stock."

Reverse Side (of Sheet)—The side of the sheet which is opposite to the top side. See "Top Side (of Sheet)."

Rivet Stock— Bar or wire suitable for the manufacture of rivets. The terms "Cold Heading Rod" or "Cold Heading Bar" are often used for this concept.

Rod—A solid wrought product of circular cross section that is long in relation to its diameter, typically supplied in straight length. In North America, the minimum diameter of a rod is 0.375 inch; below this limit, the product is called "Wire." In Europe, a rod is supplied in straight length and is often called "Round Bar"; if supplied in coiled form, the product is called "Wire." Additional terms referencing "Rod" include:

- **Alclad—**Composite rod product comprised of an aluminum alloy rod having on its surface a metallurgically bonded aluminum or aluminum alloy coating that is anodic to the core alloy to which it is bonded, thus electrolytically protecting the core alloy against corrosion.
- **Brazing—**Rod of a low melting temperature alloy for use as filler metal in brazing.
- **Cold-Drawn—**Rod brought to final dimensions by cold-drawing through a die.
- **Cold Heading—**See "Rivet Stock."
- **Extruded—**Rod brought to final dimensions by extruding.
- **Rolled—**Rod brought to final dimensions by hot rolling.
- **Welding—**Rod for use as filler metal in joining by welding.

Roll Chatter—See "Mark—Chatter."

Roll Coating—See "Streak—Coating."

Roll Grind—The uniform ground finish on the work rolls which is imparted to the sheet or plate during rolling.

Roll Hole—Hole in foil with a maximum diameter >0.008 inch (> 0.2 mm) which occurs at regular intervals throughout the rolled coil length. See also "Perforation" and "Pinhole."

Roll Mark—See "Mark—Roll."

Roll Pickup—See "Streak—Coating."

Rolled Ring—See "Forging—Rolled Ring."

Rolled-In Dirt—See "Dirt."

Rolled-in Metal—Particle of metal, other than the parent metal, rolled into the surface of the product. Rolled-in particle of the parent metal is called "Sliver." See "Sliver."

Rolled-In Scratch—See "Scratch—Rolled-In."

Rolling—Forming of solid metal in a gap between two rotating cylinders. Additional terms referencing "Rolling" include:

- **Cold—**Rolling without preheating.
- **Double—**Simultaneous rolling of two foil webs in the same gap with the two webs in contact. Sometimes the term "Pack Rolling" is used for this concept.
- **Hot—**Rolling after preheating. The purpose of hot rolling is typically to improve the efficiency of the rolling process. Surface finish and dimensional tolerance control of hot rolled metal are generally inferior to cold rolled metal.

Ingot—Ingot intended or suitable for rolling. See "Fabricating Ingot." Nomenclature of a rolling ingot includes:

- **Butt—**The end of a semi-continuously cast ingot corresponding to the start of the cast. This term can refer to the removed butt or to the relevant extremity of the ingot.
- **Edge—**One of the narrow faces (plane or of a specific geometry) of a rolling ingot parallel to the casting axis.
- **Head—**The end of a semi-continuously cast ingot corresponding to the end of the cast. This term can refer to the removed head or to the relevant extremity of the ingot. Rolling Face—One of the wide faces of a rolling ingot.

Slab—See "Plate—Hot Rolled."

Temper—Controlled reduction by rolling to develop the required mechanical properties.

Roofing Sheet—See "Sheet—Roofing."

Roundness—This term is not recommended. See "Ovality."

Rub Mark—See "Mark—Rub."

Rub, Tool—A surface area showing a scratch or abrasion resulting from contact of the hot extrusion with the press equipment or tooling or, in the case of multi-hole dies, with other sections as they exit the press. See also "Torn Surface."

—S—

Sample—Representative part, portion or piece of an inspection lot selected for inspection or testing. Additional terms referencing "Sample" include:

Layout—A prototype of a product, typically a casting or a forging, that has been subjected to detailed measurement to demonstrate conformance to an engineering drawing which sets forth the required characteristics. A layout sample can be the "first article" of a production or a sample taken out of the running production.

Limiting—A sample or specimen showing to which extent quality characteristics of a product are acceptable. Limiting samples typically demonstrate "just acceptable" and "just unacceptable" forms of a quality characteristic.

Saw Plate Bar—See "Bar, Saw Plate."

Scalping—Removal of the surface layer from an ingot or a semi-finished wrought product so that surface imperfections will not be worked into the finished product.

Scratch—Sharp linear indentation in the surface of the metal. Additional terms referencing "Scratch" include:

Drawn-In—A scratch occurring during the fabricating process and subsequently drawn over, making it relatively smooth to the touch.

Friction— See "Mark—Rub."

Handling—A more severe form of rub mark. See "Mark—Rub."

Machine—A straight indentation in the rolling direction of a rolled product, caused by contact with a sharp projection on the equipment.

Oven—A scratch that is caused by moving contact of coating against a non-moving object in an oven.

Rolled-In—A scratch that occurs during the fabricating process and is subsequently rolled over. A rolled-in scratch often appears as a grayish white ladder showing distinct transverse lines within the longitudinal indentation.

Slippage—See "Scratch—Tension."

Tension—A short longitudinal indentation parallel to the rolling direction of rolled products, resulting from relative movement between adjacent wraps of the coil during unwinding or rewinding. A tension scratch is sometimes termed "Block Mark."

Screw Stock—Bar or wire suitable for the manufacture of screws. See also "Machining Stock."

Seam, Extrusion—See "Extrusion—Seam."

Seamless—See "Profile—Seamless" and Tube—Seamless."

Section—See "Profile."

Segregation—Non-uniform distribution or concentration of impurities or alloying elements that arises during the solidification of an ingot. Additional terms referencing "Segregation" include:

Gravity—Macrosegregation caused by the settling out of heavy constituents, or rising of light constituents in a solidifying melt.

Inverse—Macrosegregation caused by interdendritic

liquid metal in a solidifying ingot or casting which is sucked towards its surface, due to volume shrinkage caused by solidification.

Macrosegregation—Segregation over macroscopic distances.

Microsegregation—Segregation over microscopic distances, typically associated with cellular or dendritic solidification.

Surface (Unwrought Product)—Thin surface layer of a cast metal characterized by concentrations of the alloying elements significantly different from the concentration in the melt. The layer is generated by interdendritic liquid metal which has been pushed through the surface of the cast metal during solidification by gravity. Surface segregation layers of non-uniform thickness which give a cast surface a characteristic appearance are also called "Liquations."

Serpentine Weave—See "Snaking."

Shape—This term is no longer recommended. The term "Profile" is preferred. See "Profile."

Shaving—Drawing of a rod, tube or wire through a die with a cutting edge in order to remove a thin layer from its surface.

Shear Strength—The maximum gross stress, i.e. maximum force divided by original cross section, which a material withstands before fracture when submitted to a shear test. Shear strength is an important quality characteristic of rivets. The shear strength is normally about 60% of the tensile strength.

Shearing—Cutting of metal by the use of a press or guillotine.

Sheet—Generally, a rolled product that is rectangular in cross section with thickness greater than 0.006 inch and less than 0.250 inch and with slit, sheared or sawed edges. There is an overlap in the thickness range of 0.006-0.0079 inch defined for foil and sheet. Sheet products in this gage range are supplied to sheet product specifications.

Alclad—Clad sheet having on one or both surfaces a metallurgically bonded aluminum coating that is anodic to the core, thus electrolytically protecting the core against corrosion. If one side only is clad, the product is often named "Alclad One Side Sheet."

Anodizing—Sheet with metallurgical characteristics and surface quality suitable for the development of protective and decorative films by anodic oxidation processes.

Brazing—Sheet of a low melting point alloy or clad with a low melting point alloy used for brazing.

Circle—Sheet, intended to be sawn, sheared or blanked into circles to be subsequently formed, drawn, etc.

Clad—Sheet consisting of an aluminum core to which a thin layer of aluminum or another metal is metallurgically bonded on one side or on both sides, typically by rolling.

Cold Rolled—Sheet the final thickness of which is obtained by cold rolling.

Coiled—Sheet in coils with slit edges.

Corrugated—Roll-formed sheet of symmetric or asymmetric profile.

Embossed—See "Sheet—Patterned."

Flat—Sheet with sheared, slit or sawed edges, which has been flattened or leveled.

Hot Rolled—Sheet the final thickness of which is obtained by hot rolling.

Lithographic—Sheet having a superior finish on one side with respect to freedom from surface imperfections and supplied with a maximum degree of flatness for use as a plate in offset printing.

One Side Bright Mill Finish—Sheet having a moderate degree of brightness on one side and a mill finish on the other.

Mill Finish—Sheet having a finish defined by the actual roll grinding and rolling conditions, without further specification from a customer or a standard. The finish of mill finish sheet can vary from sheet to sheet or within one sheet.

Painted—Sheet, one or both sides of which has a factory-applied paint coating of controlled thickness.

Patterned—Sheet on which a raised or indented pattern has been impressed or embossed on either one or both faces.

Reflector—Sheet with special requirements related to the surface quality intended and suitable for the manufacture of reflectors.

Roofing—Sheet intended and suitable for roofing application.

Satin-Finish—Sheet with a fine-textured matte finish on one or both surfaces.

Stock—See "Reroll Stock."

Tread—See "Plate—Tread."

Short Transverse Direction—See "Direction—Short Transverse."

Shot Blasting—The projection of abrasive grit, i.e. sand, small particles of steel, glass, plastic beads or other materials, or a mixture of abrasive grit, water and air on a product in order to in order to obtain a roughened surface topography. Depending upon the particle size used for this process, a matt or satin finish is produced. Surface contamination from the blast media can require additional cleaning. The term "blast cleaning" is also used for this concept.

Shrinkage—Contraction that occurs when metal cools from the hot working temperature.

Shrinkage Cavity—Void left in cast metals as a result of solidification shrinkage.

Side Crack—See "Edge—Broken (Cracked)."

Side Set—A difference in thickness between the two edges of plate, sheet or foil.

Skin Pass—A light cold rolling of sheet or strip to improve or modify the surface finish and to minimize stretcher strain on further manipulation. This operation can increase the yield strength and to a lesser extent the tensile strength.

Skip—An area of uncoated sheet which is frequently caused by equipment malfunction.

Slab—See "Plate—Hot Rolled."

Slippage Scratch—See "Scratch— Tension."

Slitter Hair—See "Hair—Slitter."

Slitting—Cutting of a coiled sheet into two or more widths by the use of rotary shears.

Sliver—Thin elongated piece of the parent metal on the surface of a product, completely or partially detached. A sliver is often rolled-over surface damage.

Slug—A piece of metal of uniform thickness, of regular or irregular shape taken from a wrought product, typically for impact extrusion, with or without a center hole. This term is also used for cast or thyxocast pieces to be formed in semisolid condition (thyxoforming).

Smudge—A dark film of debris, sometimes covering large areas, deposited on the sheet during rolling or left on the surface of a metal after electroplating or etching.

Smut—See "Smudge."

Snaking—A series of reversing lateral bows in coil products. This condition is caused by a weaving action during an unwinding or rewinding operation.

Soft Conversion—See "Conversion, Soft."

Solidus Temperature—The temperature at which liquid first appears upon heating from the solid state. For some alloys, prior homogenizing may significantly raise the solidus temperature (AA7075 for example). Exceeding the solidus temperature during heat-treating has extremely deleterious effect on material properties.

Solution Heat Treating—Heating an alloy to a suitable temperature for sufficient time to allow one or more soluble constituents to enter into solid solution where they are retained in a supersaturated state after quenching. This process can occur in an extrusion press, a furnace, a forging press or a hot rolling mill.

Solvent Pop—See "Pop, Solvent."

Specimen—That portion of a sample taken for evaluation of some specific characteristic or property for the purpose of producing test pieces. In North America, the term "Coupon" is often used instead. See also "Test Piece."

Speed Crack—See "Tear, Speed."

Speed Tear—See "Tear, Speed."

Spot, Lube—A non-uniform extraneous deposit of lube on the coated sheet.

Spring Back Effect—The elastic partial recovery of a metal after a cold forming operation such as bending. Lack of this effect is termed "dead fold."

Squareness—Characteristic of having adjacent sides,planes or axes meeting at 90°.

Stabilizing—A thermal treatment, typically at low temperatures, used to accelerate constitutional or structural changes in a solid metal in order to promote stability in dimensions, in mechanical properties, in structure or in internal stress under service conditions.

Stain—A surface discoloration. Additional terms referencing "Stain" include:

Diffusion—Patchy discoloration, which may vary from gray to brown, that can arise from diffusion in clad metal. When diffusion staining has the form of a streak, then the term "Diffusion Streak" is used. See "Streak—Diffusion.

Heat Treat—A discoloration due to non-uniform oxidation of the metal surface during heat treatment.

Oil—Surface discoloration which may vary from dark brown to white, produced during thermal treatment by incomplete decomposition of residual lubricants on the surface.

Saw Lubricant—Yellow to brown area of surface discoloration at the ends of the extruded length, caused by certain types of saw lubricants if they are not removed from the metal prior to the thermal treatment.

Water—See "Corrosion—Water Stain."

Sticking (of Foil)—Adherence of contacting foil surfaces in a coil sufficient to interfere with the normal ease of unwinding.

Straightening—Correcting operation of a drawn or extruded product, to fulfill the requirements concerning tolerances on form and dimensions. Additional terms referencing "Straightening" include:

> **Roller—**Straightening of an extruded or drawn product by passing it through a series of adequately arranged rolls. For round products, this process is typically called "Reeling."

Straightness—The extent to which the axis or the edge of a product approaches a straight line.

Strain—A measure of the change in size or shape of a body due to stress, relative to its original size or shape. Tensile or compressive strain is the change, due to force, per unity of length in an original linear dimension in the direction of the force. It is typically measured in percent. See also "Recrystallization."

Strain Hardening—Modification of a metal structure by cold working resulting in an increase in strength and hardness, generally with loss of ductility.

Streak (Stripe)—A superficial band or line which produces a non-uniform surface appearance. Wide streaks are often termed "stripes." According to the source or appearance of the streak, a more precise composite term is used, e. g. "Dirt Streak." Additional terms referencing "Streak" include:

> **Bearing—**A longitudinal discoloration, typically lighter than the surrounding metal that can occur—as a result of uneven cooling—where there are large changes in wall thickness.
>
> **Bright—**A bright superficial band or elongated mark which produces a non-uniform surface appearance.
>
> **Buff—**A dull continuous streak caused by smudge buildup on a buff used at shearing or other operations.
>
> **Burnish—**A bright region on the sheet caused by excessive roll surface wear.
>
> **Coating—**A banded surface appearance on a rolled product caused by nonuniform adherence of roll coating to a work roll during hot and/or cold rolling. If generated in the hot rolling process, it is also called "Hot Mill Pickup."
>
> **Diffusion—**Diffusion staining that has the form of a streak, which may vary from gray to brown, and that can arise from diffusion in clad metal. See "Stain—Diffusion."
>
> **Dirt—**Surface discoloration which may vary from gray to black, is parallel to the direction of rolling, and contains rolled in foreign debris. It typically results from extraneous material that drops from an overhead location onto the rolling surface and is shallow enough to be removed by etching or buffing.
>
> **Grease—**A narrow discontinuous streak caused by excessive lubricant dripping on the surface of the rolled product during rolling.
>
> **Grinding—**A streak with a helical pattern appearance transferred to a rolled product from a work roll.
>
> **Heat—**Milky colored band(s) parallel to the rolling direction which vary in both width and exact location along the length.
>
> **Herringbone—**Elongated alternately bright and dull chevron markings. See also "Mark—Strain."
>
> **Leveler—**A streak on the sheet surface in the rolling direction caused by transfer from the leveler rolls.
>
> **Pickup—**See "Streak—Coating."

Razo—A thin streak on the surface of a wrought product, only visible after chemical or electrochemical surface treatment, caused by an inclusion or a cluster of inclusions in the metal which has been elongated during hot and/or cold working. Razor streaks are often termed "stringer inclusions"

Structural—A streak on etched or anodized surfaces resulting from a non-homogeneous distribution of intermetallic phases in the metal, resulting from the solidification conditions of the ingot.

Stress—Force per unit of area. Stress is normally calculated on the basis of the original cross-sectional dimensions. The three kinds of stresses are tensile, compressive, and shear. Additional terms referencing "Stress" include: Corrosion Cracking—See "Corrosion—Stress Cracking."

Internal—Stress set up within a metal as a result of previous operations, e. g. casting, thermal treatment or working. Relieving—The reduction of internal residual stresses by thermal or mechanical means.

Residual—Internal stress left in the finished product after all fabricating operations, including stress relieving where applicable, have been carried out.

Stretcher Strain—See "Line—Lueders."

Stretching—Imparting sufficient permanent set by applying a unidirectional force to cause strain hardening and reduce internal stress and distortion. Examples include flattening of rolled metal and straightening of extruded or extruded and drawn metal."

Striation—Longitudinal non-uniform coating thickness caused by uneven application of the liquid coating.

Strip—In Europe, the term "Strip" is only used for coiled sheet whereas the term "Sheet" is only used for rolled products supplied in straight length.

Structural Quality Characteristic—A quality characteristic caused by an inadequate microstructure or macrostructure.

Structural Streak—See "Streak—Structural."

Suck-In—A defect caused when one face of a forging is sucked in to fill a projection on the opposite side.

Superplastic Forming—Forming of alloy sheet, typically biaxial, which has been specially processed to have fine grain size and a low flow stress at a critical strain rate and temperature, resulting in very large plastic deformation. Forming is typically carried out using low gas pressure to force to sheet against a single surface tool.

—T—

Tab Mark—See "Buckle—Arbor."

Tail Mark—See "Mark—Roll Bruise."

Take Up Mark—See "Scratch—Tension."

Tear, Speed—Transverse surface cracks, preferentially in corner radii or extremities of a profile, caused by localized high temperature. Also called "Speed Crack."

Telescoping—Lateral stacking, primarily in one direction, or wraps in a coil so that the edges of the coil are conical rather than flat. Improper alignment of rolls over which the metal passes before rewinding is a typical cause. See also "Oscillation."

Temper—The condition of the metal produced by mechanical and/or thermal processing, typically characterized by a certain structure and specified properties.

Tensile Strength—The ratio of maximum load before rupture in a tensile test to original cross-sectional area. Also called "Ultimate Tensile Strength."

Tensile Test—See "Test—Tensile."

Tension Scratch—See "Scratch—Tension."

Test—An operation to which the test piece is subjected in order to measure or classify a property. Additional terms referencing "Test" include:

Bend—A test intending to assess bending characteristics and ductility of a product by bending a test piece under defined conditions, typically with a predetermined radius and angle. The predetermined radius is called "Bend Radius."

Bore (of tube)—A test on tube to verify freedom from constriction by passing a metallic bob or wire of specified dimensions through the tube.

Cut-Up (of forging)—A destructive test carried out on a forging to verify details of the grain flow and mechanical properties in various positions in the forging.

Drift Expanding (of tube)—See "Test—Flare."

Dye Penetrant/Liquid Penetrant Inspection—A non-destructive test characterized by the following steps:

(1) immersing the clean and degreased test piece in a dye penetrant or covering it with a layer of dye penetrant;

(2) removing the residual superfluous dye penetrant from the surface of the test piece after a specified period;

(3) visual control of the surface of the test piece, possibly after a developer has been applied, to see if the dye seeps out from any flaws and cracks. The dye can be a fluorescent dye which can be detected by means of an U.V. lamp.

Earing—A test consisting of deep-drawing of a blank into a cup in order to assess the earing properties of the metal.

Eddy Current—A non-destructive test in which eddy-current flow is induced in the test piece, mainly for the assessment of different properties, e. g. the soundness of tubes, presence of specific surface or sub-surface defects, microstructure or thickness of surface layers.

Erichsen—A cupping test in which a piece of sheet metal, restrained only at the periphery, is deformed by a cone-shaped spherically ended plunger until fracture occurs. The height of the cup in millimeters at fracture initiation is a measure of the ductility.

Flanging—A test in which a disc-shaped rim of predetermined size is formed at the end of a tube or hollow profile test piece to assess its suitability for specific application, e. g. the manufacture of tubular rivets or flanged products. The flanging test typically assesses the soundness of extrusion seams.

Flare (of tube)—A diametrical expansion of the end of a tube sample to a predetermined amount by the insertion of a cone, to assess the quality of the tube. In Europe, the term "Drift Expanding test" is used for this concept.

Flattening (of tube)—A test in which a tube test piece is flattened in a direction perpendicular to the longitudinal axis until the diameter or major axis is reduced to a predetermined value.

Fracture—A test in which a piece of metal is notched and broken, and the fractured surface examined in order to assess grain structure and freedom from defects.

Hardness—A test for the determination of hardness properties and the estimation of strength properties, typically by relating the load applied to an indenter of prescribed form to the depth or surface area of the impression produced.

Inspection—Activities necessary to compare characteristics of a product with specified requirements.

Macro-Etching—A test for which the metal is etched in order to reveal its macrostructure.

Mullen—A measurement of bursting strength of foil by applying increasing pressure to a defined area of the test piece until it ruptures.

Pressure—A hydraulic or pneumatic test applied to a tube or a hollow profile to ensure that the metal will withstand a specified pressure for a specified time without unacceptable leakage or distortion. "Pressure Tightness" is the absence of leakage at a specified pressure.

Tensile—A test in which the test piece is stressed in tension, normally until fracture, to determine one or more of its tensile properties.

Torsion—A test in which a test piece is twisted axially for a given number of revolutions.

Ultrasonic—A non-destructive test employing high-frequency sound waves for the location and assessment of size of internal defects.

Wettability—A test in which solvents of varying concentrations are spread over a foil surface to assess residual lubricant after annealing. See also "Wettability."

Wrapping—A test consisting of winding the wire a specified number of turns around a mandrel of diameter stated in the material specification. The test can also include a specified program of unwinding or of unwinding and rewinding.

Test Piece—A piece taken from a sample or a specimen which is suitably prepared for test. In North America the terms "Coupon" and "Specimen" are often used instead.

Tolerance—Maximum allowable deviation from a specified characteristic.

Tolerance Range—The difference between the maximum limit of a parameter and the minimum limit of a parameter of a specified characteristic. The tolerance range is an absolute value without sign.

Tool—See "Extrusion—Tool."

Tooling Pad—See "Chucking Lug."

Tooling Plate—See "Plate—Tooling.".

Top Side (of Sheet)—The side of the strip with the higher surface finish requirements. For coiled sheet the top side is normally the outside of the coil. For sheet supplied in stacks the top side is typically uppermost. See also "Reverse Side."

Torn Surface—A deep longitudinal rub mark resulting from abrasion by extrusion or drawing tools.

Torsion Test—See "Test—Torsion."

Toughness—Ability of a metal to absorb energy and deform plastically before fracturing, typically measured by the energy absorbed in a notch impact test or the area under the stress-strain curve in tensile testing. See also "Fracture Toughness."

Traffic Mark—See "Mark—Traffic."

Transverse Bow—See "Bow—Transverse."

Transverse Direction—See "Direction—Transverse."

Tread Plate—See "Plate—Tread."

Trimming—Removal of excess metal from the edges of a coiled sheet. This term is sometimes also used for other semi-finished products.

Tube—A hollow wrought product of uniform cross-section with only one enclosed void and with a uniform wall thickness, supplied in straight lengths or in coiled form. Cross-sections are in the shape of circles, ovals, squares, rectangles, equilateral triangles or regular polygons and can have corners rounded, provided the inner and outer cross-sections are concentric and have the same form and orientation. Tube can be formed by extrusion or by forming and joining of sheet. Additional terms referencing "Tube" include:

Alclad—Composite tube composed of an aluminum alloy core having on either the inside or outside surface a metallurgically bonded aluminum coating that is anodic to the core, thus electrolytically protecting the core against corrosion.

Bloom—See "Tube—Stock."

Brazed—A tube produced by forming and seam-brazing sheet.

Butt Seam—See "Tube—Open Seam."

Butt Welded—A welded tube, the seam of which is formed by positioning one edge of the sheet against the other for welding.

Drawn—A tube brought to final dimensions by drawing through a die.

Embossed—A tube the outside surface of which has been roll-embossed with a design in relief regularly repeated in a longitudinal direction.

Extruded—A tube brought to final dimensions by extruding.

Finned—Tube which has integral fins or projections protruding from its outside surface.

Fluted—A tube of nominally uniform wall thickness having regular, longitudinal, concave corrugations with sharp cusps between corrugations.

Heat-Exchanger—A tube used in apparatus in which fluid inside the tube will be heated or cooled by fluid outside the tube, but the term is typically not applied to coiled tube or to tube for use in refrigerators or radiators.

Helical-Welded—A welded tube produced by winding the sheet to form a closed helix and joining the edges of the seam by welding.

Lap-Welded—A welded tube the seam of which is formed by longitudinally lapping the edges of the sheet for welding.

Lock Seam—A tube produced by forming and mechanically lock-seaming sheet.

Open Seam—A shape normally produced from sheet of nominally uniform wall thickness and approximately tubular form but having a longitudinal, unjointed seam or gap of width not greater than 25 percent of the outside diameter or greatest over-all dimension. Also referred to as "Butt Seam Tube."

Porthole/Bridge—A tube produced by extrusion of a solid billet through a porthole or bridge die. The product is characterised by one or more longitudinal extrusion seams.

Redraw—See "Tube—Stock."

Seamless—A tube which does not contain any line junctures resulting from method of manufacture.

Sized—A tube that, after extrusion, has been cold drawn a slight amount to minimize ovality.

Stepped Drawn—A drawn tube whose cross section changes abruptly in area at intervals along its length.

Stock—A semifinished tube suitable for the production of drawn tube.

Structural—Tube commonly used for structural purposes.

Welded—A tube produced by longitudinal seam-welding, typically of formed sheet. Welded tube can be fabricated by arc-welding with or without welding wire, high frequency seam welding, or any other type of welding.

Tubing—This term is not recommended. The term "tube" is preferred.

Tubing, Electrical Metallic—A tube having certain standardized length and combinations of outside diameter and wall thickness thinner than that of "Rigid Conduit," commonly designated by nominal electrical trade sizes, for use with compression type fittings as a protection for electric wiring.

Tubular Conductor—A tube product suitable for use as an electric conductor.

Tumbling (Barreling)—A treatment of products in a rotating container in the presence of abrasives and water for deburring or to produce a variety of surface textures.

Twist—The extent to which a product is twisted around its longitudinal axis.

Two-Tone—A sharp color demarcation in the appearance of the metal due to a difference in the work roll coating.

—U—

Ultimate Tensile Strength—See "Tensile Strength."

Ultrasonic Test—See "Test—Ultrasonic."

Under-Aging—See "Aging—Under."

Used Beverage Can (UBC)—Scrap consisting of used aluminum beverage cans.

—V—

Vent Mark—See "Mark—Vent."

Vickers Hardness—See "Hardness—Vickers."

Visual Quality Characteristic—A quality characteristic which can be detected by visual inspection of the material, sometimes after preparation of a sample and/or by use of a microscope. The existence of a visual quality characteristic does not necessarily imply a nonconformity, nor does it have necessarily any implication as to the usability of a product. A visual quality characteristic can be rated on a scale of severity, in accordance with appropriate specifications, e. g. to establish whether or not the product is of acceptable quality.

—W—

Weave—See "Oscillation."

Web—(1) A single thickness of foil as it leaves the rolling mill. (2) A connecting element between ribs, flanges, or bosses on profiles and forgings.

Weld Line—See “Extrusion—Seam.”

Weld, Incomplete—The junction line of metal that has passed through a die forming a hollow profile, separated and not completely rejoined. Flare testing is a method of evaluating weld integrity.

Welding—Joining two or more pieces of aluminum by applying heat and/or pressure, with or without filler metal to produce a localized union through fusion or recrystallization across the interface.

Welding Rod—See “Rod—Welding.”

Welding Wire—See “Wire—Welding.”

Wettability—The degree to which a metal surface can be wet by water. Wettability allows the assessment of the amount of residual lubricants on the surface.

Whip Mark—See “Mark—Whip.”

Whisker—See “Hair, Slitter.”

Wire—A solid wrought product that is long in relation to its cross section, which is square or rectangular with sharp or rounded corners or edges, or is round, hexagonal, or octagonal. In North America, the maximum diameter or perpendicular distance between parallel faces of a wire is 0.375 inches; above this limit the product is called “Rod” or “Bar”. In Europe, a wire is supplied in coiled form; if supplied in straight length, the product is called “Rod” or “Bar.” Additional terms referencing “Wire” include:

> **Alclad**—A composite wire product comprised of an aluminum-alloy wire having on its surface a metallurgically bonded aluminum or aluminum alloy coating that is anodic to the alloy to which it is bonded, thus electrolytically protecting the core alloy against corrosion.
>
> **Brazing**—Wire of a low melting temperature alloy for use as filler metal in brazing.
>
> **Cold-Heading**—See “Cold Heading Wire.”
>
> **Conductor**—Wire possessing the requisite electrical and mechanical properties for use as an electrical conductor.
>
> **Drawn**—Wire brought to final dimensions by drawing through a die.
>
> **Extruded**—Wire .brought to final dimensions by extruding.
>
> **Flattened**—Wire having two parallel flat surfaces and rounded edges, typically produced by roll-flattening round wire.
>
> **Rivet**—See “Cold Heading Wire.”
>
> **Welding**—Wire for use as filler metal in joining by welding.

Work Hardening—See “Strain Hardening.”

Work Rolls—Nongrooved rolls which contact the material being rolled.

Workability—See “Formability.”

Wrap, Loose—A condition in a coil due to insufficient tension which creates a small void between adjacent wraps.

Wrapping Test—See “Test—Wrapping.”

Wrinkle—See “Mark—Pinch.”

Wrought Product—A product that has been subjected to hot working and/or cold working.

—Y—

Yield Strength—The stress necessary to produce a defined small plastic deformation in a material under uniaxial tensile or compressive load. If the plastic deformation under tensile load is defined as 0.2 %, then the term “Proof Strength Rp0.2” or “Yield Strength 0.2 %” is used.

The term “Proof Strength” is used in European and ISO standards, whereas the term “Yield Strength” is used in North American documents.

6. Standards Section

Included in this and following sections are the chemical composition and mechanical property limits, dimensional tolerances, and other standards and related data for aluminum wrought products in general use. The tolerances are those included in ANSI H35.2 Standard Dimensional Tolerances for Aluminum Mill Products (see NOTE below). Tables show standard tolerances, and when none are shown it should be understood that tolerances must be agreed on between vendor and purchaser.

Various documents, including some federal and military specifications, cover requirements that are associated with defined size ranges but permit the specification to be used for material outside the defined size or thickness ranges. For such material, mechanical properties, tolerances and any other size-dependent requirements partially covered by the applicable specification must be adequately defined in the purchase order or sales contract. Use of the specification number in stenciling, marking, and/or certification identifies the material as conforming to (1) the size independent requirements of the specification and (2) the specific size-dependent requirements defined in the purchase order or sales contract. Marking or stenciling does not constitute certification.

NOTE: The user of this Aluminum Standards and Data manual should be aware that the dimensional tolerances contained herein, as abstracted from ANSI H35.2, are those in effect at the time of this manual's publication but are subject to supersession by subsequent revisions of this ANSI Standard as it is updated to respect advancing capabilities of the aluminum producing industry and the changing needs of using industries.

Standard Limits

Standard limits for chemical composition, mechanical properties, physical properties and dimensional tolerances of wrought aluminum mill products are expressed as follows:

chemical composition—Standard weight percent limits are expressed to the following decimal places:

Alloying elements and impurities

Less than .001 percent 0.000X

0.001 or greater but less than .01 percent 0.00X

0.01 or greater but less than .10 percent:

Unalloyed aluminum made by a refining process 0.0XX

Alloys and unalloyed aluminum not made by a refining process 0.0X

0.10 through .55 percent 0.XX
(It is customary to express limits of 0.30 percent through 0.55 percent as 0.X0 or 0.X5)

Over 0.55 percent .... 0.X, X.X, XX.X etc.
(except that combined Si + Fe limits for 1xxx designations must be expressed as 0.XX or 1.XX)

Aluminum content of unalloyed aluminum .... XX.XX

The standard sequence for listing alloying elements and impurities is as follows:

Silicon; Iron; Copper; Manganese; Magnesium; Chromium; Nickel; Zinc; Titanium; .... * .... ; Other Elements, Each; Other Elements, Total; Aluminum.†

*Additional elements having limits are inserted, in alphabetical order by their chemical symbols, between Titanium and other elements, each, or are listed in footnotes.

† Aluminum is specified as minimum for unalloyed aluminum and as remainder for aluminum alloys.

mechanical properties—Standard mechanical property limits are based on producer analysis of data accumulated from standard production material that has been sampled and tested using standard procedures as detailed under "Sampling and Testing" on pages 4-1 through 4-5. The limits are established after sufficient test data have been accumulated to adequately determine the form of the frequency distribution curve and to provide a reliable estimate of the population mean and standard deviation. In most instances the distribution is normal in form. For heat treatable alloys, the properties are based on the results of a minimum of 100 tests from at least 5 different cast lots and at least 10 different heat treat lots of material. No more than 10 tests from a given heat treat lot shall be included in the data analysis. For non-heat treatable alloys, the properties are based on the results of a minimum of 100 tests from at least 5 different cast lots of material that have separately passed through subsequent processing operations as at least 10 fabricated inspection lots. No more than 10 tests from a given fabricated inspection lot shall be included in the data analysis. For both heat treatable and non-heat treatable alloys, the 100 tests shall include observations from all gage ranges. Multiple gage ranges shall have at least 30 test from each gage range or be derived from regression analysis of the 100 tests. The standard mechanical property limits are subsequently established at levels at which at least 99 percent of the material is expected to conform at a confidence level of 0.95.

As additional production experience is gained and additional test data become available, it may on occasion be necessary to revise a specific limit to more accurately reflect the capability of the material. In case of doubt as to the currency of any specific mechanical property limit, verification of its status should be obtained from The Aluminum Association. Standard mechanical property limits are normally expressed as follows:

Strength (ultimate, yield, etc.)*

Less than 10.0 ksi. .... multiple of 0.5 ksi

10.0 ksi and greater .... multiple of 1.0 ksi

*Exception: For two-digit H tempers whose second figure is odd, the standard limits for strength are exactly midway between those for the adjacent two-digit H tempers whose second figures are even.

Elongation in 2 in. or 4D†* .... multiple of 1% expressed as a whole number.

†D represents specimen diameter.

*Exception: For certain products the elongation in the short transverse direction is expressed as a multiple of 0.5%.

Elongation in 10 in.

Less than 2 percent .... multiple of 0.1%
2 to 3 percent .... multiple of 0.2%
3 to 5 percent .... multiple of 0.5%
5 to 10 percent .... multiple of 1%
10 to 20 percent .... multiple of 2%
20 percent and greater .... multiple of 5%
(5 to 10, 10 to 20, 20 and greater: expressed as a whole number)

Hardness
Brinell hardness number.
500 kg load. 10 mm ball .... multiple of 5BHN expressed as a whole number

fracture toughness—Standard limits are expressed to the following places:

K_{Ic} . . . . .Xksi	$\sqrt{inch}$	where X is expressed
K_c . . . . .Xksi	$\sqrt{inch}$	as a whole number

physical properties—Standard limits are expressed to the following decimal places:

Electrical conductivity, percent of IACS† . . . . XX.X

†International Annealed Copper Standard.

dimensional tolerances—Tolerances are expressed as inch fractions or decimals, or as percentages of base values. The choice of tolerance depends on the dimension being measured and the precision of the measuring instrument. Where instruments permitting a high degree of precision are generally used, standard dimensional tolerances are expressed in decimals as follows except for foil:

Tolerance less than 0.005 in . . . . multiple of 0.0005

Tolerance of 0.005 in. and greater 0.XXX

For measurements commonly made with instruments not permitting such a high degree of precision, standard dimensional tolerances are expressed as inch fractions.

Applicable Limits

Applicable limits are determined by the specified (ordered) dimension when that dimension is subject to tolerances that are identical to those appearing in these standards.

When a dimension or value is specified to more decimal places than are used in these standards, applicable limiting values are determined by rounding off the specified dimension to the same number of places in conformance with the rounding-off method of ASTM Recommended Practice E 29 (see next column).

When the specified (ordered) dimension is subject to tolerances differing from those appearing in these standards, the applicable limits, unless otherwise specified, are determined as follows:

dimensional tolerances—When the specified (ordered) dimension is subject to un-symmetrical dimensional tolerances, the applicable limits are those that apply to a calculated value of that dimension determined so that the permissible deviations, plus and minus, bear the same proportional relationship as those appearing in these standards.

mechanical properties, physical properties, cladding thickness, and ultrasonic discontinuity limits—The applicable limits are those that apply to the specified (ordered) dimension.

Conformance to Limits

dimensional tolerances—For purposes of determining conformance to the dimensional tolerances, a measured value is not rounded off.

chemical composition and properties—For purposes of determining conformance to the limits for chemical composition and properties, an observed* value or a calculated value is rounded off as follows in accordance with ASTM E 29 (see below):

	Observed or calculated value is rounded off to*
Chemical composition Electrical conductivity Ultimate, yield strength, Elongation: Fracture toughness	Nearest unit in last right-hand place of figures of specified limit

*Exception—When the limit for chemical composition is shown as “less than” or “greater than,” the observed value is not rounded off for purposes of determining conformance to limits.

Brinell Hardness: Nearest whole BHN converted from average diameter of indentation read to nearest multiple of 0.05 mm for routine acceptance tests and to nearest multiple of 0.02 mm for referee tests.

Twist Limits

Twist is normally measured by placing the product on a flat surface and at any point along its length measuring the maximum distance between the bottom surface of the section and the flat surface. From this measurement, the actual deviation from straightness† of the section at that point is subtracted. The remainder is the twist. To convert the standard twist tolerance (degrees) to an equivalent linear value, the sine of the standard tolerance is multiplied by the width of the surface of the section that is on the flat surface. The following values are used to convert angular tolerances to linear deviation:

Tolerance, degrees	*Maximum allowable linear deviation inch per inch of width*
¼	0.004
½	0.009
1	0.017
1½	0.026
3	0.052
5	0.087
7	0.122
9	0.156
15	0.259
21	0.358

†See Table of Straightness Limits for product of interest to determine actual deviation from straightness.

Reference

For additional information on dimensional tolerances and twist limits, refer to Section 4, Appendix 2, and to Aluminum Association publication “Understanding Aluminum Extrusion Tolerances”.

Rules for Rounding Off

Rounding off method of ASTM Standard Practice E 29, for Using Significant Digits in Test Data to Determine Conformance with Specifications:

When the figure next beyond the last place to be retained is less than 5, retain unchanged the figure in the last place retained.

When the figure next beyond the last place to be retained is greater than 5, increase by 1 the figure in the last place retained.

When the figure next beyond the last place to be retained is 5, and there are no figures beyond this 5, or only zeros, increase by 1 the figure in the last place retained if it is odd; leave the figure unchanged if it is even. Increase by 1 the figure in the last place retained if there are figures beyond this 5.

Designations for Clad Products

Wrought aluminum alloy products having a metallurgically bonded coating, the composition of which may or may not be the same as that of the core, and which is applied for such purposes as corrosion protection, finishing, brazing, etc., are known collectively as clad products.

The nominal thickness of the cladding is expressed as follows:

Sheet and Plate: Percent of total thickness on a side.

Tube: Percent of total wall thickness.

Wire: Percent of total cross-sectional area.

When the cladding is aluminum or an aluminum alloy of high resistance to corrosion and is anodic to the core alloy it covers, thus physically and electrolytically protecting the core alloy against corrosion, the product is designated Alclad (sometimes expressed Alc). All alclad products are identified by the designation Alclad preceding the core alloy designation: for example, Alclad 2024 Sheet, Alclad 5056 Wire, Alclad 3003 Tube. Alclad sheet and plate, unless otherwise indicated, is clad on both sides. When clad on only one side, it is designated Alclad One Side. Alclad tube is clad on either the inside or the outside and is designated Alclad Inside or Alclad Outside.

Neither the nominal thickness (or area percentage) of the cladding, nor its alloy designation, is indicated in the designation assigned to the original alclad registration for each core alloy in each product form. As additional alclad products, differing from the original registration either in respect to the nominal thickness (or area percentage) of the cladding or its cladding alloy or both, are registered for any given core alloy and product form, those features differing from the original registration are included in the designation: for example, 4% Alclad 7075 Plate, 7072 Alclad One Side 2024 Sheet, 10% Alclad Outside 3003 Tube. When both the cladding thickness (or area percentage) and the cladding alloy are different, they are indicated in that respective order: For example, 1½% 7072 Alclad 2024 Plate.

Some specialty mill products, clad for functional purposes other than that of corrosion protection, are identified by the designation Clad preceding the core alloy number: For example, Clad 1100 Reflector Sheet. Clad specialty mill products having the same core alloy but with differing nominal thickness (or area percentage) of the cladding alloy, cladding alloy designation, or covered surfaces are designated in a manner otherwise identical to those for alclad products.

In other cases, specialty mill products clad for functional purposes other than that of corrosion protection are designated by arbitrarily assigned numeric or alpha-numeric designations: for example, No. 21 Brazing Sheet. Each designation identifies a unique combination and configuration of core and cladding alloys. Odd or even numbered designations denote one or two sides clad products, respectively.

Components of clad products in general use are listed in Table 6.1.

TABLE 6.1 Components of Clad Products

DESIGNATION	COMPONENT ALLOYS ①		TOTAL SPECIFIED THICKNESS OF COMPOSITE PRODUCT in.	SIDES CLAD	CLADDING THICKNESS PER SIDE Percent of Composite Thickness		
	CORE	CLADDING			NOMINAL	AVERAGE ② min.	AVERAGE ② max.
Alclad 2014 Sheet and Plate	2014	6003	Up thru 0.024 0.025–0.039 0.040–0.099 0.100 and over	Both Both Both Both	10 7.5 5 2.5	8 6 4 2	. . . . . . 3 ③
Alclad 2024 Sheet and Plate	2024	1230	Up thru 0.062 0.063 and over	Both Both	5 2.5	4 2	. . 3 ③
1½% Alclad 2024 Sheet and Plate	2024	1230	0.188 and over	Both	1.5	1.2	3 ③
Alclad One Side 2024 Sheet and Plate	2024	1230	Up thru 0.062 0.063 and over	One One	5 2.5	4 2	. . 3 ③
1½% Alclad One Side 2024 Sheet and Plate	2024	1230	0.188 and over	One	1.5	1.2	3 ③
Alclad 2219 Sheet and Plate	2219	7072	Up thru 0.039 0.040–0.099 0.100 and over	Both Both Both	10 5 2.5	8 4 2	. . . . 3 ③
Alclad 3003 Sheet and Plate	3003	7072	All	Both	5	4	6 ③
Alclad 3003 Tube	3003	7072	All All	Inside Outside	10 7	. . . .	. . . .
Alclad 3004 Sheet and Plate	3004	7072	All	Both	5	4	6 ③
Alclad 6061 Sheet and Plate	6061	7072	All	Both	5	4	6 ③
Alclad 7050 Sheet and Plate	7050	7072	Up thru 0.062 0.063 and over	Both Both	4 2.5	3.2 2	. . . .
7108 Alclad 7050 Sheet and Plate	7050	7108	Up thru 0.062 0.063 and over	Both Both	4 2.5	3.2 2	. . . .
Alclad 7075 Sheet and Plate	7075	7072	Up thru 0.062 0.063–0.187 0.188 and over	Both Both Both	4 2.5 1.5	3.2 2 1.2	. . . . 3 ③
2½% Alclad 7075 Sheet and Plate	7075	7072	0.188 and over	Both	2.5	2	4 ③
Alclad One Side 7075 Sheet and Plate	7075	7072	Up thru 0.062 0.063–0.187 0.188 and over	One One One	4 2.5 1.5	3.2 2 1.2	. . . . 3 ③
2½% Alclad One Side 7075 Sheet and Plate	7075	7072	0.188 and over	One	2.5	2	4 ③
7008 Alclad 7075 Sheet and Plate	7075	7008	Up thru 0.062 0.063–0.187 0.188 and over	Both Both Both	4 2.5 1.5	3.2 2 1.2	. . . . 3 ③
Alclad 7178 Sheet and Plate	7178	7072	Up thru 0.062 0.063–0.187 0.188 and over	Both Both Both	4 2.5 1.5	3.2 2 1.2	. . . . 3 ③
Alclad 7475 Sheet	7475	7072	Up thru 0.062 0.063–0.187 0.188–0.249	Both Both Both	4 2.5 1.5	3.2 2 1.2	. . . . . .
No. 7 Brazing Sheet	3003	4004	Up thru 0.024 0.025–0.062 0.063 and over	One One One	15 10 7.5	12 8 6	18 12 9
No. 8 Brazing Sheet	3003	4004	Up thru 0.024 0.025–0.062 0.063 and over	Both Both Both	15 10 7.5	12 8 6	18 12 9
No. 11 Brazing Sheet	3003	4343 ④	Up thru 0.063 0.064 and over	One One	10 5	8 4	12 6
No. 12 Brazing Sheet	3003	4343 ④	Up thru 0.063 0.064 and over	Both Both	10 5	8 4	12 6
No. 23 Brazing Sheet	6951	4045	Up thru 0.090 0.091 and over	One One	10 5	8 4	12 6
No. 24 Brazing Sheet	6951	4045	Up thru 0.090 0.091 and over	Both Both	10 5	8 4	12 6

NOTE: This table does not include all clad products registered with The Aluminum Association.

① Cladding composition is applicable only to the aluminum or aluminum alloy bonded to the alloy ingot or slab preparatory to processing to the specified composite product. The composition of the cladding may be subsequently altered by diffusion between the core and cladding due to thermal treatment.

② Average thickness per side as determined by averaging cladding thickness measurements taken at a magnification of 100 diameters on the cross-section of a transverse sample polished and etched for microscopic examination.

③ Applicable for thicknesses of 0.500 in. and greater.

④ The cladding component, in lieu of 4343 alloy, may be 5% 1xxx Clad 4343.

TABLE 6.2 Chemical Composition Limits of Wrought Aluminum Alloys [1] [2]

AA DESIG-NATION	SILICON	IRON	COPPER	MAN-GANESE	MAG-NESIUM	CHROMIUM	NICKEL	ZINC	TITAN-IUM	OTHERS [22] Each [20]	OTHERS [22] Total [3]	ALUMI-NUM Min.
1050	0.25	0.40	0.05	0.05	0.05	..	..	0.05	0.03	0.03 [9]	..	99.50[4]
1060	0.25	0.35	0.05	0.03	0.03	..	..	0.05	0.03	0.03 [9]	..	99.60[4]
1100	0.95 Si + Fe		0.05–0.20	0.05	..	..	..	0.10	..	0.05 [16]	0.15	99.00[4]
1145 [8]	0.55 Si + Fe		0.05	0.05	0.05	..	..	0.05	0.03	0.03 [9]	..	99.45[4]
1200	1.00 Si + Fe		0.05	0.05	..	..	..	0.10	0.05	0.05	0.15	99.00[4]
1230 [7]	0.70 Si + Fe		0.10	0.05	0.05	..	..	0.10	0.03	0.03 [9]	..	99.30[4]
1235	0.65 Si + Fe		0.05	0.05	0.05	..	..	0.10	0.06	0.03 [9]	..	99.35[4]
1345	0.30	0.40	0.10	0.05	0.05	..	..	0.05	0.03	0.03 [9]	..	99.45[4]
1350 [6]	0.10	0.40	0.05	0.01	..	0.01	..	0.05	..	0.03 [13]	0.10	99.50[4]
2011	0.40	0.7	5.0–6.0	..	..	..	..	0.30	..	0.05 [10]	0.15	Remainder
2014	0.50–1.2	0.7	3.9–5.0	0.40–1.2	0.20–0.8	0.10	..	0.25	0.15	0.05	0.15	Remainder
2017	0.20–0.8	0.7	3.5–4.5	0.40–1.0	0.40–0.8	0.10	..	0.25	0.15	0.05	0.15	Remainder
2018	0.9	1.0	3.5–4.5	0.20	0.45–0.9	0.10	1.7–2.3	0.25	..	0.05	0.15	Remainder
2024	0.50	0.50	3.8–4.9	0.30–0.9	1.2–1.8	0.10	..	0.25	0.15	0.05	0.15	Remainder
2025	0.50–1.2	1.0	3.9–5.0	0.40–1.2	0.05	0.10	..	0.25	0.15	0.05	0.15	Remainder
2036	0.50	0.50	2.2–3.0	0.10–0.40	0.30–0.6	0.10	..	0.25	0.15	0.05	0.15	Remainder
2117	0.8	0.7	2.2–3.0	0.20	0.20–0.50	0.10	..	0.25	..	0.05	0.15	Remainder
2124	0.20	0.30	3.8–4.9	0.30–0.9	1.2–1.8	0.10	..	0.25	0.15	0.05	0.15	Remainder
2218	0.9	1.0	3.5–4.5	0.20	1.2–1.8	0.10	1.7–2.3	0.25	..	0.05	0.15	Remainder
2219	0.20	0.30	5.8–6.8	0.20–0.40	0.02	..	..	0.10	0.02–0.10	0.05 [18]	0.15	Remainder
2319	0.20	0.30	5.8–6.8	0.20–0.40	0.02	..	..	0.10	0.10–0.20	0.05 [16]	0.15	Remainder
2618	0.10–0.25	0.9–1.3	1.9–2.7	..	1.3–1.8	..	0.9–1.2	0.10	0.04–0.10	0.05	0.15	Remainder
3003	0.6	0.7	0.05–0.20	1.0–1.5	..	..	..	0.10	..	0.05	0.15	Remainder
3004	0.30	0.7	0.25	1.0–1.5	0.8–1.3	..	..	0.25	..	0.05	0.15	Remainder
3005	0.6	0.7	0.30	1.0–1.5	0.20–0.6	0.10	..	0.25	0.10	0.05	0.15	Remainder
3105	0.6	0.7	0.30	0.30–0.8	0.20–0.8	0.20	..	0.40	0.10	0.05	0.15	Remainder
4032	11.0–13.5	1.0	0.50–1.3	..	0.8–1.3	0.10	0.50–1.3	0.25	..	0.05	0.15	Remainder
4043	4.5–6.0	0.8	0.30	0.05	0.05	..	..	0.10	0.20	0.05 [16]	0.15	Remainder
4045 [11]	9.0–11.0	0.8	0.30	0.05	0.05	..	..	0.10	0.20	0.05	0.15	Remainder
4047 [11]	11.0–13.0	0.8	0.30	0.15	0.10	..	..	0.20	..	0.05 [16]	0.15	Remainder
4145 [11]	9.3–10.7	0.8	3.3–4.7	0.15	0.15	0.15	..	0.20	..	0.05 [16]	0.15	Remainder
4343 [11]	6.8–8.2	0.8	0.25	0.10	..	..	..	0.20	..	0.05	0.15	Remainder
4643	3.6–4.6	0.8	0.10	0.05	0.10–0.30	..	..	0.10	0.15	0.05 [16]	0.15	Remainder
5005	0.30	0.7	0.20	0.20	0.50–1.1	0.10	..	0.25	..	0.05	0.15	Remainder
5050	0.40	0.7	0.20	0.10	1.1–1.8	0.10	..	0.25	..	0.05	0.15	Remainder
5052	0.25	0.40	0.10	0.10	2.2–2.8	0.15–0.35	..	0.10	..	0.05	0.15	Remainder
5056	0.30	0.40	0.10	0.05–0.20	4.5–5.6	0.05–0.20	..	0.10	..	0.05	0.15	Remainder
5083	0.40	0.40	0.10	0.40–1.0	4.0–4.9	0.05–0.25	..	0.25	0.15	0.05	0.15	Remainder
5086	0.40	0.50	0.10	0.20–0.7	3.5–4.5	0.05–0.25	..	0.25	0.15	0.05	0.15	Remainder
5154	0.25	0.40	0.10	0.10	3.1–3.9	0.15–0.35	..	0.20	0.20	0.05 [16]	0.15	Remainder
5183	0.40	0.40	0.10	0.50–1.0	4.3–5.2	0.05–0.25	..	0.25	0.15	0.05 [16]	0.15	Remainder
5252	0.08	0.10	0.10	0.10	2.2–2.8	..	..	0.05	..	0.03 [9]	0.10	Remainder
5254	0.45 Si + Fe		0.05	0.01	3.1–3.9	0.15–0.35	..	0.20	0.05	0.05	0.15	Remainder
5356	0.25	0.40	0.10	0.05–0.20	4.5–5.5	0.05–0.20	..	0.10	0.06–0.20	0.05 [16]	0.15	Remainder
5454	0.25	0.40	0.10	0.50–1.0	2.4–3.0	0.05–0.20	..	0.25	0.20	0.05	0.15	Remainder
5456	0.25	0.40	0.10	0.50–1.0	4.7–5.5	0.05–0.20	..	0.25	0.20	0.05	0.15	Remainder
5457	0.08	0.10	0.20	0.15–0.45	0.8–1.2	..	..	0.05	..	0.03 [9]	0.10	Remainder
5554	0.25	0.40	0.10	0.50–1.0	2.4–3.0	0.05–0.20	..	0.25	0.05–0.20	0.05 [16]	0.15	Remainder
5556	0.25	0.40	0.10	0.50–1.0	4.7–5.5	0.05–0.20	..	0.25	0.05–0.20	0.05 [16]	0.15	Remainder
5652	0.40 Si + Fe		0.04	0.01	2.2–2.8	0.15–0.35	..	0.10	..	0.05	0.15	Remainder
5654	0.45 Si + Fe		0.05	0.01	3.1–3.9	0.15–0.35	..	0.20	0.05–0.15	0.05 [16]	0.15	Remainder
5657	0.08	0.10	0.10	0.03	0.6–1.0	..	..	0.05	..	0.02 [19]	0.05	Remainder

For all numbered footnotes, see page 6-6.

TABLE 6.2 Chemical Composition Limits of Wrought Aluminum Alloys ① ② (concluded)

AA DESIGNATION	SILICON	IRON	COPPER	MANGANESE	MAGNESIUM	CHROMIUM	NICKEL	ZINC	TITANIUM	OTHERS ㉒ Each ⑳	OTHERS ㉒ Total ③	ALUMINUM Min.
6003 ⑦	0.35–1.0	0.6	0.10	0.8	0.8–1.5	0.35	. .	0.20	0.10	0.05	0.15	Remainder
6005	0.6–0.9	0.35	0.10	0.10	0.40–0.6	0.10	. .	0.10	0.10	0.05	0.15	Remainder
6005A	0.50-0.9	0.35	0.30	0.50 ㉗	0.40–0.7	0.30	. .	0.20	0.10	0.05	0.15	Remainder
6053	⑮	0.35	0.10	. .	1.1–1.4	0.15–0.35	. .	0.10	. .	0.05	0.15	Remainder
6061	0.40–0.8	0.7	0.15–0.40	0.15	0.8–1.2	0.04–0.35	. .	0.25	0.15	0.05	0.15	Remainder
6063	0.20–0.6	0.35	0.10	0.10	0.45–0.9	0.10	. .	0.10	0.10	0.05	0.15	Remainder
6066	0.9–1.8	0.50	0.7–1.2	0.6–1.1	0.8–1.4	0.40	. .	0.25	0.20	0.05	0.15	Remainder
6070	1.0–1.7	0.50	0.15–0.40	0.40–1.0	0.50–1.2	0.10	. .	0.25	0.15	0.05	0.15	Remainder
6082	0.7–1.3	0.50	0.10	0.40–1.0	0.6–1.2	0.25	. .	0.20	0.10	0.05	0.15	Remainder
6101 ⑫	0.30–0.7	0.50	0.10	0.03	0.35–0.8	0.03	. .	0.10	. .	0.03 ⑰	0.10	Remainder
6105	0.6–1.0	0.35	0.10	0.15	0.45–0.8	0.10	. .	0.10	0.10	0.05	0.15	Remainder
6151	0.6–1.2	1.0	0.35	0.20	0.45–0.8	0.15–0.35	. .	0.25	0.15	0.05	0.15	Remainder
6162	0.40–0.8	0.50	0.20	0.10	0.7–1.1	0.10	. .	0.25	0.10	0.05	0.15	Remainder
6201	0.50–0.9	0.50	0.10	0.03	0.6–0.9	0.03	. .	0.10	. .	0.03 ⑰	0.10	Remainder
6262	0.40–0.8	0.7	0.15–0.40	0.15	0.8–1.2	0.04–0.14	. .	0.25	0.15	0.05 ⑤	0.15	Remainder
6351	0.7–1.3	0.50	0.10	0.40–0.8	0.40–0.8	. .	. .	0.20	0.20	0.05	0.15	Remainder
6463	0.20–0.6	0.15	0.20	0.05	0.45–0.9	. .	. .	0.05	. .	0.05	0.15	Remainder
6951	0.20–0.50	0.8	0.15–0.40	0.10	0.40–0.8	. .	. .	0.20	. .	0.05	0.15	Remainder
7005	0.35	0.40	0.10	0.20–0.7	1.0–1.8	0.06–0.20	. .	4.0–5.0	0.01–0.06	0.05 ⑭	0.15	Remainder
7008 ⑦	0.10	0.10	0.05	0.05	0.7–1.4	0.12–0.25	. .	4.5–5.5	0.05	0.05	0.10	Remainder
7049	0.25	0.35	1.2–1.9	0.20	2.0–2.9	0.10–0.22	. .	7.2–8.2	0.10	0.05	0.15	Remainder
7050	0.12	0.15	2.0–2.6	0.10	1.9–2.6	0.04	. .	5.7–6.7	0.06	0.05 ㉑	0.15	Remainder
7072 ⑦	0.7 Si + Fe		0.10	0.10	0.10	. .	. .	0.8–1.3	. .	0.05	0.15	Remainder
7075	0.40	0.50	1.2–2.0	0.30	2.1–2.9	0.18–0.28	. .	5.1–6.1	0.20	0.05	0.15	Remainder
7175	0.15	0.20	1.2–2.0	0.10	2.1–2.9	0.18–0.28	. .	5.1–6.1	0.10	0.05	0.15	Remainder
7178	0.40	0.50	1.6–2.4	0.30	2.4–3.1	0.18–0.28	. .	6.3–7.3	0.20	0.05	0.15	Remainder
7475	0.10	0.12	1.2–1.9	0.06	1.9–2.6	0.18–0.25	. .	5.2–6.2	0.06	0.05	0.15	Remainder
8017	0.10	0.55–0.8	0.10–0.20	. .	0.01–0.05	. .	. .	0.05	. .	0.03 ㉓	0.10	Remainder
8030	0.10	0.30–0.8	0.15–0.30	. .	0.05	. .	. .	0.05	. .	0.03 ㉔	0.10	Remainder
8176	0.03–0.15	0.40–1.0	. .	. .	. .	. .	. .	0.10	. .	0.05 ㉕	0.15	Remainder

Note: Listed herein are designations and chemical composition limits for some wrought unalloyed aluminum and for wrought aluminum alloys registered with The Aluminum Association. This list does not include all alloys registered with The Aluminum Association. A complete list of registered designations is contained in the "Registration Record of International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys." These lists are maintained by the Technical Committee on Product Standards of the Aluminum Association.

① Composition in percent by weight maximum unless shown as a range or a minimum.

② Except for "Aluminum" and "Others," analysis normally is made for elements for which specific limits are shown. For purposes of determining conformance to these limits, an observed value or a calculated value obtained from analysis is rounded off to the nearest unit in the last right-hand place of figures used in expressing the specified limit, in accordance with ASTM Recommended Practice E 29.

③ The sum of those "Other" metallic elements 0.010 percent or more each, expressed to the second decimal before determining the sum.

④ The aluminum content for unalloyed aluminum not made by a refining process is the difference between 100.00 percent and the sum of all other analyzed metallic elements together with silicone present in amounts of 0.010 percent or more each, expressed to the second decimal before determining the sum. For alloys and unalloyed aluminum not made by a refining process, when the specified maximum is 0.XX, an observed value or a calculated value greater than 0.005 but less than 0.010% is rounded off and shown as "less than 0.01".

⑤ Also contains 0.40–0.7 percent each of lead and bismuth.

⑥ Electric conductor. Formerly designated EC.

⑦ Cladding Alloy. See Table 6.1.

⑧ Foil.

⑨ Vanadium 0.05 percent maximum.

⑩ Also contains 0.20–0.6 percent each of lead and bismuth.

⑪ Brazing alloy.

⑫ Bus conductor.

⑬ Vanadium plus titanium 0.02 percent maximum; boron 0.05 percent maximum; gallium 0.03 percent maximum.

⑭ Zirconium 0.08–0.20.

⑮ Silicon 45 to 65 percent of actual magnesium content.

⑯ Beryllium 0.0003 maximum for welding electrode and welding rod only.

⑰ Boron 0.06 percent maximum.

⑱ Vanadium 0.05–0.15; zirconium 0.10–0.25.

⑲ Gallium 0.03 percent maximum; vanadium 0.05 percent maximum.

⑳ In addition to those alloys referencing footnote ⑯, a 0.0008 weight percent maximum beryllium is applicable to any alloy to be used as welding electrode or welding rod.

㉑ Zirconium 0.08–0.15.

㉒ "Others" includes listed elements for which no specific limit is shown as well as unlisted metallic elements. The producer may analyze samples for trace elements not specified in the registration or specification. However, such analysis is not required and may not cover all metallic "Other" elements. Should any analysis by the producer or the purchaser establish that an "Others" element exceeds the limit of "Each" or that the aggregate of several "others" elements exceeds the limit of "Total," the material shall be considered nonconforming.

㉓ Boron 0.04 percent maximum; lithium 0.003 percent maximum.

㉔ Boron 0.001–0.04.

㉕ Gallium 0.03 percent maximum.

㉖ Boron 0.04 percent maximum.

㉗ 0.12-0.50 Maganese and Chromium.

TABLE 6.3 Ultrasonic Discontinuity Limits ① ② ⑦

PRODUCT	ALLOY	SIZE: THICKNESS in.	SIZE: MAXIMUM WEIGHT PER PIECE lb. ⑤	SIZE: MAXIMUM WIDTH TO THICKNESS RATIO	DISCONTINUITY CLASS ③
Plate	2014 ⑥ 2024 ⑥ 2124 2219 ⑥ 7050 ⑥ 7075 ⑥ 7178 ⑥ 7475 ⑥	0.500–1.499	2,000	. .	B
		1.500–3.000	2,000	. .	A
		3.001–6.000	2,000	. .	B
Extruded Bar and Profiles	2014 2024 2219	0.500 and Over ④	600	10 to 1	B
	7050 7075 7178	0.500–1.499 ④	600	10 to 1	B
		1.500 and Over ④	600	10 to 1	A
Cold Finished Bar and Profiles	2014 2219 2024 7050 7075 7178	0.500–1.499 ④	600	. .	B
		1.500–3.000 ④	600	. .	A
		3.001–6.000 ④	1,000	. .	B
Die Forgings and Rolled Rings	2014 2219 7049 7050 7075 7175	0.500–4.000	300	. .	B
Hand Forgings	2014 2219 7049 7050 7075 7175	1.000–8.000	600	. .	A

① Refer to "Ultrasonic Testing" in Section 4, Quality Control, for information relating to equipment and test procedures.
② Discontinuities in excess of those listed in this table are allowed if it is established that they will be removed by machining or that they are in non-critical areas as designated on zoned engineering drawings of the material to be inspected.
③ The discontinuity class limits are defined in paragraph 2 of "Ultrasonic Testing" in Section 4, Quality Control.
④ The thickness of any element of a "profile" is deemed to be the smallest dimension of that element and the discontinuity class applicable to that particular thickness applies to that element of the profile.
⑤ For plate, the maximum weight is (a) the ordered weight of a plate of rectangular geometry or (b) the planned weight of a rectangular plate prior to removing metal to produce a part or plate profile to a drawing.
⑥ Also applicable to alclad plate.
⑦ Refer to paragraph 3 of "Ultrasonic Testing" in Section 4, Quality Control, for inspection limitations dependent on entry and back surface resolution.

TABLE 6.4 Lot Acceptance Criteria for Corrosion Resistant Tempers

ALLOY AND TEMPER	LOT ACCEPTANCE CRITERIA ①: ELECTRICAL CONDUCTIVITY ② PERCENT IACS	LOT ACCEPTANCE CRITERIA ①: LEVEL OF MECHANICAL PROPERTIES ⑤	LOT ACCEPTANCE CRITERIA ①: LOT ACCEPTANCE STATUS
7049-T73, T7352	40.0 or greater	Per standard requirements	Acceptable ⑥
	38.0 thru 39.9	Per standard reqirements and yield strength does not exceed minimum by more than 9.9 ksi	Acceptable ⑥
		Per standard requirements but yield strength exceeds minimum by 10.0 ksi or more	Unacceptable ③
	Less than 38.0	Any level	Unacceptable ③
7050-T73510 and T73511	41.0 or greater	Per standard requirements	Acceptable ⑥
	40.0 thru 40.9	Per standard requirements and yield strength does not exceed 69.0 ksi	Acceptable ⑥
		Per standard requirements but yield strength exceeds 69.0 ksi	Unacceptable ③
	Less than 40.0	Any level	Unacceptable ③
7050-T74 ④ ⑨ T7451, T74510, T74511, T7452	38.0 or greater	Per standard requirements and SCF ⑧ is 32.0 or less	Acceptable ⑥
		Per standard requirements but SCF ⑧ is over 32.0	Unacceptable ③
	Less than 38.0	Any level	Unacceptable ③

TABLE 6.4 Lot Acceptance Criteria for Corrosion Resistant Tempers (concluded)

ALLOY AND TEMPER	LOT ACCEPTANCE CRITERIA ①		
	ELECTRICAL CONDUCTIVITY ② PERCENT IACS	LEVEL OF MECHANICAL PROPERTIES ⑤	LOT ACCEPTANCE STATUS
7050-T7651	37.0 or greater	Per standard requirements and SCF ⑧ is 36.0 or less	Acceptable ⑥
		Per standard requirements but SCF ⑧ is over 36.0	Unacceptable ③
	Less than 37.0	Any level	
7050-T76510 T76511	Equal or greater than 39.0	Per standard requirements	Acceptable ⑥
	37.0 but less than 39.0	Per standard requirements and SCF ⑧ is 39.0 or less	
		Per standard requirements but SCF ⑧ is greater than 39.0	Unacceptable ③
	Less than 37.0	Any level	
7075-T73, T7351 T73510, T73511, T7352	40.0 or greater	Per standard requirements	Acceptable ⑥
	38.0 thru 39.9	Per standard requirements and yield strength does not exceed minimum by more than 11.9 ksi	
		Per standard requirements but yield strength exceeds minimum by 12.0 ksi or more	Unacceptable ③
	Less than 38.0	Any level	
7075-T76, T7651 T76510, T76511	38.0 or greater	Per standard requirements	Acceptable ⑥
	36.0 thru 37.9	Per standard requirements	Suspect ⑦
	Less than 36.0	Any level	Unacceptable ③
7175-T74 ⑨, T7452, T7454	40.0 or greater	Per standard requirements	Acceptable ⑥
	38.0 thru 39.9	Per standard requirements and the longitudinal yield strength does not exceed the minimum by more than 11.9 ksi	Acceptable ⑥
		Longitudinal yield strength exceeds the minimum by 12.0 ksi or more	Unacceptable ③
	Less than 38.0	Any level	Unacceptable ③
7178-T76, T7651 T76510, T76511	38.0 or greater	Per standard requirements	Acceptable ⑥
	35.0 thru 37.9	Per standard requirements	Suspect ⑦
	Less than 35.0	Any level	Unacceptable ③
7475-T7351	40.0 or greater	Per standard requirements	Acceptable ⑥
	39.9 or less	Any level	Unacceptable ③
7475-T761	39.0 or greater	Per standard requirements and yield strength is 8.9 ksi or less above specified minimum	Acceptable ⑥
		Yield strength exceeds minimum by 9.0 ksi or more	Unacceptable ③
	38.9 or less	Any level	Unacceptable ③
7475-T7651	39.0 or greater	Per standard requirements and yield strength is 8.9 ksi or less above specified minimum	Acceptable ⑥
		Yield strength exceeds minimum by 9.0 ksi or more	Unacceptable ③
	38.9 or less	Any level	Unacceptable ③
Alclad 7475-T761	39.0 or greater	Per standard requirements and yield strength is 8.9 ksi or less above specified minimum	Acceptable ⑥
		Yield strength exceeds minimum by 9.0 ksi or more	Unacceptable ③
	38.0 through 38.9	Per standard requirement	Unacceptable ③
	37.9 or less	Any level	Unacceptable ③

① These criteria apply to all products covered in Table 6.5 in the applicable indicated tempers. Limits are also applicable to alclad sheet and plate after removal of the cladding.

② Electrical conductivity measurements are made in accordance with ASTM E1004 on the same samples used for tensile testing and at the location indicated in Table 6.5.

③ When the lot acceptance status is "unacceptable," the material is reprocessed (additional precipitation heat treatment or re-solution heat treatment and precipitation heat treatment).

④ Die forgings in the T74 (formerly T736) temper also are restricted to having yield strength, parallel to the direction of grain flow, not to exceed 72.0 ksi.

⑤ The test direction applicable to these criteria is the standard mechanical property test direction for the product; long transverse for sheet, plate, and hand forgings, longitudinal for extrusions, and parallel to the direction of grain flow for die forgings.

⑥ "Acceptable" lot acceptance status is based upon ability of material with the stated level of electrical conductivity and yield strength to demonstrate statistical compliance with its respective corrosion resistance capabilities. For the applicable corrosion resistance capabilities, refer to the mechanical properties section for the product under consideration.

⑦ When material in these tempers is found to be suspect it is either tested for exfoliation corrosion resistance per ASTM G34 (See Table 6.7) or it is reprocessed (additional precipitation heat treatment or resolution heat treatment and precipitation heat treatment). Favorable exfoliation corrosion test results must never be used as acceptance criteria for stress corrosion resistance.

⑧ The Yield Strength/Electrical Conductivity relationship is as follows: Stress Corrosion Susceptibility Factor (SCF) = Yield Strength (XX.X ksi) minus Electrical Conductivity (XX.X%IACS).

⑨ Former temper designations were T736, T73651, T736510, T736511 and T73652, respectively.

TABLE 6.5 Location for Electrical Conductivity Measurements

ALLOY AND TEMPER	PRODUCT	THICKNESS in.	LOCATION FOR ELECTRICAL CONDUCTIVITY MEASUREMENTS ②
7050-T7451 ④ 7075-T73, T7351 7475-T7351	Sheet and plate ①	All	Surface of tensile sample
7050-T7651 7075-T76, T7651 7178-T76, T7651 7475-T761, T7651	Sheet and plate ①	Up thru 0.100	Surface of tensile sample
		Over 0.100	Sub-surface after removing approximately 10% of thickness of tensile sample
7075-T73, T7351	Rolled, or cold finished from rolled, wire, rod, bar	All	Surface of tensile sample
7050-T73510, T73511 T74510 ④, T74511 ④ T76510, T76511 7075-T73, T7351 T73510, T73511 T76 T76510, T76511 7178-T76 T76510, T76511	Extruded, or cold finished from extruded, wire, rod, and bar, and extruded profiles and tube	Up thru 0.100	Surface of tensile sample ③
		Over 0.100 thru 0.500	Sub-surface after removing approximately 10% of thickness of tensile sample
		Over 0.500 thru 1.500	Sub-surface of approximately center of thickness on a plane parallel to the longitudinal center line of the material.
		Over 1.500	Sub-surface on test coupon surface that is closest to the center of the thickness and on a plane parallel to the extrusion surface.
7075-T73	Drawn tube	Up thru 0.100	Surface of tensile sample ③
		Over 0.100 thru 0.500	Sub-surface after removing approximately 10% of thickness of tensile sample
7049-T73, T7352 7050-T744, T7452 ④ 7075-T73, T7352 7175-T74 ④, T7452 ④ and T7454 ④	Forgings	All	Surface of tensile sample

① Also applies to alclad sheet and plate; however the cladding must be removed and the electrical conductivity determined on the core material.
② For curved surfaces, the conductivity is measured on a machined flat spot.
③ For smaller sizes of tube, a cut-out portion is flattened and the surface measured.
④ T74 type tempers, although not previously registered, have appeared in the literature and in some specifications as T736 tempers.

TABLE 6.6 Fracture Toughness Limits

Fracture Toughness Limits for Plate ① ②

Alloy and Temper	Thickness (in.)	K_{Ic}, ksi $\sqrt{in.}$ minimum		
		L-T	T-L	S-L
2124-T851	1.500–6.000	24	20	18
7050-T7451 ③	0.250–2.000 2.001–3.000 3.001–4.000 4.001–5.000 5.001–6.000 6.001–7.000 7.001–8.000	29 27 26 25 24 23 23	25 24 23 22 22 21 21	— 21 21 21 21 21 21
7050-T7651 ②	1.000–2.000 2.001–3.000	26 24	24 23	— 20
7475-T651	0.750–1.500	30	28	—
7475-T7351	0.750–1.249 1.250–4.000 2.750-4.000	38 40 —	32 33 —	— — 25
7475-T7651	1.250–1.500	33	30	—

Fracture Toughness Limits for Sheet ④ ⑤

Alloy and Temper	Thickness (in.)	K_c, ksi $\sqrt{in.}$ minimum		
		L-T	T-L	S-L
7475-T61	0.040–0.125 0.126–0.249	— 60	75 60	— —
7475-T761	0.040–0.125 0.126–0.249	— —	87 80	— —
ALCLAD 7475-T61	0.040-0.125 0.126-0.249	— —	75 60	— —
ALCLAD 7475-T761	0.040-0.125 0.126-0.249	100 —	87 80	— —

① When tested per ASTM Test Method E399 and ASTM Practice B645.
② Specimen thickness and test locations are defined in the applicable SAE-AMS specification.
③ T74 type tempers, although not previously registered, have appeared in the literature and in some specifications as T736 type tempers.
④ When tested per ASTM Practice B646 and ASTM Practice E561.
⑤ The minimums shown are for a mt panel, 16 inches wide. The initial crack length, $2a_0$ shall be equal to one quarter of the width, W; that is $2a_0$/W=25.

TABLE 6.7 Corrosion Resistance Test Criteria

PRODUCT	ALLOY AND TEMPER	STRESS CORROSION RESISTANCE TEST ① STRESS LEVEL	EXFOLIATION CORROSION RESISTANCE TEST ② SAMPLE LOCATION
Sheet	7075-T76	—	③
	7178-T76	—	③
	7475-T761	—	③
Plate	2124-T851 ⑥	50% RLTYS ⑤	—
	2219-T851 ⑥ 2219-T87 ⑥	75% RLTYS ⑤ 75% RLTYS ⑤	— —
	7050-T7451 ④ 7050-T7651	35 ksi 25 ksi	③ ③
	7075-T7351 7075-T7651	75% RLTYS ⑤ 25 ksi	— ③
	7178-T7651	25 ksi	③
	7475-T7351 7475-T7651	40 ksi 25 ksi	— ③
Extruded, or Cold Finished from Extruded, Wire, Rod, and Bar, and Extruded Profiles and Tube	2219-T8510, T8511 ⑥ 7050-T73510, T73511 -74510 ④, T74511 ④ -T76510, T76511 7075-T73, T7351 -T73510, T73511 -T76 -T76510, T76511 7178-T76 -T76510, T76511	30 ksi 75% RLYS ⑤ 35 ksi 17 ksi 75% RLYS ⑤ 75% RLYS ⑤ 25 ksi 25 ksi 25 ksi 25 ksi	— — ③ ③ — — ③ ③ ③ ③
Rolled, or Cold Finished from Rolled Wire, Rod and Bar	7075-T73, T7351	75% RLYS ⑤	—
Drawn Tube	7075-T73	75% RLYS ⑤	③
Hand Forgings	7049-T73, T7352 7050-T7452 ④ 7075-T73, T7352 7075-T74, T7452	75% RLYS ⑤ 35 ksi 75% RLYS ⑤ 35 ksi for thickness 3 in. and less 50% RLYS for thickness over 3 in.	— ③ — — —
Die Forgings	7049-T73, T7352 7050-T74 ④ 7075-T73, T7352 7175-T74 7175-T7452 7175-T7454	75% RLYS ⑤ 35 ksi 75% RLYS ⑤ 35 ksi 35 ksi 35 ksi	— ③ — ③ ③ ③

① Tested in accordance with ASTM G47.
② Tested in accordance with ASTM G34 and displays corrosion less than that pictured by Photo EB, Figure 2.
③ Sample location to be the same as the electrical conductivity test location per Table 6.5.
④ T74 type tempers, although not previously registered, have appeared in literature and in some specifications as T736 type tempers.
⑤ RLTYS—Registered long transverse yield strength. RLYS—Registered longitudinal yield strength.
⑥ These 2xxx alloys do not routinely require SCC lot release testing. The criteria shown are in accordance with certain government and customer specifications, but apply only when specified.

7. Sheet and Plate

Introduction

Section 7. of Aluminum Standards and Data covers the mechanical property limits and product dimensional tolerance limits for aluminum alloy sheet and plate. These limits are statistically based guaranteed limits, and may be used as the basis of design. Note that the limits applicable in any specific situation are those for the specific size of product ordered.

Product Property Limits for Aluminum Alloy Sheet and Plate

Tables 7.1 through 7.6 provide the specified aluminum industry product limits for aluminum alloy sheet and plate products, as follows:

Table 7.1 - Mechanical Property Limits - Non-Heat-Treatable Alloys
Table 7.2 - Mechanical Property Limits - Heat-Treatable Alloys
Table 7.3 - Mechanical Property Limits - Brazing Sheet
Table 7.4 - Weights per Square Foot
Table 7.5 - Weight Conversion Factors
Table 7.6 - Recommended Minimum Bend Radii for 90-Degree Cold forming

Note that the product limits shown above are statistically-based guaranteed limits, and are thus suitable for the design of aluminum alloy products.

Special Note: The applicable limits for any individual product are those that apply to the specified (ordered) dimension.

Dimensional Tolerance Limits for Aluminum Alloy Sheet and Plate

Specific aluminum industry guaranteed tolerance limits for aluminum alloy sheet and plate are shown in Tables 7.7 through 7.18, as listed below:

Table 7.7a - Sheet and Plate Thickness Tolerances (Non-Aerospace Applications)
Table 7.7b - Sheet and Plate Thickness Tolerances (Aerospace Applications)
Table 7.8 - Width Tolerances for Sheared Flat Sheet and Plate
Table 7.9 - Length Tolerances for Sheared Flat Sheet and Plate
Table 7.10 - Width and Length Tolerances for Sawed Flat Sheet and Plate
Table 7.11 - Width Tolerances for Sheared Flat Sheet and Plate
Table 7.12 - Lateral Bow Tolerances for Coiled Sheet
Table 7.13 - Lateral Bow Tolerances for Flat Sheet and Plate
Table 7.14 - Squareness Tolerances for Flat Sheet and Plate
Table 7.15 - Diameter Tolerances for Sheared or Blanked Circles
Table 7.16 - Diameter Tolerances for Sawed Circles
Table 7.17 - Flatness Tolerances for Flat Sheet
Table 7.18 - Flatness Tolerances for Sawed or Sheared Plate

Some general comments on the applicability and methods for calculating tolerances from these tables are given on p. 4-16 of Aluminum Standards and Data. For sheet and plate products, it is appropriate to note that these published tolerance limits represent industry standards that are agreed to and capable of being met by all members of the industry. Thus they represent the maximum tolerances that can be provided by any producer; in no case should tolerance ranges larger than these values be provided.

In some cases, substantially tighter limits (i.e., smaller ranges of thickness, width and/or length) may be obtained from individual producers upon special order. In this regard, for example, it is broadly understood in the industry that it is possible to order sheet and plate from many suppliers to thickness tolerances that are one-half those in the limit Table 7.7a, as illustrated in Table 4.1 in the blue pages.

For additional information of specific tolerance ranges available, contact producers directly.

Product Limits for Special Finished Sheet and Plate Products

The guaranteed mechanical, dimensional and finish characteristics of special aluminum alloy sheet and plate products are shown in Tables 7.19 through 7.43, as follows:

Painted Sheet - Table 7.19 and associated text
- Table 7.19 - Recommended Minimum Bend Radii

Commercial roofing and siding - Tables 7.20 through 7.30
- Table 7.20 - Standard Finishes for Roofing and Siding
- Table 7.21 - Designed Dimensions and Weights for Corrugated Roofing
- Table 7.22 - Designed Dimensions and Weights for Corrugated Siding
- Table 7.23 - Designed Dimensions and Weights for V-Beam Roofing and Siding
- Table 7.24 - Designed Dimensions and Weights for Ribbed Roofing
- Table 7.25 - Designed Dimensions and Weights for Ribbed Siding
- Table 7.26 - Thickness Tolerances
- Table 7.27 - Depth of Corrugation Tolerances
- Table 7.28 - Length Tolerances
- Table 7.29 - Parallelness of Corrugations
- Table 7.30 - Squareness Tolerances

Duct Sheet - Tables 7.31 through 7.34, and associated text
- Table 7.31 - Thickness Tolerances for Duct Sheet
- Table 7.32 - Width Tolerances for Flat Duct Sheet
- Table 7.33 - Width Tolerances
- Table 7.34 - Length Tolerances

Tread Plate - Tables 7.35 through 7.43
- Table 7.35 - Mechanical Property Limits for Tread Plate
- Table 7.36 - Weights per Square Foot for Tread Plate
- Table 7.37- Thickness Tolerances for Tread Plate
- Table 7.38 - Width Tolerances
- Table 7.39 - Length Tolerances
- Table 7.40 - Height of Pattern Tolerance
- Table 7.41 - Camber of Pattern Line Tolerances
- Table 7.42 - Lateral Bow Tolerances
- Table 7.43 - Squareness Tolerances

References to Other Sheet and Plate Information in Aluminum Standards and Data

TABLE 7.1 Mechanical Property Limits—Non-Heat-Treatable Alloys [1] [10]

ALLOY AND TEMPER	SPECIFIED THICKNESS [2] in.	TENSILE STRENGTHS—ksi				ELONGATION PERCENT MIN. in 2 in. or 4D [5]
		ULTIMATE		YIELD		
		min.	max.	min.	max.	
1060						
1060-O	0.006–0.019	8.0	14.0	2.5	. .	15
	0.020–0.050	8.0	14.0	2.5	. .	22
	0.051–3.000	8.0	14.0	2.5	. .	25
1060-H12 [3]	0.017–0.050	11.0	16.0	9.0	. .	6
	0.051–2.000	11.0	16.0	9.0	. .	12
1060-H14 [3]	0.009–0.019	12.0	17.0	10.0	. .	1
	0.020–0.050	12.0	17.0	10.0	. .	5
	0.051–1.000	12.0	17.0	10.0	. .	10
1060-H16 [3]	0.006–0.019	14.0	19.0	11.0	. .	1
	0.020–0.050	14.0	19.0	11.0	. .	4
	0.051–0.162	14.0	19.0	11.0	. .	5
1060-H18 [3]	0.006–0.019	16.0	. .	12.0	. .	1
	0.020–0.050	16.0	. .	12.0	. .	3
	0.051–0.128	16.0	. .	12.0	. .	4
1060-H112	0.250–0.499	11.0	. .	. .	. .	10
	0.500–1.000	10.0	. .	. .	. .	20
	1.001–3.000	9.0	. .	. .	. .	25
1100						
1100-O	0.006–0.019	11.0	15.50	3.5	. .	15
	0.020–0.031	11.0	15.50	3.5	. .	20
	0.032–0.050	11.0	15.50	3.5	. .	25
	0.051–0.249	11.0	15.50	3.5	. .	30
	0.250–3.000	11.0	15.50	3.5	. .	28
1100-H12 [3]	0.017–0.019	14.0	19.00	11.0	. .	3
	0.020–0.031	14.0	19.00	11.0	. .	4
	0.032–0.050	14.0	19.00	11.0	. .	6
	0.051–0.113	14.0	19.00	11.0	. .	8
	0.114–0.499	14.0	19.00	11.0	. .	9
	0.500–2.000	14.0	19.00	11.0	. .	12
1100-H14 [3]	0.009–0.012	16.0	21.00	14.0	. .	1
	0.013–0.019	16.0	21.00	14.0	. .	2
	0.020–0.031	16.0	21.00	14.0	. .	3
	0.032–0.050	16.0	21.00	14.0	. .	4
	0.051–0.113	16.0	21.00	14.0	. .	5
	0.114–0.499	16.0	21.00	14.0	. .	6
	0.500–1.000	16.0	21.00	14.0	. .	10
1100-H16 [3]	0.006–0.019	19.0	24.00	17.0	. .	1
	0.020–0.031	19.0	24.00	17.0	. .	2
	0.032–0.050	19.0	24.00	17.0	. .	3
	0.051–0.162	19.0	24.00	17.0	. .	4
1100-H18	0.006–0.019	22.0	. .	. .	. .	1
	0.020–0.031	22.0	. .	. .	. .	2
	0.032–0.050	22.0	. .	. .	. .	3
	0.051–0.128	22.0	. .	. .	. .	4
1100-H19	0.006–0.063	24.0	. .	. .	. .	1
1100-H112	0.250–0.499	13.0	. .	7.0	. .	9
	0.500–2.000	12.0	. .	5.0	. .	14
	2.001–3.000	11.5	. .	4.0	. .	20
1350						
1350-O	0.006–0.019	8.0	14.0	. .	. .	15
	0.020–0.031	8.0	14.0	. .	. .	20
	0.032–0.050	8.0	14.0	. .	. .	25
	0.051–0.249	8.0	14.0	. .	. .	30
	0.250–3.000	8.0	14.0	. .	. .	28
1350-H12	0.017–0.019	12.0	17.0	. .	. .	3
	0.020–0.031	12.0	17.0	. .	. .	4
	0.032–0.050	12.0	17.0	. .	. .	6
	0.051–0.113	12.0	17.0	. .	. .	8
	0.114–0.499	12.0	17.0	. .	. .	9
	0.500–2.000	12.0	17.0	. .	. .	12
1350-H14	0.009–0.012	14.0	19.0	. .	. .	1
	0.013–0.019	14.0	19.0	. .	. .	2
	0.020–0.031	14.0	19.0	. .	. .	3
	0.032–0.050	14.0	19.0	. .	. .	4
	0.051–0.113	14.0	19.0	. .	. .	5
	0.114–0.499	14.0	19.0	. .	. .	6
	0.500–1.000	14.0	19.0	. .	. .	10

For all numbered footnotes, see page 7-11.

TABLE 7.1 Mechanical Property Limits—Non-Heat-Treatable Alloys [1] [10] (continued)

ALLOY AND TEMPER	SPECIFIED THICKNESS [2] in.	TENSILE STRENGTHS—ksi				ELONGATION PERCENT MIN. in 2 in. or 4D [5]
		ULTIMATE		YIELD		
		min.	max.	min.	max.	
1350 (Continued)						
1350-H16	0.006–0.019	16.0	21.0	. .	. .	1
	0.020–0.031	16.0	21.0	. .	. .	2
	0.032–0.050	16.0	21.0	. .	. .	3
	0.051–0.162	16.0	21.0	. .	. .	4
1350-H18	0.006–0.019	18.0	. .	. .	. .	1
	0.020–0.031	18.0	. .	. .	. .	2
	0.032–0.050	18.0	. .	. .	. .	3
	0.051–0.128	18.0	. .	. .	. .	4
1350-H112	0.250–0.499	11.0	. .	. .	. .	10
	0.500–1.000	10.0	. .	. .	. .	16
	1.001–1.500	9.0	. .	. .	. .	22
3003						
3003-O	0.006–0.007	14.0	19.0	5.0	. .	14
	0.008–0.012	14.0	19.0	5.0	. .	18
	0.013–0.031	14.0	19.0	5.0	. .	20
	0.032–0.050	14.0	19.0	5.0	. .	23
	0.051–0.249	14.0	19.0	5.0	. .	25
	0.250–3.000	14.0	19.0	5.0	. .	23
3003-H12 [3]	0.017–0.019	17.0	23.0	12.0	. .	3
	0.020–0.031	17.0	23.0	12.0	. .	4
	0.032–0.050	17.0	23.0	12.0	. .	5
	0.051–0.113	17.0	23.0	12.0	. .	6
	0.114–0.161	17.0	23.0	12.0	. .	7
	0.162–0.249	17.0	23.0	12.0	. .	8
	0.250–0.499	17.0	23.0	12.0	. .	9
	0.500–2.000	17.0	23.0	12.0	. .	10
3003-H14 [3]	0.009–0.012	20.0	26.0	17.0	. .	1
	0.013–0.019	20.0	26.0	17.0	. .	2
	0.020–0.031	20.0	26.0	17.0	. .	3
	0.032–0.050	20.0	26.0	17.0	. .	4
	0.051–0.113	20.0	26.0	17.0	. .	5
	0.114–0.161	20.0	26.0	17.0	. .	6
	0.162–0.249	20.0	26.0	17.0	. .	7
	0.250–0.499	20.0	26.0	17.0	. .	8
	0.500–1.000	20.0	26.0	17.0	. .	10
3003-H16 [3]	0.006–0.019	24.0	30.0	21.0	. .	1
	0.020–0.031	24.0	30.0	21.0	. .	2
	0.032–0.050	24.0	30.0	21.0	. .	3
	0.051–0.162	24.0	30.0	21.0	. .	4
3003-H18 [3]	0.006–0.019	27.0	. .	24.0	. .	1
	0.020–0.031	27.0	. .	24.0	. .	2
	0.032–0.050	27.0	. .	24.0	. .	3
	0.051–0.128	27.0	. .	24.0	. .	4
3003-H19	0.006–0.063	29.0	. .	. .	. .	1
3003-H112	0.250–0.499	17.0	. .	10.0	. .	8
	0.500–2.000	15.0	. .	6.0	. .	12
	2.001–3.000	14.5	. .	6.0	. .	18
ALCLAD 3003 [8]						
Alclad 3003-O	0.006–0.007	13.0	18.0	4.5	. .	14
	0.008–0.012	13.0	18.0	4.5	. .	18
	0.013–0.031	13.0	18.0	4.5	. .	20
	0.032–0.050	13.0	18.0	4.5	. .	23
	0.051–0.249	13.0	18.0	4.5	. .	25
	0.250–0.499	13.0	18.0	4.5	. .	23
	0.500–3.000	14.0 [4]	19.0 [4]	5.0 [4]	. .	23
Alclad 3003-H12 [3]	0.017–0.031	16.0	22.0	11.0	. .	4
	0.032–0.050	16.0	22.0	11.0	. .	5
	0.051–0.113	16.0	22.0	11.0	. .	6
	0.114–0.161	16.0	22.0	11.0	. .	7
	0.162–0.249	16.0	22.0	11.0	. .	8
	0.250–0.499	16.0	22.0	11.0	. .	9
	0.500–2.000	17.0 [4]	23.0 [4]	12.0 [4]	. .	10

For all numbered footnotes, see page 7-11.

TABLE 7.1 Mechanical Property Limits—Non-Heat-Treatable Alloys ① ⑩ (continued)

ALLOY AND TEMPER	SPECIFIED THICKNESS ② in.	TENSILE STRENGTHS—ksi ULTIMATE min.	ULTIMATE max.	YIELD min.	YIELD max.	ELONGATION PERCENT MIN. in 2 in. or 4D ⑤
ALCLAD 3003 ⑧ (Continued)						
Alclad 3003-H14 ③	0.009–0.012	19.0	25.0	16.0	. .	1
	0.013–0.019	19.0	25.0	16.0	. .	2
	0.020–0.031	19.0	25.0	16.0	. .	3
	0.032–0.050	19.0	25.0	16.0	. .	4
	0.051–0.113	19.0	25.0	16.0	. .	5
	0.114–0.161	19.0	25.0	16.0	. .	6
	0.162–0.249	19.0	25.0	16.0	. .	7
	0.250–0.499	19.0	25.0	16.0	. .	8
	0.500–1.000	20.0 ④	26.0 ④	17.0 ④	. .	10
Alclad 3003-H16 ③	0.006–0.019	23.0	29.0	20.0	. .	1
	0.020–0.031	23.0	29.0	20.0	. .	2
	0.032–0.050	23.0	29.0	20.0	. .	3
	0.051–0.162	23.0	29.0	20.0	. .	4
Alclad 3003-H18	0.006–0.019	26.0	. .	. .	. .	1
	0.020–0.031	26.0	. .	. .	. .	2
	0.032–0.050	26.0	. .	. .	. .	3
	0.051–0.128	26.0	. .	. .	. .	4
Alclad 3003-H112	0.250–0.499	16.0	. .	9	. .	8
	0.500–2.000	15.0 ④	. .	6.0 ④	. .	12
	2.001–3.000	14.5 ④	. .	6.0 ④	. .	18
3004						
3004-O	0.006–0.007	22.0	29.0	8.5	. .	. .
	0.008–0.019	22.0	29.0	8.5	. .	10
	0.020–0.031	22.0	29.0	8.5	. .	14
	0.032–0.050	22.0	29.0	8.5	. .	16
	0.051–0.249	22.0	29.0	8.5	. .	18
	0.250–3.000	22.0	29.0	8.5	. .	16
3004-H32 ③	0.017–0.019	28.0	35.0	21.0	. .	1
	0.020–0.031	28.0	35.0	21.0	. .	3
	0.032–0.050	28.0	35.0	21.0	. .	4
	0.051–0.113	28.0	35.0	21.0	. .	5
	0.114–2.000	28.0	35.0	21.0	. .	6
3004-H34 ③	0.009–0.019	32.0	38.0	25.0	. .	1
	0.020–0.050	32.0	38.0	25.0	. .	3
	0.051–0.113	32.0	38.0	25.0	. .	4
	0.114–1.000	32.0	38.0	25.0	. .	5
3004-H36 ③	0.006–0.007	35.0	41.0	28.0	. .	. .
	0.008–0.019	35.0	41.0	28.0	. .	1
	0.020–0.031	35.0	41.0	28.0	. .	2
	0.032–0.050	35.0	41.0	28.0	. .	3
	0.051–0.162	35.0	41.0	28.0	. .	4
3004-H38 ③	0.006–0.007	38.0	. .	31.0	. .	. .
	0.008–0.019	38.0	. .	31.0	. .	1
	0.020–0.031	38.0	. .	31.0	. .	2
	0.032–0.050	38.0	. .	31.0	. .	3
	0.051–0.128	38.0	. .	31.0	. .	4
3004-H112	0.250–3.000	23.0	. .	9.0	. .	7
ALCLAD 3004 ⑧						
Alclad 3004-O	0.006–0.007	21.0	28.0	8.0	. .	. .
	0.008–0.019	21.0	28.0	8.0	. .	10
	0.020–0.031	21.0	28.0	8.0	. .	14
	0.032–0.050	21.0	28.0	8.0	. .	16
	0.051–0.249	21.0	28.0	8.0	. .	18
	0.250–0.499	21.0	28.0	8.0	. .	16
	0.500–3.000	22.0 ④	29.0 ④	8.5 ④	. .	16
Alclad 3004-H32 ③	0.017–0.019	27.0	34.0	20.0	. .	1
	0.020–0.031	27.0	34.0	20.0	. .	3
	0.032–0.050	27.0	34.0	20.0	. .	4
	0.051–0.113	27.0	34.0	20.0	. .	5
	0.114–0.249	27.0	34.0	20.0	. .	6
	0.250–0.499	27.0	34.0	20.0	. .	6
	0.500–2.000	28.0 ④	35.0 ④	21.0 ④	. .	6
Alclad 3004-H34 ③	0.009–0.019	31.0	37.0	24.0	. .	1
	0.020–0.050	31.0	37.0	24.0	. .	3
	0.051–0.113	31.0	37.0	24.0	. .	4
	0.114–0.249	31.0	37.0	24.0	. .	5
	0.250–0.499	31.0	37.0	24.0	. .	5
	0.500–1.000	32.0 ④	38.0 ④	25.0 ④	. .	5

For all numbered footnotes, see page 7-11.

TABLE 7.1 Mechanical Property Limits—Non-Heat-Treatable Alloys ① ⑩ (continued)

ALLOY AND TEMPER	SPECIFIED THICKNESS ② in.	TENSILE STRENGTHS—ksi				ELONGATION PERCENT MIN. in 2 in. or 4D ⑤
		ULTIMATE		YIELD		
		min.	max.	min.	max.	
ALCLAD 3004 ⑧ (Continued)						
Alclad 3004-H36 ③	0.006–0.007	34.0	40.0	27.0	. .	. .
	0.008–0.019	34.0	40.0	27.0	. .	1
	0.020–0.031	34.0	40.0	27.0	. .	2
	0.032–0.050	34.0	40.0	27.0	. .	3
	0.051–0.162	34.0	40.0	27.0	. .	4
Alclad 3004-H38	0.006–0.007	37.0	. .	. .	. .	. .
	0.008–0.019	37.0	. .	. .	. .	1
	0.020–0.031	37.0	. .	. .	. .	2
	0.032–0.050	37.0	. .	. .	. .	3
	0.051–0.128	37.0	. .	. .	. .	4
Alclad 3004-H112	0.250–0.499	22.0	. .	8.5	. .	7
	0.500–3.000	23.0 ④	. .	9.0 ④	. .	7
3005						
3005-O	0.006–0.007	17.0	24.0	6.5	. .	10
	0.008–0.012	17.0	24.0	6.5	. .	12
	0.013–0.019	17.0	24.0	6.5	. .	14
	0.020–0.031	17.0	24.0	6.5	. .	16
	0.032–0.050	17.0	24.0	6.5	. .	18
	0.051–0.249	17.0	24.0	6.5	. .	20
3005-H12	0.017–0.019	20.0	27.0	17.0	. .	1
	0.020–0.050	20.0	27.0	17.0	. .	2
	0.051–0.113	20.0	27.0	17.0	. .	3
	0.114–0.161	20.0	27.0	17.0	. .	4
	0.162–0.249	20.0	27.0	17.0	. .	5
3005-H14	0.009–0.031	24.0	31.0	21.0	. .	1
	0.032–0.050	24.0	31.0	21.0	. .	2
	0.051–0.113	24.0	31.0	21.0	. .	3
	0.114–0.249	24.0	31.0	21.0	. .	4
3005-H16	0.006–0.031	28.0	35.0	25.0	. .	1
	0.032–0.113	28.0	35.0	25.0	. .	2
	0.114–0.162	28.0	35.0	25.0	. .	3
3005-H18	0.006–0.031	32.0	. .	29.0	. .	1
	0.032–0.128	32.0	. .	29.0	. .	2
3005-H19	0.006–0.012	34.0	. .	. .	. .	. .
	0.013–0.063	34.0	. .	. .	. .	1
3005-H25	0.006–0.019	26.0	34.0	22.0	. .	1
	0.020–0.031	26.0	34.0	22.0	. .	2
	0.032–0.050	26.0	34.0	22.0	. .	3
	0.051–0.080	26.0	34.0	22.0	. .	4
3005-H26	0.006–0.019	28.0	36.0	24.0	. .	1
	0.020–0.031	28.0	36.0	24.0	. .	2
	0.032–0.050	28.0	36.0	24.0	. .	3
	0.051–0.080	28.0	36.0	24.0	. .	4
3005-H27	0.006–0.019	29.5	37.5	26.0	. .	1
	0.020–0.031	29.5	37.5	26.0	. .	2
	0.032–0.050	29.5	37.5	26.0	. .	3
	0.051–0.080	29.5	37.5	26.0	. .	4
3005-H28	0.006–0.019	31.0	. .	27.0	. .	1
	0.020–0.031	31.0	. .	27.0	. .	2
	0.032–0.050	31.0	. .	27.0	. .	3
	0.051–0.080	31.0	. .	27.0	. .	4
3105						
3105-O	0.013–0.019	14.0	21.0	5.0	. .	16
	0.020–0.031	14.0	21.0	5.0	. .	18
	0.032–0.080	14.0	21.0	5.0	. .	20
3105-H12	0.017–0.019	19.0	26.0	15.0	. .	1
	0.020–0.031	19.0	26.0	15.0	. .	1
	0.032–0.050	19.0	26.0	15.0	. .	2
	0.051–0.080	19.0	26.0	15.0	. .	3
3105-H14	0.013–0.019	22.0	29.0	18.0	. .	1
	0.020–0.031	22.0	29.0	18.0	. .	1
	0.032–0.050	22.0	29.0	18.0	. .	2
	0.051–0.080	22.0	29.0	18.0	. .	2
3105-H16	0.013–0.031	25.0	32.0	21.0	. .	1
	0.032–0.050	25.0	32.0	21.0	. .	2
	0.051–0.080	25.0	32.0	21.0	. .	2

For all numbered footnotes, see page 7-11.

TABLE 7.1 Mechanical Property Limits—Non-Heat-Treatable Alloys ① ⑩ (continued)

ALLOY AND TEMPER	SPECIFIED THICKNESS ② in.	TENSILE STRENGTHS—ksi				ELONGATION PERCENT MIN. in 2 in. or 4D ⑤
		ULTIMATE		YIELD		
		min.	max.	min.	max.	
3105 (Continued)						
3105-H18	0.013–0.031 0.032–0.050 0.051–0.080	28.0 28.0 28.0	. . . . . .	24.0 24.0 24.0	. . . . . .	1 1 2
3105-H22	0.013–0.019 0.020–0.031 0.032–0.050 0.051–0.080	19.0 19.0 19.0 19.0	. . . .	15.0 15.0 15.0 15.0	. . . .	3 4 5 6
3105-H24	0.013–0.019 0.020–0.031 0.032–0.050 0.051–0.080	22.0 22.0 22.0 22.0	. . . .	18.0 18.0 18.0 18.0	. . . .	2 3 4 6
3105-H25	0.013–0.019 0.020–0.031 0.032–0.050 0.051–0.080	23.0 23.0 23.0 23.0	. . . .	19.0 19.0 19.0 19.0	. . . .	2 3 4 6
3105-H26	0.013–0.031 0.032–0.050 0.051–0.080	25.0 25.0 25.0	. . . . . .	21.0 21.0 21.0	. . . . . .	3 4 5
3105-H28	0.013–0.031 0.032–0.050 0.051–0.080	28.0 28.0 28.0	. . . . . .	24.0 24.0 24.0	. . . . . .	2 3 4
5005						
5005-O	0.006–0.007 0.008–0.012 0.013–0.019 0.020–0.031 0.032–0.050 0.051–0.113 0.114–0.249 0.250–3.000	15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0	21.0 21.0 21.0 21.0 21.0 21.0 21.0 21.0	5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0	. . . .	12 14 16 18 20 21 22 22
5005-H12	0.017–0.019 0.020–0.031 0.032–0.050 0.051–0.113 0.114–0.161 0.162-.0249 0.250–0.499 0.500–2.000	18.0 18.0 18.0 18.0 18.0 18.0 18.0 18.0	24.0 24.0 24.0 24.0 24.0 24.0 24.0 24.0	14.0 14.0 14.0 14.0 14.0 14.0 14.0 14.0	. . . .	2 3 4 6 7 8 9 10
5005-H14	0.009–0.031 0.032–0.050 0.051–0.113 0.114–0.161 0.162–0.249 0.250–0.499 0.500–1.000	21.0 21.0 21.0 21.0 21.0 21.0 21.0	27.0 27.0 27.0 27.0 27.0 27.0 27.0	17.0 17.0 17.0 17.0 17.0 17.0 17.0	. . . .	1 2 3 5 6 8 10
5005-H16	0.006–0.031 0.032–0.050 0.051–0.162	24.0 24.0 24.0	30.0 30.0 30.0	20.0 20.0 20.0	. . . . . .	1 2 3
5005-H18	0.006–0.031 0.032–0.050 0.051–0.128	27.0 27.0 27.0	. . . . . .	. . . . . .	. . . . . .	1 2 3
5005-H32 ③	0.017–0.019 0.020–0.031 0.032–0.050 0.051–0.113 0.114–0.161 0.162–0.249 0.250–2.000	17.0 17.0 17.0 17.0 17.0 17.0 17.0	23.0 23.0 23.0 23.0 23.0 23.0 23.0	12.0 12.0 12.0 12.0 12.0 12.0 12.0	. . . .	3 4 5 7 8 9 10
5005-H34 ③	0.009–0.012 0.013–0.031 0.032–0.050 0.051–0.113 0.114–0.161 0.162–0.249 0.250–0.499 0.500–1.000	20.0 20.0 20.0 20.0 20.0 20.0 20.0 20.0	26.0 26.0 26.0 26.0 26.0 26.0 26.0 26.0	15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0	. . . .	2 3 4 5 6 7 8 10
5005-H36 ③	0.006–0.007 0.008–0.019 0.020–0.031 0.032–0.162	23.0 23.0 23.0 23.0	29.0 29.0 29.0 29.0	18.0 18.0 18.0 18.0	. . . .	1 2 3 4

For all numbered footnotes, see page 7-11.

TABLE 7.1 Mechanical Property Limits—Non-Heat-Treatable Alloys ① ⑩ (continued)

ALLOY AND TEMPER	SPECIFIED THICKNESS ② in.	TENSILE STRENGTHS—ksi				ELONGATION PERCENT MIN. in 2 in. or 4D ⑤
		ULTIMATE		YIELD		
		min.	max.	min.	max.	
5005 (Continued)						
5005-H38	0.006–0.012	26.0	. .	. .	. .	1
	0.013–0.019	26.0	. .	. .	. .	2
	0.020–0.031	26.0	. .	. .	. .	3
	0.032–0.128	26.0	. .	. .	. .	4
5005-H39	0.006–0.063	28.0	. .	. .	. .	1
5005-H112	0.250–0.499	17.0	. .	. .	. .	8
	0.500–2.000	15.0	. .	. .	. .	12
	2.001–3.000	14.5	. .	. .	. .	18
5050						
5050-O	0.006–0.007	18.0	24.0	6.0	. .	. .
	0.008–0.019	18.0	24.0	6.0	. .	16
	0.020–0.031	18.0	24.0	6.0	. .	18
	0.032–0.113	18.0	24.0	6.0	. .	20
	0.114–0.249	18.0	24.0	6.0	. .	22
	0.250–3.000	18.0	24.0	6.0	. .	20
5050-H32 ③	0.017–0.050	22.0	28.0	16.0	. .	4
	0.051–0.249	22.0	28.0	16.0	. .	6
5050-H34 ③	0.009–0.031	25.0	31.0	20.0	. .	3
	0.032–0.050	25.0	31.0	20.0	. .	4
	0.051–0.249	25.0	31.0	20.0	. .	5
5050-H36 ③	0.006–0.019	27.0	33.0	22.0	. .	2
	0.020–0.050	27.0	33.0	22.0	. .	3
	0.051–0.162	27.0	33.0	22.0	. .	4
5050-H38	0.006–0.007	29.0	. .	. .	. .	. .
	0.008–0.031	29.0	. .	. .	. .	2
	0.032–0.050	29.0	. .	. .	. .	3
	0.051–0.128	29.0	. .	. .	. .	4
5050-H39	0.006–0.063	31.0	. .	. .	. .	1
5050-H112	0.250–3.000	20.0	. .	8.0	. .	12
5052						
5052-O	0.006–0.007	25.0	31.0	9.5	. .	. .
	0.008–0.012	25.0	31.0	9.5	. .	14
	0.013–0.019	25.0	31.0	9.5	. .	15
	0.020–0.031	25.0	31.0	9.5	. .	16
	0.032–0.050	25.0	31.0	9.5	. .	18
	0.051–0.113	25.0	31.0	9.5	. .	19
	0.114–0.249	25.0	31.0	9.5	. .	20
	0.250–3.000	25.0	31.0	9.5	. .	18
5052-H32 ③	0.017–0.019	31.0	38.0	23.0	. .	4
	0.020–0.050	31.0	38.0	23.0	. .	5
	0.051–0.113	31.0	38.0	23.0	. .	7
	0.114–0.249	31.0	38.0	23.0	. .	9
	0.250–0.499	31.0	38.0	23.0	. .	11
	0.500–2.000	31.0	38.0	23.0	. .	12
5052-H34 ③	0.009–0.019	34.0	41.0	26.0	. .	3
	0.020–0.050	34.0	41.0	26.0	. .	4
	0.051–0.113	34.0	41.0	26.0	. .	6
	0.114–0.249	34.0	41.0	26.0	. .	7
	0.250–1.000	34.0	41.0	26.0	. .	10
5052-H36 ③	0.006–0.007	37.0	44.0	29.0	. .	2
	0.008–0.031	37.0	44.0	29.0	. .	3
	0.032–0.162	37.0	44.0	29.0	. .	4
5052-H38 ③	0.006–0.007	39.0	. .	32.0	. .	2
	0.008–0.031	39.0	. .	32.0	. .	3
	0.032–0.128	39.0	. .	32.0	. .	4
5052-H39	0.006–0.063	41.0	. .	. .	. .	1
5052-H112	0.250–0.499	28.0	. .	16.0	. .	7
	0.500–2.000	25.0	. .	9.5	. .	12
	2.001–3.000	25.0	. .	9.5	. .	16
5052-H391	0.008–0.125	42.0	. .	35.0	. .	3
5083						
5083-O	0.051–1.500	40.0	51.0	18.0	29.0	16
	1.501–3.000	39.0	50.0	17.0	29.0	16
	3.001–4.000	38.0	. .	16.0	. .	16
	4.001–5.000	38.0	. .	16.0	. .	14
	5.001–7.000	37.0	. .	15.0	. .	14
	7.001–8.000	36.0	. .	14.0	. .	12

For all numbered footnotes, see page 7-11.

TABLE 7.1 Mechanical Property Limits—Non-Heat-Treatable Alloys ① ⑩ (continued)

ALLOY AND TEMPER	SPECIFIED THICKNESS ② in.	TENSILE STRENGTHS—ksi				ELONGATION PERCENT MIN. in 2 in. or 4D ⑤
		ULTIMATE		YIELD		
		min.	max.	min.	max.	
5083 (Continued)						
5083-H32	0.125-0.187	44.0	56.0	31.0	. .	10
	0.188-1.500	44.0	56.0	31.0	. .	12
	1.501-3.000	41.0	56.0	29.0	. .	12
5083-H112	0.250–1.500	40.0	. .	18.0	. .	12
	1.501–3.000	39.0	. .	17.0	. .	12
5083-H116 ⑥ ⑨	0.063–0.499	44.0	. .	31.0	. .	10
	0.500–1.250	44.0	. .	31.0	. .	12
	1.251–1.500	44.0	. .	31.0	. .	12
	1.501–3.000	41.0	. .	29.0	. .	12
5083-H321⑨	0.125–0.187	44.0	56.0	31.0	. .	10
	0.188–1.500	44.0	56.0	31.0	. .	12
	1.501–3.000	41.0	56.0	29.0	. .	12
5086						
5086-O	0.020–0.050	35.0	44.0	14.0	. .	15
	0.051–0.249	35.0	44.0	14.0	. .	18
	0.250–2.000	35.0	44.0	14.0	. .	16
5086-H32 ③	0.020–0.050	40.0	47.0	28.0	. .	6
	0.051–0.249	40.0	47.0	28.0	. .	8
	0.250–2.000	40.0	47.0	28.0	. .	12
5086-H34 ③	0.009–0.019	44.0	51.0	34.0	. .	4
	0.020–0.050	44.0	51.0	34.0	. .	5
	0.051–0.249	44.0	51.0	34.0	. .	6
	0.250–1.000	44.0	51.0	34.0	. .	10
5086-H36 ③	0.006–0.019	47.0	54.0	38.0	. .	3
	0.020–0.050	47.0	54.0	38.0	. .	4
	0.051–0.162	47.0	54.0	38.0	. .	6
5086-H38 ③	0.006–0.020	50.0	. .	41.0	. .	3
5086-H112	0.188–0.499	36.0	. .	18.0	. .	8
	0.500–1.000	35.0	. .	16.0	. .	10
	1.001–2.000	35.0	. .	14.0	. .	14
	2.001–3.000	34.0	. .	14.0	. .	14
5086-H116 ⑥ ⑨	0.063–0.249	40.0	. .	28.0	. .	8
	0.250–0.499	40.0	. .	28.0	. .	10
	0.500–1.250	40.0	. .	28.0	. .	10
	1.251–2.000	40.0	. .	28.0	. .	10
5154						
5154-O	0.020–0.031	30.0	41.0	11.0	. .	12
	0.032–0.050	30.0	41.0	11.0	. .	14
	0.051–0.113	30.0	41.0	11.0	. .	16
	0.114–3.000	30.0	41.0	11.0	. .	18
5154-H32 ③	0.020–0.050	36.0	43.0	26.0	. .	5
	0.051–0.249	36.0	43.0	26.0	. .	8
	0.250–2.000	36.0	43.0	26.0	. .	12
5154-H34 ③	0.009–0.050	39.0	46.0	29.0	. .	4
	0.051–0.161	39.0	46.0	29.0	. .	6
	0.162–0.249	39.0	46.0	29.0	. .	7
	0.250–1.000	39.0	46.0	29.0	. .	10
5154-H36 ③	0.006–0.050	42.0	49.0	32.0	. .	3
	0.051–0.113	42.0	49.0	32.0	. .	4
	0.114–0.162	42.0	49.0	32.0	. .	5
5154-H38 ③	0.006–0.050	45.0	. .	35.0	. .	3
	0.051–0.113	45.0	. .	35.0	. .	4
	0.114–0.128	45.0	. .	35.0	. .	5
5154-H112	0.250–0.499	32.0	. .	18.0	. .	8
	0.500–2.000	30.0	. .	11.0	. .	11
	2.001–3.000	30.0	. .	11.0	. .	15
5252						
5252-H24	0.030–0.090	30.0	38.0	. .	. .	10
5252-H25	0.030–0.090	31.0	39.0	. .	. .	9
5252-H28	0.030–0.090	38.0	. .	. .	. .	3
5254						
5254-O	0.020–0.031	30.0	41.0	11.0	. .	12
	0.032–0.050	30.0	41.0	11.0	. .	14
	0.051–0.113	30.0	41.0	11.0	. .	16
	0.114–3.000	30.0	41.0	11.0	. .	18

For all numbered footnotes, see page 7-11.

TABLE 7.1 Mechanical Property Limits—Non-Heat-Treatable Alloys ① ⑩ (continued)

ALLOY AND TEMPER	SPECIFIED THICKNESS ② in.	TENSILE STRENGTHS—ksi ULTIMATE min.	ULTIMATE max.	YIELD min.	YIELD max.	ELONGATION PERCENT MIN. in 2 in. or 4D ⑤
5254 (Continued)						
5254-H34 ③	0.009–0.050	39.0	46.0	29.0	. .	4
	0.051–0.161	39.0	46.0	29.0	. .	6
	0.162–0.249	39.0	46.0	29.0	. .	7
	0.250–1.000	39.0	46.0	29.0	. .	10
5254-H36 ③	0.006–0.050	42.0	49.0	32.0	. .	3
	0.051–0.113	42.0	49.0	32.0	. .	4
	0.114–0.162	42.0	49.0	32.0	. .	5
5254-H38 ③	0.006–0.050	45.0	. .	35.0	. .	3
	0.051–0.113	45.0	. .	35.0	. .	4
	0.114–0.128	45.0	. .	35.0	. .	5
5254-H112	0.250–0.499	32.0	. .	18.0	. .	8
	0.500–2.000	30.0	. .	11.0	. .	11
	2.001–3.000	30.0	. .	11.0	. .	15
5454						
5454-O	0.020–0.031	31.0	41.0	12.0	. .	12
	0.032–0.050	31.0	41.0	12.0	. .	14
	0.051–0.113	31.0	41.0	12.0	. .	16
	0.114–3.000	31.0	41.0	12.0	. .	18
5454-H32 ③	0.020–0.050	36.0	44.0	26.0	. .	5
	0.051–0.249	36.0	44.0	26.0	. .	8
	0.250–2.000	36.0	44.0	26.0	. .	12
5454-H34 ③	0.020–0.050	39.0	47.0	29.0	. .	4
	0.051–0.161	39.0	47.0	29.0	. .	6
	0.162–0.249	39.0	47.0	29.0	. .	7
	0.250–1.000	39.0	47.0	29.0	. .	10
5454-H112	0.250–0.499	32.0	. .	18.0	. .	8
	0.500–2.000	31.0	. .	12.0	. .	11
	2.001–3.000	31.0	. .	12.0	. .	15
5456						
5456-O	0.051–1.500	42.0	53.0	19.0	30.0	16
	1.501–3.000	41.0	52.0	18.0	30.0	16
	3.001–5.000	40.0	. .	17.0	. .	14
	5.001–7.000	39.0	. .	16.0	. .	14
	7.001–8.000	38.0	. .	15.0	. .	12
5456-H32	0.188-0.499	46.0	59.0	33.0	. .	12
	0.500-1.500	44.0	56.0	31.0	. .	12
	1.501-3.000	41.0	54.0	29.0	. .	12
5456-H112	0.250–1.500	42.0	. .	19.0	. .	12
	1.501–3.000	41.0	. .	18.0	. .	12
5456-H116 ⑥ ⑨	0.063–0.499	46.0	. .	33.0	. .	10
	0.500–1.250	46.0	. .	33.0	. .	12
	1.251–1.500	44.0	. .	31.0	. .	12
	1.501–3.000	41.0	. .	29.0	. .	12
	3.001–4.000	40.0	. .	25.0	. .	12
5456-H321⑨	0.100-0.187	48.0	59.0	34.0	. .	10
	0.188–0.499	46.0	59.0	33.0	. .	12
	0.500–1.500	44.0	56.0	31.0	. .	12
	1.501–3.000	41.0	54.0	29.0	. .	12
5457						
5457-O	0.030–0.090	16.0	22.0	. .	. .	20
5652						
5652-O	0.006–0.007	25.0	31.0	9.5	. .	. .
	0.008–0.012	25.0	31.0	9.5	. .	14
	0.013–0.019	25.0	31.0	9.5	. .	15
	0.020–0.031	25.0	31.0	9.5	. .	16
	0.032–0.050	25.0	31.0	9.5	. .	18
	0.051–0.113	25.0	31.0	9.5	. .	19
	0.114–0.249	25.0	31.0	9.5	. .	20
	0.250–3.000	25.0	31.0	9.5	. .	18
5652-H32 ③	0.017–0.019	31.0	38.0	23.0	. .	4
	0.020–0.050	31.0	38.0	23.0	. .	5
	0.051–0.113	31.0	38.0	23.0	. .	7
	0.114–0.249	31.0	38.0	23.0	. .	9
	0.250–0.499	31.0	38.0	23.0	. .	11
	0.500–2.000	31.0	38.0	23.0	. .	12

For all numbered footnotes, see page 7-11.

TABLE 7.1 Mechanical Property Limits—Non-Heat-Treatable Alloys ① ⑩ (concluded)

ALLOY AND TEMPER	SPECIFIED THICKNESS ② in.	TENSILE STRENGTHS—ksi				ELONGATION PERCENT MIN. in 2 in. or 4D ⑤
		ULTIMATE		YIELD		
		min.	max.	min.	max.	
5652 (Continued)						
5652-H34 ③	0.009–0.019	34.0	41.0	26.0	. .	3
	0.020–0.050	34.0	41.0	26.0	. .	4
	0.051–0.113	34.0	41.0	26.0	. .	6
	0.114–0.249	34.0	41.0	26.0	. .	7
	0.250–1.000	34.0	41.0	26.0	. .	10
5652-H36 ③	0.006–0.007	37.0	44.0	29.0	. .	2
	0.008–0.031	37.0	44.0	29.0	. .	3
	0.032–0.162	37.0	44.0	29.0	. .	4
5652-H38 ③	0.006–0.007	39.0	. .	32.0	. .	2
	0.008–0.031	39.0	. .	32.0	. .	3
	0.032–0.128	39.0	. .	32.0	. .	4
5652-H112	0.250–0.499	28.0	. .	16.0	. .	7
	0.500–2.000	25.0	. .	9.5	. .	12
	2.001–3.000	25.0	. .	9.5	. .	16
5657						
5657-H241 ⑦	0.030–0.090	18.0	26.0	. .	. .	13
5657-H25	0.030–0.090	20.0	28.0	. .	. .	8
5657-H26	0.030–0.090	22.0	30.0	. .	. .	7
5657-H28	0.030–0.090	25.0	. .	. .	. .	5

Footnotes for Pages 7-3 through 7-11

① The data base and criteria upon which these mechanical property limits are established are outlined on page 6-1 under “Mechanical Properties.”
② Type of test specimen used depends on thickness of material; see “Sampling and Testing,” pages 4-1 through 4-5.
③ For the corresponding H2 temper, limits for maximum ultimate tensile strength and minimum yield strength do not apply.
④ This table specifies the properties applicable to the test specimens, and since for plate 0.500 inch or over in thickness the cladding material is removed during the preparation of the test specimens, the listed properties are applicable to the core material only. Tensile and yield strengths of the composite plate are slightly lower depending on the thickness of the cladding.
⑤ D represents specimen diameter.
⑥ Also applies to material previously designated H117.
⑦ This material is subject to some recrystallization and the attendant loss of brightness.
⑧ See page 6-4 for specific cladding thicknesses.
⑨ Materials in these tempers, when tested upon receipt by the purchaser are required to pass ASTM G 66 and ASTM G 67 tests as defined in ASTM B 928. The resistance to inter-granular corrosion of individual lots is determined by microscope examination to assure a microstructure that is predominately free of a continous grain boundary network of aluminum-magnesium precipitate. The microstructure is compared to that in a previously established acceptable reference photomicrograph.
⑩ Processes such as flattening, leveling, or straightening coiled products subsequent to shipment by the producer may alter the mechanical properties of the metal (refer to Certification, Section 4).

TABLE 7.2 Mechanical Property Limits—Heat-Treatable Alloys ① ⑭

ALLOY AND TEMPER	SPECIFIED THICKNESS ② in.	TENSILE STRENGTH—ksi				ELONGATION PERCENT MIN. in 2 in. or 4D ③
		ULTIMATE		YIELD		
		min.	max.	min.	max.	
2014						
2014-O	0.020–0.499	. .	32.0	. .	16.0	16
Sheet and plate	0.500–1.000	. .	32.0	. .	. .	10
2014-T3	0.020–0.039	59.0	. .	35.0	. .	14
Flat Sheet	0.040–0.249	59.0	. .	36.0	. .	14
2014-T4 Coiled Sheet	0.020–0.249	59.0	. .	35.0	. .	14
2014-T451 ⑦ ⑧	0.250–0.499	58.0	. .	36.0	. .	14
Plate	0.500–1.000	58.0	. .	36.0	. .	14
	1.001–2.000	58.0	. .	36.0	. .	12
	2.001–3.000	57.0	. .	36.0	. .	8
2014-T42 ④ ⑩ Sheet and plate	0.020–1.000	58.0	. .	34.0	. .	14
2014-T6 and T62 ④ ⑩	0.020–0.039	64.0	. .	57.0	. .	6
Sheet	0.040–0.249	66.0	. .	58.0	. .	7
2014-T62 ④ ⑩ and T651 ⑦	0.250–.0499	67.0	. .	59.0	. .	7
Plate	0.500–1.000	67.0	. .	59.0	. .	6
	1.001–2.000	67.0	. .	59.0	. .	4
	2.001–2.500	65.0	. .	58.0	. .	2
	2.501–3.000	63.0	. .	57.0	. .	2
	3.001–4.000	59.0	. .	55.0	. .	1
ALCLAD 2014 ⑥						
Alclad 2014-O	0.020–0.499	. .	30.0	. .	14.0	16
Sheet and Plate	0.500–1.000	. .	32.0 ⑤	. .	. .	10
Alclad 2014-T3	0.020–0.024	54.0	. .	33.0	. .	14
Flat sheet	0.025–0.039	55.0	. .	34.0	. .	14
	0.040–0.249	57.0	. .	35.0	. .	15
Alclad 2014-T4	0.020–0.024	54.0	. .	31.0	. .	14
Coiled sheet	0.025–0.039	55.0	. .	32.0	. .	14
	0.040–0.128	57.0	. .	34.0	. .	15
	0.129–0.249	57.0	. .	34.0	. .	15
Alclad 2014-T451 ⑦ ⑧	0.250–0.499	57.0	. .	36.0	. .	15
Plate	0.500–1.000	58.0 ⑤	. .	36.0 ⑤	. .	14
	1.001–2.000	58.0 ⑤	. .	36.0 ⑤	. .	12
	2.001–3.000	57.0 ⑤	. .	36.0 ⑤	. .	8
Alclad 2014-T42 ④ ⑩	0.020–0.024	54.0	. .	31.0	. .	14
Sheet and plate	0.025–0.039	55.0	. .	32.0	. .	14
	0.040–0.128	57.0	. .	34.0	. .	15
	0.129–0.249	57.0	. .	34.0	. .	15
	0.250–0.499	57.0	. .	34.0	. .	15
	0.500–1.000	58.0 ⑤	. .	34.0 ⑤	. .	14
Alclad 2014-T6 and	0.020–0.024	62.0	. .	54.0	. .	7
T62 ④ ⑩ Sheet	0.025–0.039	63.0	. .	55.0	. .	7
	0.040–0.249	64.0	. .	57.0	. .	8
Alclad 2014-T62 ④ ⑩	0.250–0.499	64.0	. .	57.0	. .	8
and T651 ⑦ Plate	0.500–1.000	67.0 ⑤	. .	59.0 ⑤	. .	6
	1.001–2.000	67.0 ⑤	. .	59.0 ⑤	. .	4
	2.001–2.500	65.0 ⑤	. .	58.0 ⑤	. .	2
	2.501–3.000	63.0 ⑤	. .	57.0 ⑤	. .	2
	3.001–4.000	59.0 ⑤	. .	55.0 ⑤	. .	1
2024						
2024-O	0.010–0.499	. .	32.0	. .	14.0	12
Sheet and plate	0.500–1.750	. .	32.0	. .		12
2024-T3 ⑧	0.008–0.009	63.0	. .	42.0	. .	10
Sheet	0.010–0.020	63.0	. .	42.0	. .	12
	0.021–0.128	63.0	. .	42.0	. .	15
	0.129–0.249	64.0	. .	42.0	. .	15
2024-T351 ⑦ ⑧	0.250–0.499	64.0	. .	42.0	. .	12
Plate	0.500–1.000	63.0	. .	42.0	. .	8
	1.001–1.500	62.0	. .	42.0	. .	7
	1.501–2.000	62.0	. .	42.0	. .	6
	2.001–3.000	60.0	. .	42.0	. .	4
	3.001–4.000	57.0	. .	41.0	. .	4
2024-T361 ⑧ ⑪	0.020–0.062	67.0	. .	50.0	. .	8
Flat sheet and plate	0.063–0.249	68.0	. .	51.0	. .	9
	0.250–0.499	66.0	. .	49.0	. .	9
	0.500	66.0	. .	49.0	. .	10

For all numbered footnotes, see page 7-21.

TABLE 7.2 Mechanical Property Limits—Heat-Treatable Alloys ① ⑭ (continued)

ALLOY AND TEMPER	SPECIFIED THICKNESS ② in.	TENSILE STRENGTH—ksi				ELONGATION PERCENT MIN. in 2 in. or 4D ③
		ULTIMATE		YIELD		
		min.	max.	min.	max.	
2024 (Continued)						
2024-T4	0.010–0.020	62.0	. .	40.0	. .	12
Sheet	0.021–0.249	62.0	. .	40.0	. .	15
2024-T42 ④ ⑩	0.010–0.020	62.0	. .	38.0	. .	12
Sheet and plate	0.021–0.249	62.0	. .	38.0	. .	15
	0.250–0.499	62.0	. .	38.0	. .	12
	0.500–1.000	61.0	. .	38.0	. .	8
	1.001–1.500	60.0	. .	38.0	. .	7
	1.501–2.000	60.0	. .	38.0	. .	6
	2.001–3.000	58.0	. .	38.0	. .	4
2024-T62 ④ ⑩	0.010–0.499	64.0	. .	50.0	. .	5
Sheet and plate	0.500–3.000	63.0	. .	50.0	. .	5
2024-T72 ④ ⑩ Sheet	0.010–0.249	60.0	. .	46.0	. .	5
2024-T81 Flat sheet	0.010–0.249	67.0	. .	58.0	. .	5
2024-T851 ⑦	0.250–0.499	67.0	. .	58.0	. .	5
Plate	0.500–1.000	66.0	. .	58.0	. .	5
	1.001–1.499	66.0	. .	57.0	. .	5
2024-T861 ⑪	0.020–0.062	70.0	. .	62.0	. .	3
Flat sheet and plate	0.063–0.249	71.0	. .	66.0	. .	4
	0.250–0.499	70.0	. .	64.0	. .	4
	0.500	70.0	. .	64.0	. .	4
ALCLAD 2024 ⑥						
Alclad 2024-O	0.008–0.009	. .	30.0	. .	14.0	10
Sheet and plate	0.010–0.032	. .	30.0	. .	14.0	12
	0.033–0.062	. .	30.0	. .	14.0	12
	0.063–0.187	. .	32.0	. .	14.0	12
	0.188–0.499	. .	32.0	. .	14.0	12
	0.500–1.750	. .	32.0 ⑤	. .	. .	12
Alclad 2024-T3 ⑧	0.008–0.009	58.0	. .	39.0	. .	10
Sheet	0.010–0.020	59.0	. .	39.0	. .	12
	0.021–0.062	59.0	. .	39.0	. .	15
	0.063–0.128	61.0	. .	40.0	. .	15
	0.129–0.249	62.0	. .	40.0	. .	15
Alclad 2024-T351 ⑦ ⑧	0.250–0.499	62.0	. .	40.0	. .	12
Plate	0.500–1.000	63.0 ⑤	. .	42.0 ⑤	. .	8
	1.001–1.500	62.0 ⑤	. .	42.0 ⑤	. .	7
	1.501–2.000	62.0 ⑤	. .	42.0 ⑤	. .	6
	2.001–3.000	60.0 ⑤	. .	42.0 ⑤	. .	4
	3.001–4.000	57.0 ⑤	. .	41.0 ⑤	. .	4
Alclad 2024-T361 ⑧ ⑪	0.020–0.062	61.0	. .	47.0	. .	8
Flat sheet and plate	0.063–0.187	64.0	. .	48.0	. .	9
	0.188–0.249	64.0	. .	48.0	. .	9
	0.250–0.499	64.0	. .	48.0	. .	9
	0.500	66.0 ⑤	. .	49.0 ⑤	. .	10
Alclad 2024-T4	0.010–0.020	58.0	. .	36.0	. .	12
Sheet	0.021–0.062	58.0	. .	36.0	. .	15
	0.063–0.128	61.0	. .	38.0	. .	15
Alclad 2024-T42 ④ ⑩	0.008–0.009	55.0	. .	34.0	. .	10
Sheet and plate	0.010–0.020	57.0	. .	34.0	. .	12
	0.021–0.062	57.0	. .	34.0	. .	15
	0.063–0.187	60.0	. .	36.0	. .	15
	0.188–0.249	60.0	. .	36.0	. .	15
	0.250–0.499	60.0	. .	36.0	. .	12
	0.500–1.000	61.0 ⑤	. .	38.0 ⑤	. .	8
	1.001–1.500	60.0 ⑤	. .	38.0 ⑤	. .	7
	1.501–2.000	60.0 ⑤	. .	38.0 ⑤	. .	6
	2.001–3.000	58.0 ⑤	. .	38.0 ⑤	. .	4
Alclad 2024-T62 ④ ⑩	0.010–0.062	60.0	. .	47.0	. .	5
Sheet and plate	0.063–0.187	62.0	. .	49.0	. .	5
	0.188–0.499	62.0	. .	49.0	. .	5
Alclad 2024-T72 ④ ⑩	0.010–0.062	56.0	. .	43.0	. .	5
Sheet	0.063–0.187	58.0	. .	45.0	. .	5
	0.188–0.249	58.0	. .	45.0	. .	5
Alclad 2024-T81	0.010–0.062	62.0	. .	54.0	. .	5
Flat sheet	0.063–0.187	65.0	. .	56.0	. .	5
	0.188–0.249	65.0	. .	56.0	. .	5
Alclad 2024-T851 ⑦	0.250–0.499	65.0	. .	56.0	. .	5
Plate	0.500–1.000	66.0 ⑤	. .	58.0 ⑤	. .	5

For all numbered footnotes, see page 7-21.

TABLE 7.2 Mechanical Property Limits—Heat-Treatable Alloys [1] [14] (continued)

ALLOY AND TEMPER	SPECIFIED THICKNESS [2] in.	TENSILE STRENGTH—ksi ULTIMATE min.	ULTIMATE max.	YIELD min.	YIELD max.	ELONGATION PERCENT MIN. in 2 in. or 4D [3]
ALCLAD 2024 (Continued)						
Alclad 2024-T861 [11]	0.020–0.062	64.0	. .	58.0	. .	3
Flat sheet and plate	0.063–0.187	69.0	. .	64.0	. .	4
	0.188–0.249	69.0	. .	64.0	. .	4
	0.250–0.499	68.0	. .	62.0	. .	4
	0.500	70.0 [5]	. .	64.0 [5]	. .	4
1½% ALCLAD 2024 [6]						
1½% Alclad 2024-O	0.188–0.499	. .	32.0	. .	14.0	12
Sheet and plate	0.500–1.750	. .	32.0 [5]	. .	. .	12
1½% Alclad 2024-T3 [8] Sheet	0.188–0.249	63	. .	41.0	. .	15
1½% Alclad 2024-T351 [7] [8]	0.250–0.499	63.0	. .	41.0	. .	12
Plate	0.500–1.000	63.0 [5]	. .	42.0 [5]	. .	8
	1.001–1.500	62.0 [5]	. .	42.0 [5]	. .	7
	1.501–2.000	62.0 [5]	. .	42.0 [5]	. .	6
	2.001–3.000	60.0 [5]	. .	42.0 [5]	. .	4
	3.001–4.000	57.0 [5]	. .	41.0 [5]	. .	4
1½% Alclad 2024-T361 [8] [11]	0.188–0.249	65.0	. .	49.0	. .	9
Flat sheet and plate	0.250–0.499	65.0	. .	48.0	. .	9
	0.500	66.0 [5]	. .	49.0 [5]	. .	10
1½% Alclad 2024-T42	0.188–0.249	61.0	. .	37.0	. .	15
Sheet and plate [4] [10]	0.250–0.499	61.0	. .	37.0	. .	12
	0.500–1.000	61.0 [5]	. .	38.0 [5]	. .	8
	1.001–1.500	60.0 [5]	. .	38.0 [5]	. .	7
	1.501–2.000	60.0 [5]	. .	38.0 [5]	. .	6
	2.001–3.000	58.0 [5]	. .	38.0 [5]	. .	4
1½% Alclad 2024-T62 [4] [10] Sheet and plate	0.188–0.499	62.0	. .	49.0	. .	5
1½% Alclad 2024-T72 [4] [10] Sheet	0.188–0.249	59.0	. .	45.0	. .	5
1½% Alclad 2024-T81 Flat sheet	0.188–0.249	66.0	. .	57.0	. .	5
1½% Alclad 2024-T851 [7]	0.250–0.499	66.0	. .	57.0	. .	5
Plate	0.500–1.000	66.0 [5]	. .	58.0 [5]	. .	5
1½% Alclad 2024-T861 [11]	0.188–0.249	70.0	. .	65.0	. .	4
Flat sheet and plate	0.250–0.499	69.0	. .	63.0	. .	4
	0.500	70.0 [5]	. .	64.0 [5]	. .	4
ALCLAD ONE SIDE 2024 [6]						
Alclad One Side 2024-O	0.008–0.009	. .	31.0	. .	14.0	10
Sheet and plate	0.010–0.062	. .	31.0	. .	14.0	12
	0.063–0.499	. .	32.0	. .	14.0	12
Alclad One Side 2024-T3 [8]	0.010–0.020	61.0	. .	40.0	. .	12
Sheet	0.021–0.062	61.0	. .	40.0	. .	15
	0.063–0.128	62.0	. .	41.0	. .	15
	0.129–0.249	63.0	. .	41.0	. .	15
Alclad One Side 2024-T351 [7] [8] Plate	0.250–0.499	63.0	. .	41.0	. .	12
Alclad One Side 2024-	0.020–0.062	64.0	. .	48.0	. .	8
T361 [8] [11] Sheet and plate	0.063–0.249	66.0	. .	49.0	. .	9
	0.250–0.499	65.0	. .	48.0	. .	9
Alclad One Side 2024-T42 [4] [10]	0.010–0.020	59.0	. .	35.0	. .	12
Sheet and plate	0.021–0.062	59.0	. .	36.0	. .	15
	0.063–0.249	61.0	. .	37.0	. .	15
	0.250–0.499	61.0	. .	37.0	. .	12
Alclad One Side 2024-T62 [4] [10]	0.010–0.062	62.0	. .	48.0	. .	5
Sheet and plate	0.063–0.499	63.0	. .	49.0	. .	5
Alclad One Side 2024-T72 [4] [10]	0.010–0.062	58.0	. .	44.0	. .	5
Flat sheet	0.063–0.249	59.0	. .	45.0	. .	5
Alclad One Side 2024-T81	0.010–0.062	64.0	. .	56.0	. .	5
Flat sheet	0.063–0.249	66.0	. .	57.0	. .	5
Alclad One Side 2024-T851 [7] Plate	0.250–0.499	66.0	. .	57.0	. .	5
Alclad One Side 2024-T861 [11]	0.020–0.062	67.0	. .	60.0	. .	3
Sheet and plate	0.063–0.249	70.0	. .	65.0	. .	4
	0.250–0.499	69.0	. .	63.0	. .	4

For all numbered footnotes, see page 7-21.

TABLE 7.2 Mechanical Property Limits—Heat-Treatable Alloys ① ⑭ (continued)

ALLOY AND TEMPER	SPECIFIED THICKNESS ② in.	TENSILE STRENGTH—ksi ULTIMATE		TENSILE STRENGTH—ksi YIELD		ELONGATION PERCENT MIN. in 2 in. or 4D ③
		min.	max.	min.	max.	
1½% ALCLAD ONE SIDE 2024 ⑥						
1½% Alclad One Side 2024-O Sheet and plate	0.188–0.499	. .	32.0	. .	14.0	12
1½% Alclad One Side 2024-T3 ⑧ Sheet	0.188–0.249	63.0	. .	41.0	. .	15
1½% Alclad One Side 2024-T351 ⑦ ⑧ Plate	0.250–0.499	63.0	. .	41.0	. .	12
1½% Alclad One Side 2024-T361 ⑧ ⑪ Sheet and plate	0.188–0.249 0.250–0.499	66.0 65.0	. . . .	49.0 48.0	. . . .	9 9
1½% Alclad One Side 2024-T42 ④ ⑩ Sheet and plate	0.188–0.249 0.250–0.499	61.0 61.0	. . . .	37.0 37.0	. . . .	15 12
1½% Alclad One Side 2024-T62 ④ ⑩ Sheet and plate	0.188–0.499	63.0	. .	49.0	. .	5
1½% Alclad One Side 2024-T72 ④ ⑩ Flat sheet	0.188–0.249	59.0	. .	45.0	. .	5
1½% Alclad One Side 2024-T81 Flat sheet	0.188–0.249	66.0	. .	57.0	. .	5
1½% Alclad One Side 2024-T851 ⑦ Plate	0.250–0.499	66.0	. .	57.0	. .	5
1½% Alclad One Side 2024-T861 ⑪ Sheet and plate	0.188–0.249 0.250–0.499	70.0 69.0	. . . .	65.0 63.0	. . . .	4 4
2036						
2036-T4 Flat sheet	0.025–0.125	42.0	. .	23.0	. .	20

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ALLOY AND TEMPER	SPECIFIED THICKNESS ② in.	AXIS OF TEST SPECIMEN	TENSILE STRENGTH—ksi ULTIMATE		TENSILE STRENGTH—ksi YIELD		ELONGATION PERCENT MIN. in 2 in. or 4D ③
			min.	max.	min.	max.	
2124-T351 ⑦ Plate	1.000–1.499	Longitudinal Long Transverse	61.0 62.0	. . . .	45.0 42.0	. . . .	14 13
	1.500–2.000	Longitudinal Long Transverse Short Transverse	61.0 62.0 58.0	. . . . . .	45.0 42.0 38.0	. . . . . .	14 13 4.5
	2.001–3.000	Longitudinal Long Transverse Short Transverse	61.0 62.0 58.0	. . . . . .	45.0 41.0 38.0	. . . . . .	14 10 4
2124-T851 ⑦ ⑯ Plate	1.000–2.000	Longitudinal Long Transverse Short Transverse	66.0 66.0 64.0 ⑮	. . . . . .	57.0 57.0 55.0 ⑮	. . . . . .	6 5 1.5 ⑮
	2.001–3.000	Longitudinal Long Transverse Short Transverse	65.0 65.0 63.0	. . . . . .	57.0 57.0 55.0	. . . . . .	6 4 1.5
	3.001–4.000	Longitudinal Long Transverse Short Transverse	65.0 65.0 62.0	. . . . . .	56.0 56.0 54.0	. . . . . .	5 4 1.5
	4.001–5.000	Longitudinal Long Transverse Short Transverse	64.0 64.0 61.0	. . . . . .	55.0 55.0 53.0	. . . . . .	5 4 1.5
	5.001–6.000	Longitudinal Long Transverse Short Transverse	63.0 63.0 58.0	. . . . . .	54.0 54.0 51.0	. . . . . .	5 4 1.5

For all numbered footnotes, see page 7-21.

TABLE 7.2 Mechanical Property Limits—Heat-Treatable Alloys ① ⑭ (continued)

ALLOY AND TEMPER	SPECIFIED THICKNESS ② in.	TENSILE STRENGTH—ksi				ELONGATION PERCENT MIN. in 2 in. or 4D ③
		ULTIMATE		YIELD		
		min.	max.	min.	max.	
2219						
2219-O Sheet and plate	0.020–2.000	. .	32.0	. .	16.0	12
2219-T31 ⑧ Flat sheet	0.020–0.039	46.0	. .	29.0	. .	8
	0.040–0.249	46.0	. .	28.0	. .	10
2219-T351 ⑦ ⑧ Plate	0.250–2.000	46.0	. .	28.0	. .	10
	2.001–3.000	44.0	. .	28.0	. .	10
	3.001–4.000	42.0	. .	27.0	. .	9
	4.001–5.000	40.0	. .	26.0	. .	9
	5.001–6.000	39.0	. .	25.0	. .	8
2219-T37 ⑧ Flat sheet and plate	0.020–0.039	49.0	. .	38.0	. .	6
	0.040–2.000	49.0	. .	37.0	. .	6
	2.001–2.500	49.0	. .	37.0	. .	6
	2.501–3.000	47.0	. .	36.0	. .	6
	3.001–4.000	45.0	. .	35.0	. .	5
	4.001–5.000	43.0	. .	34.0	. .	4
2219-T62 ④ ⑩ Sheet and plate	0.020–0.039	54.0	. .	36.0	. .	6
	0.040–0.249	54.0	. .	36.0	. .	7
	0.250–1.000	54.0	. .	36.0	. .	8
	1.001–2.000	54.0	. .	36.0	. .	7
2219-T81 Flat sheet	0.020–0.039	62.0	. .	46.0	. .	6
	0.040–0.249	62.0	. .	46.0	. .	7
2219-T851 ⑦ Plate	0.250–1.000	62.0	. .	46.0	. .	8
	1.001–2.000	62.0	. .	46.0	. .	7
	2.001–3.000	62.0	. .	45.0	. .	6
	3.001–4.000	60.0	. .	44.0	. .	5
	4.001–5.000	59.0	. .	43.0	. .	5
	5.001–6.000	57.0	. .	42.0	. .	4
2219-T87 Flat sheet and plate	0.020–0.039	64.0	. .	52.0	. .	5
	0.040–0.249	64.0	. .	52.0	. .	6
	0.250–1.000	64.0	. .	51.0	. .	7
	1.001–2.000	64.0	. .	51.0	. .	6
	2.001–3.000	64.0	. .	51.0	. .	6
	3.001–4.000	62.0	. .	50.0	. .	4
	4.001–5.000	61.0	. .	49.0	. .	3
ALCLAD 2219 ⑥						
Alclad 2219-O Sheet and plate	0.020–0.499	. .	32.0	. .	16.0	12
	0.500–2.000	. .	32.0 ⑤	. .	16.0 ⑤	. .
Alclad 2219-T31 ⑧ Flat sheet	0.040–0.099	42.0	. .	25.0	. .	10
	0.100–0.249	44.0	. .	26.0	. .	10
Alclad 2219-T351 ⑦ ⑧ Plate	0.250–0.499	44.0	. .	26.0	. .	10
Alclad 2219-T37 ⑧ Flat sheet and plate	0.040–0.099	45.0	. .	34.0	. .	6
	0.100–0.249	47.0	. .	35.0	. .	6
	0.250–0.499	47.0	. .	35.0	. .	6
Alclad 2219-T62 ④ ⑩ Sheet and plate	0.020–0.039	44.0	. .	29.0	. .	6
	0.040–0.099	49.0	. .	32.0	. .	7
	0.100–0.249	51.0	. .	34.0	. .	7
	0.250–0.499	51.0	. .	34.0	. .	8
	0.500–1.000	54.0 ⑤	. .	36.0 ⑤	. .	8
	1.001–2.000	54.0 ⑤	. .	36.0 ⑤	. .	7
Alclad 2219-T81 Flat sheet	0.020–0.039	49.0	. .	37.0	. .	6
	0.040–0.099	55.0	. .	41.0	. .	7
	0.100–0.249	58.0	. .	43.0	. .	7
Alclad 2219-T851 ⑦ Plate	0.250–0.499	58.0	. .	42.0	. .	8
Alclad 2219-T87 Flat sheet and plate	0.040–0.099	57.0	. .	46.0	. .	6
	0.100–0.249	60.0	. .	48.0	. .	6
	0.250–0.499	60.0	. .	48.0	. .	7
6061						
6061-O Sheet and plate	0.006–0.007	. .	22.0	. .	12.0	10
	0.008–0.009	. .	22.0	. .	12.0	12
	0.010–0.020	. .	22.0	. .	12.0	14
	0.021–0.128	. .	22.0	. .	12.0	16
	0.129–0.499	. .	22.0	. .	12.0	18
	0.500–1.000	. .	22.0	. .	. .	18
	1.001–3.000	. .	22.0	. .	. .	16
6061-T4 Sheet	0.006–0.007	30.0	. .	16.0	. .	10
	0.008–0.009	30.0	. .	16.0	. .	12
	0.010–0.020	30.0	. .	16.0	. .	14
	0.021–0.249	30.0	. .	16.0	. .	16

For all numbered footnotes, see page 7-21.

TABLE 7.2 Mechanical Property Limits—Heat-Treatable Alloys [1] [14] (continued)

ALLOY AND TEMPER	SPECIFIED THICKNESS [2] in.	TENSILE STRENGTH—ksi				ELONGATION PERCENT MIN. in 2 in. or 4D [3]
		ULTIMATE		YIELD		
		min.	max.	min.	max.	
6061 (Continued)						
6061-T451 [7] [8]	0.250–1.000	30.0	. .	16.0	. .	18
Plate	1.001–3.000	30.0	. .	16.0	. .	16
6061-T42 [4] [10]	0.006–0.007	30.0	. .	14.0	. .	10
Sheet and plate	0.008–0.009	30.0	. .	14.0	. .	12
	0.010–0.020	30.0	. .	14.0	. .	14
	0.021–0.249	30.0	. .	14.0	. .	16
	0.250–1.000	30.0	. .	14.0	. .	18
	1.001–3.000	30.0	. .	14.0	. .	16
6061-T6 and T62 [4] [10]	0.006–0.007	42.0	. .	35.0	. .	4
Sheet	0.008–0.009	42.0	. .	35.0	. .	6
	0.010–0.020	42.0	. .	35.0	. .	8
	0.021–0.249	42.0	. .	35.0	. .	10
6061-T62 [4] [10] and	0.250–0.499	42.0	. .	35.0	. .	10
T651 [7] Plate	0.500–1.000	42.0	. .	35.0	. .	9
	1.001–2.000	42.0	. .	35.0	. .	8
	2.001–4.000	42.0	. .	35.0	. .	6
	4.001–6.000 [9]	40.0	. .	35.0	. .	6
ALCLAD 6061 [6]						
Alclad 6061-O	0.010–0.020	. .	20.0	. .	12.0	14
Sheet and plate	0.021–0.128	. .	20.0	. .	12.0	16
	0.129–0.499	. .	20.0	. .	12.0	18
	0.500–1.000	. .	22.0 [5]	. .	. .	18
	1.001–3.000	. .	22.0 [5]	. .	. .	16
Alclad 6061-T4	0.010–0.020	27.0	. .	14.0	. .	14
Sheet	0.021–0.249	27.0	. .	14.0	. .	16
Alclad 6061-T451 [7] [8]	0.250–0.499	27.0	. .	14.0	. .	18
Plate	0.500–1.000	30.0 [5]	. .	16.0 [5]	. .	18
	1.001–3.000	30.0 [5]	. .	16.0 [5]	. .	16
Alclad 6061-T42 [4] [10]	0.010–0.020	27.0	. .	12.0	. .	14
Sheet and plate	0.021–0.249	27.0	. .	12.0	. .	16
	0.250–0.499	27.0	. .	12.0	. .	18
	0.500–1.000	30.0 [5]	. .	14.0 [5]	. .	18
	1.001–3.000	30.0 [5]	. .	14.0 [5]	. .	16
Alclad 6061-T6	0.010–0.020	38.0	. .	32.0	. .	8
and T62 [4] [10] Sheet	0.021–0.249	38.0	. .	32.0	. .	10
Alclad 6061-T62 [4] [10]	0.250–0.499	38.0	. .	32.0	. .	10
and T651 [7] Plate	0.500–1.000	42.0 [5]	. .	35.0 [5]	. .	9
	1.001–2.000	42.0 [5]	. .	35.0 [5]	. .	8
	2.001–3.000	42.0 [5]	. .	35.0 [5]	. .	6
	3.001–4.000	42.0 [5]	. .	35.0 [5]	. .	6
	4.001–5.000 [9]	40.0 [5]	. .	35.0 [5]	. .	6

ALLOY AND TEMPER	SPECIFIED THICKNESS [2] in.	AXIS OF TEST SPECIMEN	TENSILE STRENGTH—ksi				ELONGATION PERCENT MIN. in 2 in. or 4D [3]
			ULTIMATE		YIELD		
			min.	max.	min.	max.	
7050							
7050-	0.250–2.000	Longitudinal	74.0	. .	64.0	. .	10
T7451 [16] [17] [18] [20] Plate		Long Transverse	74.0	. .	64.0	. .	9
	2.001–3.000	Longitudinal	73.0	. .	63.0	. .	9
		Long Transverse	73.0	. .	63.0	. .	8
		Short Transverse	68.0	. .	59.0	. .	2
	3.001–4.000	Longitudinal	72.0	. .	62.0	. .	9
		Long Transverse	72.0	. .	62.0	. .	6
		Short Transverse	68.0	. .	58.0	. .	3
	4.001–5.000	Longitudinal	71.0	. .	61.0	. .	9
		Long Transverse	71.0	. .	61.0	. .	5
		Short Transverse	67.0	. .	57.0	. .	3
	5.001–6.000	Longitudinal	70.0	. .	60.0	. .	8
		Long Transverse	70.0	. .	60.0	. .	4
		Short Transverse	67.0	. .	57.0	. .	3
	6.001–7.000	Longitudinal	69.0	. .	59.0	. .	7
		Long Transverse	69.0	. .	59.0	. .	4
		Short Transverse	66.0	. .	56.0	. .	3
	7.001–8.000	Longitudinal	68.0	. .	58.0	. .	6
		Long Transverse	68.0	. .	58.0	. .	4
		Short Transverse	65.0	. .	55.0	. .	3

For all numbered footnotes, see page 7-21.

TABLE 7.2 Mechanical Property Limits—Heat-Treatable Alloys [1] [14] (continued)

ALLOY AND TEMPER	SPECIFIED THICKNESS [2] in.	AXIS OF TEST SPECIMEN	TENSILE STRENGTH—ksi				ELONGATION PERCENT MIN. in 2 in. or 4D [3]
			ULTIMATE		YIELD		
			min.	max.	min.	max.	
7050 (Continued)							
7050-T7651 [16] [19] [21] Plate	0.250–1.000	Longitudinal	76.0	. .	66.0	. .	9
		Long Transverse	76.0	. .	66.0	. .	8
	1.001–1.500	Longitudinal	77.0	. .	67.0	. .	9
		Long Transverse	77.0	. .	67.0	. .	8
	1.501–2.000	Longitudinal	76.0	. .	66.0	. .	9
		Long Transverse	76.0	. .	66.0	. .	8
	2.001–3.000	Longitudinal	76.0	. .	66.0	. .	8
		Long Transverse	76.0	. .	66.0	. .	7
		Short Transverse	70.0	. .	60.0	. .	1.5

ALLOY AND TEMPER	SPECIFIED THICKNESS [2] in.	TENSILE STRENGTH—ksi				ELONGATION PERCENT MIN. in 2 in. or 4D [3]
		ULTIMATE		YIELD		
		min.	max.	min.	max.	
7075						
7075-O Sheet and plate	0.015–0.499	. .	40.0	. .	21.0	10
	0.500–2.000	. .	40.0	. .	. .	10
7075-T6 and T62 [4] [10] Sheet	0.008–0.011	74.0	. .	63.0	. .	5
	0.012–0.039	76.0	. .	67.0	. .	8
	0.040–0.062	78.0	. .	68.0	. .	9
	0.063–0.125	78.0	. .	68.0	. .	9
	0.126–0.187	79.0	. .	69.0	. .	9
	0.188–0.249	80.0	. .	69.0	. .	9
7075-T62 [4] [10] and T651 [7] Plate	0.250–0.499	78.0	. .	67.0	. .	9
	0.500–1.000	78.0	. .	68.0	. .	7
	1.001–2.000	77.0	. .	67.0	. .	6
	2.001–2.500	76.0	. .	64.0	. .	5
	2.501–3.000	72.0	. .	61.0	. .	5
	3.001–3.500	71.0	. .	58.0	. .	5
	3.501–4.000	67.0	. .	54.0	. .	3
7075-T73 Sheet	0.040–0.249	67.0	. .	56.0	. .	8
7075-T7351 [7] [12] Plate	0.250–1.000	69.0	. .	57.0	. .	7
	1.001–2.000	69.0	. .	57.0	. .	6
	2.001–2.500	66.0	. .	52.0	. .	6
	2.501–3.000	64.0	. .	49.0	. .	6
	3.001–3.500	63.0	. .	49.0	. .	6
	3.501–4.000	61.0	. .	48.0	. .	6
7075-T76 [13] Sheet	0.063–0.125	73.0	. .	62.0	. .	8
	0.126–0.249	73.0	. .	62.0	. .	8
7075-T7651 [7] [13] Plate	0.250–0.499	72.0	. .	61.0	. .	8
	0.500–1.000	71.0	. .	60.0	. .	6
	1.001–2.000	71.0	. .	60.0	. .	5
ALCLAD 7075 [6]						
Alclad 7075-O Sheet and plate	0.008–0.014	. .	36.0	. .	20.0	9
	0.015–0.062	. .	36.0	. .	20.0	10
	0.063–0.187	. .	38.0	. .	20.0	10
	0.188–0.499	. .	39.0	. .	21.0	10
	0.500–1.000	. .	40.0 [5]	. .	. .	10
Alclad 7075-T6 and T62 [4] [10] Sheet	0.008–0.011	68.0	. .	58.0	. .	5
	0.012–0.039	71.0	. .	61.0	. .	8
	0.040–0.062	72.0	. .	62.0	. .	9
	0.063–0.125	74.0	. .	64.0	. .	9
	0.126–0.187	74.0	. .	64.0	. .	9
	0.188–0.249	76.0	. .	65.0	. .	9
Alclad 7075-T62 [4] [10] and T651 [7] Plate	0.250–0.499	75.0	. .	65.0	. .	9
	0.500–1.000	78.0 [5]	. .	68.0 [5]	. .	7
	1.001–2.000	77.0 [5]	. .	67.0 [5]	. .	6
	2.001–2.500	76.0 [5]	. .	64.0 [5]	. .	5
	2.501–3.000	72.0 [5]	. .	61.0 [5]	. .	5
	3.001–3.500	71.0 [5]	. .	58.0 [5]	. .	5
	3.501–4.000	67.0 [5]	. .	54.0 [5]	. .	3
Alclad 7075-T73 Sheet	0.040–0.062	63.0	. .	51.0	. .	8
	0.063–0.187	64.0	. .	52.0	. .	8
	0.188–0.249	66.0	. .	54.0	. .	8
Alclad 7075-T7351 [7] [12] Plate	0.250–0.499	66.0	. .	54.0	. .	8
	0.500–1.000	69.0 [5]	. .	57.0 [5]	. .	7

For all numbered footnotes, see page 7-21.

TABLE 7.2 Mechanical Property Limits—Heat-Treatable Alloys ① ⑭ (continued)

ALLOY AND TEMPER	SPECIFIED THICKNESS ② in.	TENSILE STRENGTH—ksi ULTIMATE min.	ULTIMATE max.	YIELD min.	YIELD max.	ELONGATION PERCENT MIN. in 2 in. or 4D ③
ALCLAD 7075 ⑥ (Continued)						
Alclad 7075-T76 ⑬ Sheet	0.040–0.062	67.0	. .	56.0	. .	8
	0.063–0.125	68.0	. .	57.0	. .	8
	0.125–0.187	68.0	. .	57.0	. .	8
	0.188–0.249	70.0	. .	59.0	. .	8
Alclad 7075-T7651 ⑦ ⑬ Plate	0.250–0.499	69.0	. .	58.0	. .	8
	0.500–1.000	71.0 ⑤	. .	60.0 ⑤	. .	6
2½% ALCLAD 7075 ⑥						
2½% Alclad 7075-O Sheet and plate	0.188–0.499	. .	39.0	. .	20.0	10
	0.500–1.000	. .	40.0 ⑤	. .	. .	10
2½% Alclad 7075-T6 and T62 ④ ⑩ Sheet	0.188–0.249	74.0	. .	64.0	. .	8
2½% Alclad 7075-T62 ④ ⑩ and T651 ⑦ Plate	0.250–0.499	74.0	. .	64.0	. .	9
	0.500–1.000	78.0 ⑤	. .	68.0 ⑤	. .	7
	1.001–2.000	77.0 ⑤	. .	67.0 ⑤	. .	6
	2.001–2.500	76.0 ⑤	. .	64.0 ⑤	. .	5
	2.501–3.000	72.0 ⑤	. .	61.0 ⑤	. .	5
	3.001–3.500	71.0 ⑤	. .	58.0 ⑤	. .	5
	3.501–4.000	67.0 ⑤	. .	54.0 ⑤	. .	3
2½% Alclad 7075-T73 Sheet	0.188–0.249	64.0	. .	53.0	. .	8
2½% Alclad 7075-T7351 ⑦ ⑫ Plate	0.250–0.499	65.0	. .	54.0	. .	8
	0.500–1.000	69.0 ⑤	. .	57.0 ⑤	. .	7
2½% Alclad 7075-T76 ⑬ Sheet	0.188–0.249	69.0	. .	59.0	. .	8
2½% Alclad 7075-T7651 ⑦ ⑬ Plate	0.250–0.499	68.0	. .	58.0	. .	8
	0.500–1.000	71.0 ⑤	. .	60.0 ⑤	. .	6
ALCLAD ONE SIDE 7075 ⑥						
Alclad One Side 7075-O Sheet and plate	0.015–0.062	. .	38.0	. .	21.0	10
	0.063–0.187	. .	39.0	. .	21.0	10
	0.188–0.499	. .	39.0	. .	21.0	10
	0.500–1.000	. .	40.0 ⑤	. .	. .	10
Alclad One Side 7075-T6 and T62 ④ ⑩ Sheet	0.008–0.011	71.0	. .	60.0	. .	5
	0.012–0.039	74.0	. .	64.0	. .	8
	0.040–0.062	75.0	. .	65.0	. .	9
	0.063–0.125	76.0	. .	66.0	. .	9
	0.126–0.187	77.0	. .	67.0	. .	9
	0.188–0.249	78.0	. .	67.0	. .	9
Alclad One Side 7075 T62 ④ ⑩ and T651 ⑦ Plate	0.250–0.499	76.0	. .	66.0	. .	9
	0.500–1.000	78.0 ⑤	. .	68.0 ⑤	. .	7
	1.001–2.000	77.0 ⑤	. .	67.0 ⑤	. .	6
2½% ALCLAD ONE SIDE 7075 ⑥						
2½% Alclad One Side 7075-O Sheet and plate	0.188–0.499	. .	39.0	. .	21.0	10
	0.500–1.000	. .	40.0 ⑤	. .	. .	10
2½% Alclad One Side 7075-T6 and T62 ④ ⑩ Sheet	0.188–0.249	76.0	. .	65.0	. .	8
2½% Alclad One Side 7075 T62 ④ ⑩ and T651 ⑦ Plate	0.250–0.499	76.0	. .	65.0	. .	9
	0.500–1.000	78.0 ⑤	. .	68.0 ⑤	. .	7
	1.001–2.000	77.0 ⑤	. .	67.0 ⑤	. .	6
7008 ALCLAD 7075 ⑥						
7008 Alclad 7075-O Sheet and plate	0.015–0.062	. .	40.0	. .	21.0	10
	0.063–0.187	. .	40.0	. .	21.0	10
	0.188–0.499	. .	40.0	. .	21.0	10
	0.500–2.000	. .	40.0⑤	. .	. .	10
7008 Alclad 7075-T6 and T62 ④ ⑩ Sheet	0.015–0.039	73.0	. .	63.0	. .	7
	0.040–0.062	75.0	. .	65.0	. .	8
	0.063–0.087	75.0	. .	65.0	. .	8
	0.188–0.249	76.0	. .	66.0	. .	8
7008 Alclad 7075-T62 ④ ⑩ and T651 ⑦ Plate	0.250–0.499	76.0	. .	66.0	. .	9
	0.500–1.000	78.0 ⑤	. .	68.0 ⑤	. .	7
	1.001–2.000	77.0 ⑤	. .	67.0 ⑤	. .	6
	2.001–2.500	76.0 ⑤	. .	64.0 ⑤	. .	5
	2.501–3.000	72.0 ⑤	. .	61.0 ⑤	. .	5
	3.001–3.500	71.0 ⑤	. .	58.0 ⑤	. .	5
	3.501–4.000	67.0 ⑤	. .	54.0 ⑤	. .	3

For all numbered footnotes, see page 7-21.

TABLE 7.2 Mechanical Property Limits—Heat-Treatable Alloys ① ⑭ (continued)

ALLOY AND TEMPER	SPECIFIED THICKNESS ② in.	TENSILE STRENGTH—ksi				ELONGATION PERCENT MIN. in 2 in. or 4D ③
		ULTIMATE		YIELD		
		min.	max.	min.	max.	
7008 ALCLAD 7075 ⑥ (Continued)						
7008 Alclad 7075-T76 ⑬	0.040–0.062	70.0	. .	59.0	. .	8
Sheet	0.063–0.187	71.0	. .	60.0	. .	8
	0.188–0.249	72.0	. .	61.0	. .	8
7008 Alclad 7075-T7651 ⑦ ⑬	0.250–0.499	71.0	. .	60.0	. .	8
Plate	0.500–1.000	71.0 ⑤	. .	60.0 ⑤	. .	6
7178						
7178-O	0.015–0.499	. .	40.0	. .	21.0	10
Sheet and plate	0.500	. .	40.0	. .	. .	10
7178-T6 and T62 ④ ⑩	0.015–0.044	83.0	. .	72.0	. .	7
Sheet	0.045–0.249	84.0	. .	73.0	. .	8
7178-T62 ④ ⑩ and	0.250–0.499	84.0	. .	73.0	. .	8
T651 ⑦	0.500–1.000	84.0	. .	73.0	. .	6
Plate	1.001–1.500	84.0	. .	73.0	. .	4
	1.501–2.000	80.0	. .	70.0	. .	3
7178-T76 ⑬ Sheet	0.045–0.249	75.0	. .	64.0	. .	8
7178-T7651 ⑦ ⑬	0.250–0.499	74.0	. .	63.0	. .	8
Plate	0.500–1.000	73.0	. .	62.0	. .	6
ALCLAD 7178 ⑥						
Alclad 7178-O	0.015–0.062	. .	36.0	. .	20.0	10
Sheet and plate	0.063–0.187	. .	38.0	. .	20.0	10
	0.188–0.499	. .	40.0	. .	21.0	10
	0.500	. .	40.0	. .	. .	10
Alclad 7178-T6 and	0.015–0.044	76.0	. .	66.0	. .	7
T62 ④ ⑩ Sheet	0.045–0.062	78.0	. .	68.0	. .	8
	0.063–0.187	80.0	. .	70.0	. .	8
	0.188–0.249	82.0	. .	71.0	. .	8
Alclad 7178-T62 ④ ⑩	0.250–0.499	82.0	. .	71.0	. .	8
and T651 ⑦	0.500–1.000	84.0 ⑤	. .	73.0 ⑤	. .	6
Plate	1.001–1.500	84.0 ⑤	. .	73.0 ⑤	. .	4
	1.501–2.000	80.0 ⑤	. .	70.0 ⑤	. .	3
Alclad 7178-T76 ⑬	0.045–0.062	71.0	. .	60.0	. .	8
Sheet	0.063–0.187	71.0	. .	60.0	. .	8
	0.188–0.249	73.0	. .	61.0	. .	8
Alclad 7178-T7651 ⑦ ⑬	0.250–0.499	72.0	. .	60.0	. .	8
Plate	0.500–1.000	73.0 ⑤	. .	62.0 ⑤	. .	6

ALLOY AND TEMPER	SPECIFIED THICKNESS ② in.	AXIS OF TEST SPECIMEN	TENSILE STRENGTH—ksi				ELONGATION PERCENT MIN. in 2 in. or 4D ③
			ULTIMATE		YIELD		
			min.	max.	min.	max.	
7475							
7475-T61	0.040-0.249	Longitudinal	75.0	. .	66.0	. .	9
Sheet		Long Transverse	75.0	. .	64.0	. .	9
7475-T7351	0.250–1.500	Longitudinal	71.0	. .	60.0	. .	10
		Long Transverse	71.0	. .	60.0	. .	9
Plate	1.001–1.500	Short Transverse	67.0 ㉒	. .	56.0 ㉒	. .	4 ㉒
	1.501–2.000	Longitudinal	70.0	. .	58.0	. .	10
		Long Transverse	70.0	. .	58.0	. .	8
		Short Transverse	66.0	. .	54.0	. .	4
	2.001–2.500	Longitudinal	69.0	. .	57.0	. .	10
		Long Transverse	69.0	. .	57.0	. .	8
		Short Transverse	65.0	. .	53.0	. .	4
	2.501–3.000	Longitudinal	68.0	. .	56.0	. .	10
		Long Transverse	68.0	. .	56.0	. .	8
		Short Transverse	65.0	. .	53.0	. .	3
	3.001–3.500	Longitudinal	65.0	. .	53.0	. .	10
		Long Transverse	65.0	. .	53.0	. .	8
		Short Transverse	64.0	. .	51.0	. .	3
	3.501–4.000	Longitudinal	64.0	. .	52.0	. .	9
		Long Transverse	64.0	. .	52.0	. .	7
		Short Transverse	63.0	. .	50.0	. .	3

For all numbered footnotes, see page 7-21.

TABLE 7.2 Mechanical Property Limits—Heat-Treatable Alloys ① ⑭ (concluded)

7475 (Continued)

ALLOY AND TEMPER	SPECIFIED THICKNESS ② in.	AXIS OF TEST SPECIMEN	TENSILE STRENGTH—ksi ULTIMATE min.	max.	YIELD min.	max.	ELONGATION PERCENT MIN. in 2 in. or 4D ③
7475-T651 Plate	0.250-0.499	Longitudinal	77.0	. .	69.0	. .	10
		Long Transverse	78.0	. .	67.0	. .	10
	0.500–1.000	Longitudinal	77.0	. .	70.0	. .	9
		Long Transverse	78.0	. .	68.0	. .	9
	1.001–1.500	Longitudinal	77.0	. .	70.0	. .	9
		Long Transverse	78.0	. .	68.0	. .	9
7475-T761 Sheet	0.040-0.249	Longitudinal	71.0	. .	61.0	. .	9
		Long Transverse	71.0	. .	60.0	. .	9
7475-T7651 Plate	0.250–0.499	Longitudinal	70.0	. .	60.0	. .	9
		Long Transverse	71.0	. .	60.0	. .	9
	0.500-1.000	Longitudinal	69.0	. .	59.0	. .	8
		Long Transverse	70.0	. .	59.0	. .	8
		Longitudinal	69.0	. .	59.0	. .	6
	1.001–1.500	Long Transverse	70.0	. .	59.0	. .	6
7475 ⑥							
ALCLAD 7475-T61 Sheet	0.040-0.062	Longitudinal	69.0	. .	69.0	. .	9
		Long Transverse	69.0	. .	69.0	. .	9
	0.063–0.187	Longitudinal	70.0	. .	62.0	. .	9
		Long Transverse	70.0	. .	60.0	. .	9
	0.188–0.249	Longitudinal	72.0	. .	63.0	. .	9
		Long Transverse	72.0	. .	61.0	. .	9
ALCLAD 7475-T761 Sheet	0.40–0.062	Longitudinal	66.0	. .	66.0	. .	9
		Long Transverse	66.0	. .	66.0	. .	9
	0.63-0.187	Longitudinal	67.0	. .	67.0	. .	9
		Long Transverse	68.0	. .	68.0	. .	9
	0.188-0.249	Longitudinal	69.0	. .	69.0	. .	9
		Long Transverse	70.0	. .	70.0	. .	9

Footnotes for Pages 7-12 through 7-22

① The data base and criteria upon which these mechanical property limits are established are outlined on page 6-1 under "Mechanical Properties."
② Type of specimen used depends on thickness of material; see "Sampling and Testing," pages 4-1 through 4-5
③ D represents specimen diameter.
④ These properties can usually be obtained by the user, when the material is properly solution heat treated or solution and precipitation heat treated from the O (annealed) or F (as fabricated) temper. These properties also apply to samples of material in the O or F tempers, which are solution heat treated or solution and precipitation treated by the producer to determine that the material will respond to proper heat treatment. Properties attained by the user, however, may be lower than those listed if the material has been formed or otherwise cold or hot worked, particularly in the annealed temper, prior to solution heat treatment.
⑤ This table specifies the properties applicable to the test specimens, and since for plate 0.500 or over in thickness the cladding material is removed during preparation of the test specimens, the listed properties are applicable to the core material only. Tensile and yield strengths of the composite plate are slightly lower depending upon the thickness of the cladding.
⑥ See page 6-4 for specific cladding thicknesses.
⑦ For stress-relieved tempers the characteristics and properties other than those specified may differ somewhat from the corresponding characteristics and properties of material in the basic temper.
⑧ Upon artificial aging, T3 /T31, T37, T351, T361 and T451 temper material shall be capable of developing the mechanical properties applicable to the T81, T87, T851, T861 and T651 tempers, respectively.
⑨ The properties for this thickness apply only to the T651 temper.
⑩ This temper is not available from the material producer.
⑪ Tempers T361 and T861 formerly designated T36 and T86, respectively.
⑫ Material in this temper, 0.750 inch and thicker, when tested in accordance with ASTM G47 in the short transverse direction at a stress level of 75 percent of the specified minimum yield strength, will exhibit no evidence of stress corrosion cracking. Capability of individual lots to resist stress corrosion is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined on pages 6-7 and 6-8.
⑬ Material in this temper, when tested in accordance with ASTM G34, will exhibit exfoliation less than that shown in Photo EB, Figure 2, of ASTM G34. Also, material 0.750 inch and thicker, when tested in accordance with ASTM G47 in the short transverse direction of stress level of 25 ksi, will exhibit no evidence of stress corrosion cracking. Capability of individual lots to resist exfoliation corrosion and stress corrosion cracking is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined on pages 6-7 and 6-8.
⑭ Processes such as flattening, leveling, or straightening coiled products subsequent to shipment by the producer may alter the mechanical properties of the metal (refer to Certification, Section 4).
⑮ Applicable only to 1.500 inch and greater thickness.
⑯ See Table 6.6 for fracture toughness limits.
⑰ T7451 temper, although not previously registered, has appeared in the literature and in some specifications as T73651.
⑱ Material in this temper, 0.750 inch and thicker, when tested in accordance with ASTM G47 in the short transverse direction at a stress level of 35 ksi, will exhibit no evidence of stress corrosion cracking. Capability of individual lots to resist stress corrosion is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined on pages 6-7 and 6-8.
⑲ Material in this temper, 0.750 inch and thicker, when tested in accordance with ASTM G47 in the short transverse direction at a stress level of 25 ksi, will exhibit no evidence of stress corrosion cracking. Capability of individual lots to resist stress corrosion is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined on pages 6-7 and 6-8.
⑳ Material in this temper, when tested at any plane in accordance with ASTM G34, will exhibit exfoliation less than that shown in Photo EB, Figure 2, of ASTM G34. Capability of individual lots to resist exfoliation corrosion and stress corrosion cracking is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined on pages 6-7 and 6-8.
㉑ Material in this temper, when tested at $^1/_{10}$ plane in accordance with ASTM G34, will exhibit exfoliation less than that shown in Photo EB, Figure 2, of ASTM G34. Capability of individual lots to resist exfoliation corrosion and stress corrosion cracking is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined on pages 6-7 through 6-10.
㉒ Applies to 1.500 in. only.

TABLE 7.3 Mechanical Property Limits—Brazing Sheet ① ⑭

ALLOY AND TEMPER	SPECIFIED THICKNESS ② in.	TENSILE STRENGTH—ksi				ELONGATION PERCENT MIN. in 2 in. or 4D ③
		ULTIMATE		YIELD		
		min.	max.	min.	max.	
NO. 11 OR NO. 12 BRAZING SHEET ⑥						
No. 11 or No. 12-O	0.006–0.007	. .	20.0	. .	. .	12
Sheet	0.008–0.012	. .	20.0	. .	. .	15
	0.013–0.031	. .	20.0	. .	. .	18
	0.032–0.050	. .	20.0	. .	. .	20
	0.051–0.249	. .	20.0	. .	. .	23
No. 11 or No. 12-H12	0.019–0.050	17.0	23.0	. .	. .	4
Sheet	0.051–0.249	17.0	23.0	. .	. .	6
No. 11 or No. 12-H14	0.019–0.050	20.0	26.0	. .	. .	3
Sheet	0.051–0.249	20.0	26.0	. .	. .	5
NO. 23 OR NO. 24 BRAZING SHEET ⑥						
No. 23 or No. 24-O	0.020–0.031	. .	21.0	. .	. .	18
Sheet	0.032–0.050	. .	21.0	. .	. .	20
	0.051–0.249	. .	21.0	. .	. .	23
No. 23 or No. 24	0.008–0.019	20.0	. .	11.0	. .	15
–T42 ④ ⑩ Sheet	0.020–0.249	20.0	. .	11.0	. .	17
No. 23 or No. 24	0.010–0.020	35.0	. .	30.0	. .	6
–T62 ④ ⑩ Sheet	0.021–0.249	35.0	. .	30.0		8

For all numbered footnotes, see page 7-21.

TABLE 7.4 Weights per Square Foot

All sheet and plate thicknesses in this table are ANSI Standard thicknesses (ANSI B32.1). The weights per square foot for an alloy with density of 0.100 pound per cubic inch is shown for each thickness. Weight conversion factors for other alloys are shown in Table 7.5.

NOTE: THE COMMONLY USED THICKNESS ARE SHOWN IN **BOLD** TYPE.

THICKNESS—in.		WEIGHT lb./sq. ft.	THICKNESS—in.		WEIGHT lb./sq. ft.
DECIMAL	FRACTION		DECIMAL	FRACTION	
.006	..	0.084	.312	5/16	4.49
.007	..	0.101	.328	21/64	4.72
.008	..	0.115	.344	11/32	4.95
.009	..	0.130	.359	23/64	5.17
.010	..	0.144	**.375**	3/8	5.40
.011	..	0.158	.391	25/64	5.63
.012	..	0.173	.406	13/32	5.85
.013	..	0.187	.422	27/64	6.08
.014	..	0.202	.438	7/16	6.31
.016	1/64	0.230	.453	29/64	6.52
.018	..	0.259	.469	15/32	6.75
.019	..	0.274	.484	31/64	6.97
.020	..	0.288	**.500**	1/2	7.20
.021	..	0.302	.531	17/32	7.65
.022	..	0.317	.562	9/16	8.09
.024	..	0.346	.594	19/32	8.55
.025	..	0.360	**.625**	5/8	9.00
.026	..	0.374	.656	21/32	9.45
.028	..	0.403	.688	11/16	9.91
.030	..	0.432	.719	23/32	10.4
.032	..	0.461	**.750**	3/4	10.8
.034	..	0.490	.812	13/16	11.7
.036	..	0.518	.875	7/8	12.6
.038	..	0.547	.938	15/16	13.5
.040	..	0.576	**1.000**	1	14.4
.042	..	0.605	1.125	1 1/2	16.2
.045	..	0.648	1.250	1 1/4	18.0
.048	..	0.691	1.375	1 3/8	19.8
.050	..	0.720	1.500	1 1/2	21.6
.053	..	0.763	1.625	1 5/8	23.4
.056	..	0.806	1.750	1 3/4	25.2
.060	..	0.864	1.875	1 7/8	27.0
.063	1/16	0.907	2.000	2	28.8
.067	..	0.965	2.125	2 1/8	30.6
.071	..	1.02	2.250	2 1/4	32.4
.075	..	1.08	2.375	2 3/8	34.2
.080	..	1.15	2.500	2 1/2	36.0
.085	..	1.22	2.625	2 5/8	37.8
.090	..	1.30	2.750	2 3/4	39.6
.095	..	1.37	2.875	2 7/8	41.4
.100	..	1.44	3.000	3	43.2
.106	..	1.53	3.250	3 1/4	46.8
.112	..	1.61	3.500	3 1/2	50.4
.118	..	1.70	3.750	3 3/4	54.0
.125	1/8	1.80	4.000	4	57.6
.132	..	1.90	4.250	4 1/4	61.2
.140	..	2.02	4.500	4 1/2	64.8
.150	..	2.16	4.750	4 3/4	68.4
.160	..	2.30	5.000	5	72.0
.170	..	2.45	5.250	5 1/4	75.6
.180	..	2.59	5.500	5 1/2	79.2
.190	..	2.74	5.750	5 3/4	82.8
.200	..	2.88	6.000	6	86.4
.212	..	3.05	6.250	6 1/4	90.0
.224	..	3.23	6.500	6 1/2	93.6
.236	..	3.40	6.750	6 3/4	97.2
.250	1/4	3.60	7.000	7	100.8
.266	17/64	3.83	7.250	7 1/4	104.4
.281	9/32	4.05	7.500	7 1/2	108.0
.297	19/64	4.28	7.750	7 3/4	111.6
			8.000	8	115.2

TABLE 7.5 Weight Conversion Factors

Where weights of aluminum sheet and plate have been computed on the basis of 0.100 pound per cubic inch, as in Table 7.4, the weights for specific alloys can be determined by means of the "Weight Conversion Factors" listed in the following table:

ALUMINUM ALLOY	DENSITY lb./cu. in.	WEIGHT CONVERSION FACTOR
1060	0.0975	0.975
1100	0.098	0.98
1350	0.0975	0.975
2014	0.101	1.01
2024	0.100	1.00
2219	0.103	1.03
2036	0.100	1.00
2124	0.100	1.00
3003	0.099	0.99
3004	0.098	0.98
3005	0.098	0.98
3105	0.098	0.98
5005	0.098	0.98
5050	0.097	0.97
5052	0.097	0.97
5083	0.096	0.96
5086	0.096	0.96

ALUMINUM ALLOY	DENSITY lb./cu. in.	WEIGHT CONVERSION FACTOR
5154	0.096	0.96
5252	0.096	0.96
5254	0.096	0.96
5454	0.097	0.97
5456	0.096	0.96
5457	0.097	0.97
5652	0.097	0.97
5657	0.097	0.97
6061	0.098	0.98
7049	0.103	1.03
7050	0.102	1.02
7075	0.101	1.01
7178	0.102	1.02
7475	0.101	1.01

Example: Find the weight per square foot of 0.125 sheet in alloy 6061. The weight per square foot listed for this thickness on page 7-23 is 1.80 pounds. Multiplying this weight by the factor 0.98 given above for alloy 6061 gives 1.76 pounds per square foot.

TABLE 7.6 Recommended Minimum Bend Radii for 90-Degree Cold Forming of Sheet and Plate ① ② ③ ④ ⑤

Alloy	Temper	RADII FOR VARIOUS THICKNESSES EXPRESSED IN TERMS OF THICKNESS "t"							
		1/64 in.	1/32 in.	1/16 in.	1/8 in.	3/16 in.	1/4 in.	3/8 in.	1/2 in.
1100	O	0	0	0	0	½t	1t	1t	1½t
	H12	0	0	0	½t	1t	1t	1½t	2t
	H14	0	0	0	1t	1t	1½t	2t	2½t
	H16	0	½t	1t	1½t	1½t	2½t	3t	4t
	H18	1t	1t	1½t	2½t	3t	3½t	4t	4½t
2014	O	0	0	0	½t	1t	1t	2½t	4t
	T3	1½t	2½t	3t	4t	5t	5t	6t	7t
	T4	1½t	2½t	3t	4t	5t	5t	6t	7t
	T6	3t	4t	4t	5t	6t	8t	8½t	9½t
2024	O	0	0	0	½t	1t	1t	2½t	4t
	T3	2½t	3t	4t	5t	5t	6t	7t	7½t
	T361⑥	3t	4t	5t	6t	6t	8t	8½t	9½t
	T4	2½t	3t	4t	5t	5t	6t	7t	7½t
	T81	4½t	5½t	6t	7½t	8t	9t	10t	10½t
	T861⑥	5t	6t	7t	8½t	9½t	10t	11½t	11½t
2036	T4	. .	1t	1t	. .	. .	. .	. .	. .
3003	O	0	0	0	0	½t	1t	1t	1½t
	H12	0	0	0	½t	1t	1t	1½t	2t
	H14	0	0	0	1t	1t	1½t	2t	2½t
	H16	½t	1t	1t	1½t	2½t	3t	3½t	4t
	H18	1t	1½t	2t	2½t	3½t	4½t	5½t	6½t
3004	O	0	0	0	½t	1t	1t	1t	1½t
	H32	0	0	½t	1t	1t	1½t	1½t	2t
	H34	0	1t	1t	1½t	1½t	2½t	2½t	3t
	H36	1t	1t	1½t	2½t	3t	3½t	4t	4½t
	H38	1t	1½t	2½t	3t	4t	5t	5½t	6½t
3105	H25	½t	½t	½t	. .	. .	. .	. .	. .
5005	O	0	0	0	0	½t	1t	1t	1½t
	H12	0	0	0	½t	1t	1t	1½t	2t
	H14	0	0	0	1t	1½t	1½t	2t	2½t
	H16	½t	1t	1t	1½t	2½t	3t	3½t	4t
	H18	1t	1½t	2t	2½t	3½t	4½t	5½t	6½t
	H32	0	0	0	½t	1t	1t	1½t	2t
	H34	0	0	0	1t	1½t	1½t	2t	2½t
	H36	½t	1t	1t	1½t	2½t	3t	3½t	4t
	H38	1t	1½t	2t	2½t	3½t	4½t	5½t	6½t

For all numbered footnotes, see page 7-25.

TABLE 7.6 Recommended Minimum Bend Radii for 90-Degree Cold Forming of Sheet and Plate ① ② ③ ④ ⑤ (continued)

Alloy	Temper	RADII FOR VARIOUS THICKNESSES EXPRESSED IN TERMS OF THICKNESS "t"							
		1/64 in.	1/32 in.	1/16 in.	1/8 in.	3/16 in.	1/4 in.	3/8 in.	1/2 in.
5050	O	0	0	0	½t	1t	1t	1½t	1½t
	H32	0	0	0	1t	1t	1½t	. .	. .
	H34	0	0	1t	1½t	1½t	2t	. .	. .
	H36	1t	1t	1½t	2t	2½t	3t	. .	. .
	H38	1t	1½t	2½t	3t	4t	5t	. .	. .
5052	O	0	0	0	½t	1t	1t	1½t	1½t
	H32	0	0	1t	1½t	1½t	1½t	1½t	2t
	H34	0	1t	1½t	2t	2t	2½t	2½t	3t
	H36	1t	1t	1½t	2½t	3t	3½t	4t	4½t
	H38	1t	1½t	2½t	3t	4t	5t	5½t	6½t
5083	O	. .	. .	½t	1t	1t	1t	1½t	1½t
	H32	. .	. .	1t	1½t	1½t	1½t	2t	2½t
	H321	. .	. .	1t	1½t	1½t	1½t	2t	2½t
5086	O	0	0	½t	1t	1t	1t	1½t	1½t
	H32	0	½t	1t	1½t	1½t	2t	2½t	3t
	H34	½t	1t	1½t	2t	2½t	3t	3½t	4t
	H36	1½t	2t	2½t	3t	3½t	4t	4½t	5t
5154	O	0	0	½t	1t	1t	1t	1½t	1½t
	H32	0	½t	1t	1½t	1½t	2t	2½t	3½t
	H34	½t	1t	1½t	2t	2½t	3t	3½t	4t
	H36	1t	1½t	2t	3t	3½t	4t	4½t	5t
	H38	1½t	2½t	3t	4t	5t	5t	6½t	6½t
5252	H25	0	0	1t	2t	. .	. .	. .	. .
	H28	1t	1½t	2½t	3t	. .	. .	. .	. .
5254	O	0	0	½t	1t	1t	1t	1½t	1½t
	H32	0	½t	1t	1½t	1½t	2t	2½t	3½t
	H34	½t	1t	1½t	2t	2½t	3t	3½t	4t
	H36	1t	1½t	2t	3t	3½t	4t	4½t	5t
	H38	1½t	2½t	3t	4t	5t	5t	6½t	6½t
5454	O	0	½t	1t	1t	1t	1½t	1½t	2t
	H32	½t	½t	1t	2t	2t	2½t	3t	4t
	H34	½t	1t	1½t	2t	2½t	3t	3½t	4t
5456	O	. .	. .	1t	1t	1½t	1½t	2t	2t
	H32	. .	. .	. .	2t	2t	2½t	3t	3½t
	H321	. .	. .	. .	2t	2t	2½t	3t	3½t
5457	O	0	0	0	. .	. .	. .	. .	. .
5652	O	0	0	0	½t	1t	1t	1½t	1½t
	H32	0	0	1t	1½t	1½t	1½t	1½t	2t
	H34	0	1t	1½t	2t	2t	2½t	2½t	3t
	H36	1t	1t	1½t	2½t	3t	3½t	4t	4½t
	H38	1t	1½t	2½t	3t	4t	5t	52t	62t
5657	H25	0	0	0	1t	. .	. .	. .	. .
	H28	1t	1½t	2½t	3t	. .	. .	. .	. .
6061	O	0	0	0	1t	1t	1t	1½t	2t
	T4	0	0	1t	1½t	2½t	3t	3½t	4t
	T6	1t	1t	1½t	2½t	3t	3½t	4½t	5t
7050	T7	. .	. .	. .	. .	. .	8t	9t	9½t
7072	O	0	0	. .	. .	. .	. .	. .	. .
	H14	0	0	. .	. .	. .	. .	. .	. .
	H18	1t	1t	. .	. .	. .	. .	. .	. .
7075	O	0	0	1t	1t	1½t	2½t	3½t	4t
	T6	3t	4t	5t	6t	6t	8t	9t	9½t
7178	O	0	0	1t	1½t	1½t	2½t	3½t	4t
	T6	3t	4t	5t	6t	6t	8t	9t	9½t

① The radii listed are the minimum recommended for bending sheets and plates without fracturing in a standard press brake with air bend dies. Other types of bending operations may require larger radii or permit smaller radii. The minimum permissible radii will also vary with the design and condition of the tooling.
② Alclad sheet in the heat-treatable alloys can be bent over slightly smaller radii than the corresponding tempers of the bare alloy.
③ Heat-treatable alloys can be formed over appreciably smaller radii immediately after solution heat treatment.
④ The H112 temper (applicable to non-heat treatable alloys) is supplied in the as-fabricated condition without special property control but usually can be formed over radii applicable to the H14 (or H34) temper or smaller.
⑤ The reference test method is ASTM E290.
⑥ Tempers T361 and T861 formerly designated T36 and T86, respectively.

TABLE 7.7a Sheet and Plate Thickness Tolerances ① (Applicable to All Alloys Not Included in the Aerospace Alloys Table 7.7b or Not Specified for Aerospace Applications)

NOTE: ALSO APPLICABLE TO ALLOYS WHEN SUPPLIED AS ALCLAD.

SPECIFIED THICKNESS, in.		SPECIFIED WIDTH—in.							
		Up thru 39.37	Over 39.37 Thru 59.06	Over 59.06 Thru 78.74	Over 78.74 Thru 98.43	Over 98.43 Thru 118.11	Over 118.11 Thru 137.80	Over 137.80 Thru 157.48	Over 157.48 Thru 177.17
Over	Thru	TOLERANCES—in. plus and minus							
0.0059	0.010	0.0010	0.0015	. .	. .	. .	. .	. .	. .
0.010	0.016	0.0010	0.0015	. .	. .	. .	. .	. .	. .
0.016	0.025	0.0015	0.0020	0.0030	0.0035	. .	. .	. .	. .
0.025	0.032	0.0020	0.0025	0.0035	0.0040	. .	. .	. .	. .
0.032	0.039	0.0020	0.0030	0.0035	0.0045	0.006	. .	. .	. .
0.039	0.047	0.0025	0.0035	0.0045	0.006	0.007	0.008	. .	. .
0.047	0.063	0.0030	0.0035	0.0050	0.006	0.007	0.009	. .	. .
0.063	0.079	0.0035	0.0040	0.006	0.007	0.008	0.010	. .	. .
0.079	0.098	0.0035	0.0045	0.006	0.007	0.009	0.011	. .	. .
0.098	0.126	0.0045	0.006	0.007	0.009	0.011	0.013	. .	. .
0.126	0.158	0.006	0.007	0.009	0.011	0.013	0.015	. .	. .
0.158	0.197	0.007	0.009	0.011	0.013	0.015	0.018	. .	. .
0.197	0.248	0.009	0.011	0.013	0.015	0.018	0.022	0.027	. .
0.248	0.315	0.012	0.014	0.015	0.018	0.022	0.027	0.035	0.043
0.315	0.394	0.015	0.017	0.020	0.023	0.027	0.033	0.041	0.051
0.394	0.630	0.023	0.023	0.027	0.032	0.035	0.043	0.053	0.065
0.630	0.984	0.031	0.031	0.037	0.043	0.047	0.058	0.070	0.085
0.984	1.575	0.039	0.039	0.047	0.055	0.065	0.075	0.090	0.105
1.575	2.362	0.055	0.055	0.060	0.070	0.085	0.100	0.115	. .
2.362	3.150	0.075	0.075	0.085	0.100	0.105	0.125	. .	. .
3.150	3.937	0.100	0.100	0.115	0.125	0.130	0.160	. .	. .
3.937	6.299	0.130	0.130	0.145	0.165	. .	. .	. .	. .
6.300	8.000	0.160	0.160	0.160	0.165	. .	. .	. .	. .

TABLE 7.7b Sheet and Plate Thickness Tolerances ① (Applicable to All Alloys Specified for Aerospace Applications)

(INCLUDES AEROSPACE ALLOYS 2014, 2024, 2124, 2219, 2324, 2419, 7050, 7075, 7150, 7178 and 7475)

NOTE: ALSO APPLICABLE TO ALLOYS WHEN SUPPLIED AS ALCLAD.

SPECIFIED THICKNESS		SPECIFIED WIDTH—in.											
		Up thru 39.37	Over 39.37 thru 47.24	Over 47.24 thru 55.12	Over 55.12 thru 59.06	Over 59.06 thru 70.87	Over 70.87 thru 78.74	Over 78.74 thru 86.61	Over 86.61 thru 98.43	Over 98.43 thru 118.11	Over 118.11 thru 137.80	Over 137.80 thru 157.48	Over 157.48 thru 177.17
Over	Thru	TOLERANCE—in. plus and minus											
0.0059	0.010	0.0010	0.0020	0.0020	0.0020	. .	. .	. .	. .	. .	. .	. .	. .
0.010	0.016	0.0015	0.0025	0.0025	0.0025	. .	. .	. .	. .	. .	. .	. .	. .
0.016	0.025	0.0015	0.0025	0.0025	0.0025	. .	. .	. .	. .	. .	. .	. .	. .
0.025	0.032	0.0015	0.0015	0.0020	0.0030	0.0030	. .	. .	. .	. .	. .	. .	. .
0.032	0.039	0.0015	0.0015	0.0020	0.0030	0.0030	0.0035	0.0035	0.007	. .	. .	. .	. .
0.039	0.047	0.0020	0.0020	0.0020	0.0030	0.0030	0.0035	0.0035	0.008	0.010	0.011	. .	. .
0.047	0.063	0.0020	0.0020	0.0030	0.0030	0.0030	0.0035	0.0035	0.009	0.011	0.013	. .	. .
0.063	0.079	0.0020	0.0020	0.0030	0.0035	0.0035	0.0035	0.0035	0.010	0.013	0.015	. .	. .
0.079	0.098	0.0025	0.0025	0.0035	0.0040	0.0040	0.0045	0.0045	0.011	0.015	0.018	. .	. .
0.098	0.126	0.0035	0.0035	0.0035	0.0045	0.0045	0.0045	0.0045	0.013	0.016	0.020	. .	. .
0.126	0.158	0.0040	0.0040	0.0045	0.007	0.007	0.009	0.009	0.015	0.018	0.022	. .	. .
0.158	0.197	0.006	0.007	0.007	0.009	0.009	0.011	0.011	0.018	0.022	0.026	. .	. .
0.197	0.248	0.009	0.012	0.012	0.012	0.017	0.017	0.021	0.021	0.025	0.029	. .	. .
0.248	0.315	0.012	0.015	0.015	0.015	0.019	0.019	0.024	0.024	0.029	0.033	0.041	0.051
0.315	0.394	0.017	0.018	0.018	0.018	0.022	0.022	0.028	0.028	0.033	0.039	0.047	0.059
0.394	0.630	0.023	0.023	0.023	0.023	0.028	0.028	0.033	0.033	0.039	0.047	0.059	0.070
0.630	0.984	0.031	0.031	0.031	0.031	0.037	0.037	0.043	0.043	0.051	0.060	0.070	0.085
0.984	1.575	0.039	0.039	0.039	0.039	0.047	0.047	0.055	0.055	0.065	0.075	0.090	0.105
1.575	2.362	0.055	0.055	0.055	0.055	0.060	0.060	0.070	0.070	0.090	0.100	0.115	. .
2.362	3.150	0.075	0.075	0.075	0.075	0.085	0.085	0.100	0.100	0.110	0.125	. .	. .
3.150	3.937	0.100	0.100	0.100	0.100	0.115	0.115	0.130	0.130	0.150	0.160	. .	. .
3.937	6.299	0.130	0.130	0.130	0.130	0.145	0.145	0.165	0.165	. .	. .	. .	. .
6.300	8.000	0.160	0.160	0.160	0.160	0.160	0.160	0.165	0.165	. .	. .	. .	. .

Note: Capability to provide tighter tolerances may vary with supplier.

① When a dimension tolerance is specified other than as equal bilateral tolerance, the value of the standard tolerance is that which applies to the mean of the maximum and minimum dimension permissible under the tolerance for the dimension under consideration.

TABLE 7.8 Width Tolerances—Sheared Flat Sheet and Plate

SPECIFIED THICKNESS in.	SPECIFIED WIDTH—in.					
	Up thru 6	Over 6 thru 24	Over 24 thru 60	Over 60 thru 96	Over 96 thru 132	Over 132 thru 168
	TOLERANCES ②—in.					
0.006–0.124	±1/16	±3/32	±1/8	±1/8	±5/32	. .
0.125–0.249	±3/32	±3/32	±1/8	±5/32	±3/16	. .
0.250–0.499	+1/4	+5/16	+3/8	+3/8	+7/16	+1/2

TABLE 7.9 Length Tolerances—Sheared Flat Sheet and Plate

SPECIFIED THICKNESS in.	SPECIFIED LENGTH—in.							
	Up thru 30	Over 30 thru 60	Over 60 thru 120	Over 120 thru 240	Over 240 thru 360	Over 360 thru 480	Over 480 thru 600	Over 600 thru 720
	TOLERANCES ②—in.							
0.006–0.124	±1/16	±3/32	±1/8	±5/32	±3/16	±7/32	±9/32	. .
0.125–0.249	±3/32	±3/32	±1/8	±5/32	±7/32	±1/4	±5/16	. .
0.250–8.000	+1/4	+3/8	+7/16	+1/2	+9/16	+5/8	+11/16	+3/4

TABLE 7.10 Width and Length Tolerances—Sawed Flat Sheet and Plate

SPECIFIED THICKNESS in.	SPECIFIED LENGTH—in.							
	Up thru 30	Over 30 thru 60	Over 60 thru 120	Over 120 thru 240	Over 240 thru 360	Over 360 thru 480	Over 480 thru 600	Over 600 thru 720
	TOLERANCES ②—in.							
0.080–0.249	±1/8	±1/8	±3/16	±1/4	±1/4	±5/16	±3/8	±7/16
0.250–8.000	+1/4	+5/16	+3/8	+1/2	+9/16	+5/8	+3/4	+7/8

TABLE 7.11 Width Tolerances ①—Slit Coiled Sheet

SPECIFIED THICKNESS in.	SPECIFIED WIDTH—in.					
	Up thru 6	Over 6 thru 12	Over 12 thru 24	Over 24 thru 48	Over 48 thru 60	Over 60 thru 96
	TOLERANCES ②—in. plus and minus					
0.006–0.125	0.010	1/64	1/32	3/64	1/16	1/8
0.126–0.186	0.012	1/32	1/32	1/16	3/32	. .
0.187–0.249	0.016	1/32	3/64	3/32	1/8	. .

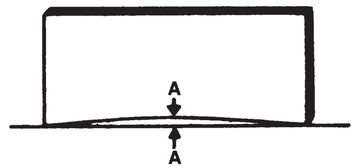
For all numbered footnotes, see page 7-28.

TABLE 7.12 Lateral Bow Tolerances ①—Coiled Sheet

SPECIFIED THICKNESS in.	SPECIFIED WIDTH—in.				
	1/2 thru 1	Over 1 thru 2	Over 2 thru 4	Over 4 thru 10	Over 10
	TOLERANCE—in. in 6 ft. Allowable Deviation of a Side Edge from a Straight Line				
0.006–0.064	3/4	9/16	3/8	1/4	3/16
0.065–0.125	. .	. .	3/8	1/4	3/16

TABLE 7.13 Lateral Bow Tolerances—Flat Sheet and Plate

ALLOWABLE DEVIATION OF A SIDE EDGE FROM A STRAIGHT LINEN

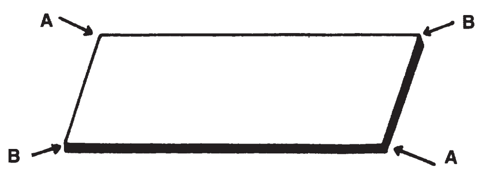


Maximum allowable value of AA

SPECIFIED THICKNESS in.	SPECIFIED WIDTH in.	SPECIFIED LENGTH—in. Up thru 60	Over 60 thru 90	Over 90 thru 120	Over 120 thru 150	Over 150 thru 180	Over 180 thru 210	Over 210 thru 240
		TOLERANCE—in.						
0.006–0.125	Up thru 4	0.250	0.563	1.000	1.563	2.250	3.000	4.000 ⑤
	Over 4 thru 10	0.094	0.219	0.375	0.563	0.875	1.156	1.500 ⑤
	Over 10 thru 35	0.063	0.125	0.188	0.250	0.375	0.500	0.750 ⑤
	Over 35	0.032	0.063	0.125	0.188	0.250	0.375	0.500 ⑤
0.126–0.249	Over 4 thru 15	0.063	0.125	0.250	0.375	0.563	0.750	1.000 ⑤
	Over 15	0.032	0.063	0.125	0.188	0.250	0.375	0.500 ⑤
0.250–8.000	Up thru 10	0.250	0.563	1.000	1.563	2.250	3.000	4.000 ⑤
	Over 10 thru 18	0.063	0.125	0.250	0.406	0.594	0.781	1.000 ⑤
	Over 18	0.032	0.094	0.125	0.219	0.312	0.438	0.562 ⑤

TABLE 7.14 Squareness Tolerances—Flat Sheet and Plate

ALLOWABLE DIFFERENCE IN LENGTH OF DIAGONALS ④ —Inches



Maximum difference between AA and BB

SPECIFIED LENGTH ft.	SPECIFIED WIDTH—ft. Up thru 3	Over 3
Up thru 12	$\frac{3}{32}$ · width, ft ③	$\frac{5}{64}$ · width, ft ③
Over 12	$\frac{9}{64}$ · width, ft ③	$\frac{7}{64}$ · width, ft ③

① When a dimension tolerance is specified other than as an equal bilateral tolerance, the maximum value of the standard tolerance is that which applies to the mean of the maximum and minimum dimensions permissible under the tolerance for the dimension under consideration.
② Tolerances applicable at ambient mill temperatures. A change in dimension of 0.013 in. per 100 in. per 10°F must be recognized.
③ If specified width is other than an exact multiple of 12 in., tolerance is determined by using the next largest exact multiple. For example, if specified width is 53 in. and specified length is 72 in., the tolerance is $\frac{5}{64}$ in. · 5 = $\frac{25}{64}$ in. This result is then rounded to $\frac{7}{16}$ in. in accordance with footnote ④ .
④ Use values for calculating only. Round result upward to nearest $\frac{1}{16}$ in.
⑤ Also applicable to any 240-inch increment of longer sheet or plate.

TABLE 7.15 Diameter Tolerances—Sheared or Blanked Sheet and Plate Circles ①

SPECIFIED THICKNESS in.	SPECIFIED DIAMETER				
	Up thru 18	Over 18 thru 36	Over 36 thru 96	Over 96 thru 132	Over 132 thru 168
	ALLOWABLE DEVIATION FROM SPECIFIED DIAMETER in. plus and minus  Difference between AA and specified diameter				
0.006–0.249	1/32	3/64	1/16	1/8	3/16
0.250–0.375	. .	1/16	1/8	3/16	1/4
0.376–0.625	. .	1/8	3/16	1/4	3/8
0.626–0.875	. .	3/16	1/4	3/8	1/2
0.876–1.250	. .	1/4	3/8	1/2	5/8

TABLE 7.16 Diameter Tolerances—Sawed Sheet and Plate Circles ①

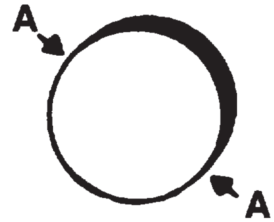
SPECIFIED THICKNESS in.	SPECIFIED DIAMETER			
	Up thru 18	Over 18 thru 60	Over 60 thru 132	Over 132 thru 168
	ALLOWABLE DEVIATION FROM SPECIFIED DIAMETER in. plus and minus  Difference between AA and specified diameter			
0.080–1.000	1/8	3/16	1/4	1/2
1.001–3.000	1/4	3/8	1/2	3/4

TABLE 7.17 Flatness Tolerances—Flat Sheet ②

Alloy (Includes Alclads)	Specified Thickness in.	Longitudinal or Transverse Distance (ft.) Center to Center of Buckles or Edge Waves ③				
		Up thru 2	Over 2 thru 3	Over 3 thru 4	Over 4 thru 6	Over 6
		TOLERANCES, in. ④ ⑤ ⑥				
1060, 1100, 1350, 3003, 3005, 3105, 5005, 5050, 5X57	0.020 thru 0.064 0.065 thru 0.249	1/8 1/8	3/16 3/16	3/16 5/16	5/16 3/8	3/8 1/2
3004, 5052, 5083, 5086, 5252, 5X54, 5456, 5652, brazing sheet, and all heat treatable alloys	0.020 thru 0.064 0.065 thru 0.249	3/16 3/16	3/16 5/16	5/16 3/8	3/8 1/2	1/2 9/16

① When a dimension tolerance is specified other than as an equal bilateral tolerance, the maximum value of the standard tolerance is that which applies to the mean of the maximum and minimum dimensions permissible under the tolerance for the dimension under consideration.
② Not applicable to cut-to-length sheet, panel flat sheet, coiled sheet, or sheet over 60 in. wide. Flatness tolerances, including coil set flatness tolerances, for these excluded products, should be as agreed upon in advance between producer and purchaser. (See Section 5, Terminology, for a definition of Sheet, Coiled Cut-to-Length).
③ Also applicable to overall length or width of sheet if only one longitudinal and/or transverse buckle or edge wave is present.
④ Allowable deviation from flat with the sheet positioned on flat horizontal surface to minimize deviation.
⑤ Not applicable to O, F and HX8 and harder tempers.
⑥ Not applicable to end or corner turnup.

TABLE 7.18 Flatness Tolerances—Sawed or Sheared Plate

LONGITUDINAL FLATNESS

SPECIFIED THICKNESS, in.	TOLERANCE ① in.—Allowable Deviation from Flat	
	TX51 tempers ②	Other than TX51 tempers ② ⑦
0.250–3.000	3/16 in any 6 ft ③	1/4 in any 6 ft or less
3.001–8.000	1/8 in any 6 ft or less	1/4 in any 6 ft or less

TRANSVERSE FLATNESS

SPECIFIED THICKNESS, in.	TOLERANCE ① in.—Allowable Deviation from Flat				
	Widths over 4 ft thru 6 ft ④		Widths over 2 ft thru 4 ft		Widths 2 ft and less
	TX51 tempers ②	Other than TX51 tempers ② ⑦	TX51 tempers ②	Other than TX51 tempers ② ⑦	All tempers ⑦
0.250–0.624	3/8	1/2	5/16	3/8	Only short-span flatness tolerance applies
0.625–1.500	5/16	3/8	3/16	1/4	
1.501–3.000	3/16	1/4	3/16	3/16	
3.001–8.000	1/8	1/4	1/8	3/16	

SHORT-SPAN FLATNESS ⑤

SPECIFIED THICKNESS, in.	TOLERANCE ⑥ in.—Allowable Deviation from Flat	
	TX51 tempers ②	Other than TX51 tempers ② ⑦
0.250–0.624	.100	.125
0.625–8.000	.075	.090

① As measured with plate resting on a flat surface concave side upward, using a straightedge and a feeler gauge, dial gauge or scale.
② TX51 is a general designation for the following stress-relieved tempers: T351, T451, T651, T851, T7351 and T7651.
③ For pieces ordered to less than 6 ft length, the tolerance is 1/8 in. for the total length.
④ For widths over 6 ft, these tolerances apply for any 6 ft of total width.
⑤ Short-span flatness is the deviation from flat over full span for spans 2 ft and less.
⑥ As measured with the plate resting on a flat surface.
⑦ Not applicable to O, F, and HX8 and harder tempers.

Quality Standards for Painted Sheet ①

Scope

This standard covers minimum quality requirements and conformance tests for decorative and protective organic finishes on aluminum alloy sheet for exterior applications.

Substrate

Painted sheet is produced from a variety of alloys and tempers having mechanical properties and dimensional tolerances prior to painting as listed on pages 7-3 through 7-11 and 7-26 through 7-29, respectively. Mechanical properties of the painted sheet will be reduced from those of the bare products, but the amount of reduction will vary with the original alloy and temper used as well as with the paint system employed. For minimum mechanical properties and forming capabilities applicable to any specified painted product, consult the supplier.

Pretreatment

The sheet is first cleaned by suitable methods to remove possible surface contaminants, followed by the uniform application of a pretreatment, which, in conjunction with the baked organic coating, produces sheet meeting all quality and production lot acceptance tests listed in these standards.

Qualification Tests and Test Methods

Prior to their use, specific basic paint formulations are subjected to the qualifying tests listed hereunder. Custom colors formulated similarly to the basic formulations for delivery within a few weeks cannot be subjected to long-term testing prior to use. However if failure is noted when they are subsequently tested, such custom colors are either discontinued or reformulated for improved performance. All lots of painted sheet are subjected to, and must pass, production lot acceptance tests listed later in these standards.

Natural Weather Exposure

No checking, crazing or adhesion loss, and only slight-to-moderate chalking and slight fading or color change, when tested as follows:

Test Method. One year outdoor exposure at Miami, Florida, at a 45° angle facing south. Following exposure examine film visually in adequately lighted area for checking, crazing, blistering, peeling, flaking, fading or color change. Determine degree of chalking in accordance with ASTM D 4214. Paint crazing from forming is not to be considered a failure.

Accelerated Weather Exposure

No adhesion loss, only slight chalking and fading or color change, plus normal water staining when tested as follows:

Test Method. 500 hours in accordance with ASTM D 822 using Type E apparatus described in ASTM G 23, or 1,000 hours in accordance with ASTM D822 using Type D apparatus described in ASTM G23. Following exposure, examine film visually in adequately lighted area for conformance to requirement.

Salt Spray Resistance

Undercutting of film from scored line, 1/16 inch maximum when tested as follows:

Test Method. 1,000 hours in accordance with ASTM B117. Film scored diagonally sufficiently deep to expose base metal and edges exposed.

Humidity Resistance

No formation of blisters to an extent greater than illustration for Few Blisters of No. 8 Size in Figure 4 of ASTM D714 when tested as follows:

Test Method. 1,000 hours at 100 percent relative humidity in cabinet operated in accordance with ASTM D2247.

Chemical Resistance

No loss of adhesion or gloss and no color change or staining when tested as follows:

Test Method. Totally immerse separate samples in mineral spirits, 2.0 percent trisodium phosphate solution and 2.0 percent Ivory soap solution for 24 hours at room temperature (77°F). Also immerse a separate sample for 72 hours in a 3.0 percent detergent solution maintained at 100°F. The detergent solution shall be prepared using a detergent composed of a mixture of chemicals as follows:

Technical Grade Reagents	*Percent/Weight*
Tetrasodium Pyrophosphate, Hydrated	45.0
Sodium Sulfate, Anhydrous	23.5
Sodium Alkylarylsulfonate*	22.0
Sodium Metasilicate, Hydrated	7.5
Sodium Carbonate, Anhydrous	2.0

* Nacconal 90°F–Allied Chemical Company

Following immersion of the samples in the various media for the indicated time periods, they shall be removed and rinsed, then allowed to recover for 24 hours before determining whether the foregoing requirement has been met. Appropriate methods for determining adhesion and gloss are given elsewhere in these standards. Examination for color change or staining shall be made visually in an adequately lighted area.

Production Lot Acceptance

Each lot of painted sheet is subjected to and must pass the following tests:

Surface Appearance

Commercially smooth and substantially free from flow lines, streaks, blisters or other surface imperfections.

Test Method. Visual examination in an adequately lighted area. ②

For all numbered footnotes, see page 7-32.

Dry Film Hardness

No film rupture shall occur when tested as follows with an Eagle Turquoise pencil, grade HB minimum.

Test Method. Strip the wood from the pencil leaving 1/8 to ¼ in. length of full diameter lead. A mechanical pencil with lead refills equivalent to Eagle Turquoise pencil, Grade HB minimum, may be substituted. Using fine grit sand or emery paper, flatten end of lead so it is 90° to pencil axis. Hold pencil at 45° to film surface and push forward about ¼ in. using as much downward pressure as can be applied without breaking the pencil lead.

Color Uniformity

Color uniformity will be commercially constant when tested as follows:

Test Method. Check visually under a uniform light source such as Macbeth North Daylight Lamp.

Dry Film Thickness

Thickness of cured non-metallic paint films, including primer where used, will be 0.0008 in. minimum. Thickness of cured metallic paint finish coats will be 0.0006 in. minimum.

Test Method. Method C of ASTM D1400.

Specular Gloss

Painted sheet is supplied at a variety of gloss levels, of which the most popular levels with associated tolerances are as follows:

High Gloss Colors: 80 minimum
Medium Gloss Colors: 30 to 50 (as specified) ±8
Low Gloss Colors: 10±3

Test Method. ASTM D523.

Film Adhesion ③

No removal of the film will occur when tested as follows:

Test Method. Using a sharp knife or similar instrument, make 10 parallel cuts through the film at about 1/16 in. spacing. Make 10 similar cuts at 90° to and crossing the first 10. Apply No. 600, ¾ in. wide, Scotch cellophane tape firmly to the area and pull off sharply.

Impact Resistance ④

High gloss vinyl and medium gloss fluoropolymer films are recommended for severe forming: Painted sheet shall withstand direct and reverse impact sufficient to rupture it, with no loss of adhesion between the film and the base sheet when tested as follows:

Test Method. Subject the sample at room temperature to an impact force of sufficient magnitude to cause metal rupture by use of a Gardner Variable Impact Tester or equivalent with a 5/8 in. diameter mandrel. Apply Scotch cellophane tape No. 600, ¾ in. wide, firmly to the deformed area and pull off sharply.

High gloss alkyd, acrylic, siliconized acrylic, polyester and siliconized polyester films are recommended for moderate forming for sheet tempers other than annealed. Minute fracturing of the film is permissible, but no film shall be removed from the base metal when painted sheet is subjected to direct and reverse impacts of 40 in./lb, or less, when tested as follows:

Test Method. Subject the sample at room temperature to 40 in.-lb impact force by use of a Gardner Variable Impact Tester or equivalent with a 5/8 in. diameter mandrel. If metal is ruptured, decrease the impact in 5 in.-lb increments until no metal fracture occurs. Apply Scotch cellophane tape No. 600, ¾ in. wide, firmly to the deformed area and pull off sharply.

Recommended Minimum Bend Radii

Sheet having applied paint films recommended for moderate or severe forming as described in the paragraph introducing table 7.19 can be bent through 90° or 180° angles at the minimum radii specified in table 7.19. Slight microchecking of the film may occur, but good adherence between film and base metal will be maintained.

Test Method. Bend painted sheet to approximate angle (90° or 180°) at radius listed in table 7.19 for type film, alloy-temper and gauge using suitable laboratory (Niagara Bar Folder or equivalent) or production equipment. Apply No. 600, ¾ inch wide, Scotch cellophane tape firmly to bend area and pull off sharply.

Footnotes for Pages 7-31 and 7-32

① Dimensional tolerances for painted sheet are the same as those for unpainted sheet (see pages 7-26 through 7-28) and are applicable before the paint is applied.

② Pressure mottling may appear on either flat or coiled painted sheet, but the condition will dissipate upon short exposure to heat and/or weathering. If it is not corrected by such exposure, contact the supplier.

③ Many applications for painted aluminum sheet require a back coating which is usually applied in a thickness of about 0.1 to 0.2 mil. This adhesive requirement also applies to these back coatings.

④ For medium gloss paints other than fluoropolymers and low gloss paints and annealed painted sheet, impact resistance is subject to special agreement.

TABLE 7.19 Recommended Minimum Bend Radii ① in Terms of Metal Thickness "T" ②—Painted Sheet

90° BENDS FOR HIGH GLOSS ALKYD, ACRYLIC, SILICONIZED ACRYLIC, POLYESTER, OR SILICONIZED POLYESTER FILMS RECOMMENDED FOR MODERATE FORMING; AND 180° BENDS FOR HIGH GLOSS VINYL AND MEDIUM GLOSS FLUOROPOLYMER FILMS RECOMMENDED FOR SEVERE FORMING. FOR SHEET PAINTED WITH MEDIUM GLOSS PAINTS OTHER THAN FLUOROPOLYMERS OR WITH LOW GLOSS PAINTS, MINIMUM BEND RADIUS USUALLY MUST BE GREATER THAN SHOWN IN THE TABLE TO PREVENT OR MINIMIZE PAINT MICROCRACKING.

ALLOY	TEMPER BEFORE FILM APPLICATION	THICKNESS OF BASE SHEET—in.					
		0.016	0.025	0.032	0.040	0.050	0.064
1100	O	1T	1T	1T	1T	1T	1T
	H12	1T	1T	1T	1T	1T	1T
	H14	1T	1T	1T	1T	1T	1T
	H16	1T	1T	1T	1T	2T	3T
	H18	2T	2T	3T	3T	4T	5T
3003	O	1T	1T	1T	1T	1T	1T
	H12	1T	1T	1T	1T	1T	1T
	H14	1T	1T	1T	1T	1T	1T
	H16	1T	1T	2T	3T	3T	4T
	H18	2T	3T	4T	5T	6T	7T
3105	O	1T	1T	1T	1T	1T	1T
	H12	1T	1T	1T	1T	1T	1T
	H14	1T	1T	1T	1T	1T	1T
	H16	1T	1T	2T	3T	3T	4T
	H18	2T	3T	4T	5T	6T	7T
5005	O	1T	1T	1T	1T	1T	1T
	H32	1T	1T	1T	1T	1T	1T
	H34	1T	1T	1T	1T	1T	1T
	H36	1T	1T	2T	3T	3T	4T
	H38	2T	3T	4T	5T	6T	7T
5052	O	1T	1T	1T	1T	1T	1T
	H32	1T	1T	1T	1T	1T	1T
	H34	1T	1T	1T	2T	2T	3T
	H36	2T	3T	3T	3T	4T	5T
	H38	2T	3T	4T	5T	6T	7T

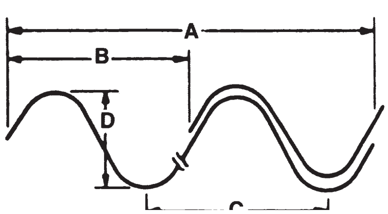
① Minimum radius over which painted sheet may be bent varies with type and gloss of paint, nature of forming operation, type of forming equipment, and design and condition of tools. Minimum radius for a specific material, or hardest alloy and temper for a specific radius, can be closely determined only by actual trial under contemplated conditions of fabrication.
② The reference test method is ASTM E290.

TABLE 7.20 Standard Finishes for Roofing and Siding

PRODUCT	THICKNESS in.	FINISH			
		MILL FINISH	STUCCO EMBOSSED	PAINTED	LOW REFLECTANCE ①
Corrugated roofing	0.024	X	X	X	
	0.032	X	X	X	X
	0.040	X	X	X	X
Corrugated siding	0.024	X	X	X	
	0.032	X	X	X	X
V-beam roofing and siding	0.032	X	X	X	X
	0.040	X	X	X	X
	0.050	X	X	X	X
Ribbed roofing	0.036	X			
	0.040	X			
	0.050	X			
Ribbed siding	0.032		X	X	
	0.040		X	X	

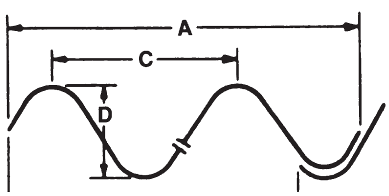
① The specular gloss number of the Low Reflectance aluminum sheet is an average of 10 or less when measured in accordance with ASTM method D 523 at an angle of 85 degrees. This average is obtained thus: A representative sample is cut from the coil or sheet across the entire width (approximately one foot across the width of the coil or sheet). This sample is then cut into 12-by-12 inch sizes. Each of these smaller samples is then read in accordance with ASTM procedure, that is, in the direction of rolling and at least 10 readings per piece. After the results of each sample are obtained, the average reflectance value of the original sample is computed by totaling all the readings obtained and dividing by the total number made.

TABLE 7.21 Designed Dimensions and Weights for Corrugated Roofing



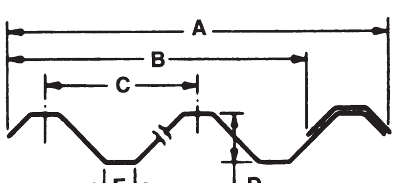
NOMINAL THICK-NESS ① in.	NOMINAL OVER-ALL WIDTH ④ in.	NOMINAL COVERAGE WIDTH ② in.	NOMINAL PITCH OF CORRUGA-TION in.	NOMINAL DEPTH OF CORRUGA-TION ③ in.	NOMINAL WEIGHT PER 100 SQUARE FEET ④ lb
	DIM. A	DIM B.	DIM C.	DIM D.	
0.024	35	32	2⅔	⅞	41
0.024	48⅓	45⅓	2⅔	⅞	41
0.032	35	32	2⅔	⅞	55
0.032	48⅓	45⅓	2⅔	⅞	55
0.032	48⅜	45⅜	2⅔	⅞	55
0.040	48⅓	45⅓	2⅔	⅞	69

TABLE 7.22 Designed Dimensions and Weights for Corrugated Siding



NOMINAL THICK-NESS ① in.	NOMINAL OVER-ALL WIDTH ④ in.	NOMINAL COVERAGE WIDTH ⑤ in.	NOMINAL PITCH OF CORRUGA-TION in.	NOMINAL DEPTH OF CORRUGA-TION ③ in.	NOMINAL WEIGHT PER 100 SQUARE FEET ④ lb
	DIM. A	DIM B.	DIM C.	DIM D.	
0.024	33¾	32	2⅔	⅞	41
0.024	47	45⅓	2⅔	⅞	41
0.032	33¾	32	2⅔	⅞	55
0.032	47	45⅓	2⅔	⅞	55
0.032	47⅛	45⅜	2⅔	⅞	55

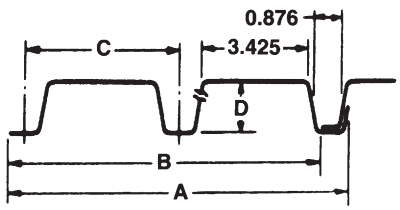
TABLE 7.23 Designed Dimensions and Weights for V-Beam Roofing and Siding



NOMINAL THICK-NESS ① in.	NOMINAL OVER-ALL WIDTH ④ in.	NOMINAL COVERAGE WIDTH ⑤ in.	NOMINAL PITCH OF CORRUGA-TION in.	NOMINAL DEPTH OF CORRUGA-TION ③ in.	NOMINAL WIDTH OF CROWN AND VALLEY in.	NOMINAL WEIGHT PER 100 SQUARE FEET ④ lb
	DIM. A	DIM B.	DIM C.	DIM D.	DIM E.	
0.032	41⅝	39	4⅞	1¾	¾	58
0.032	45	42⅔	5⅛	1¾	1⅛	58
0.040	41⅝	39	4⅞	1¾	¾	72
0.040	45	42⅔	5⅓	1¾	1⅛	73
0.050	41⅝	39	4⅞	1¾	¾	90
0.050	45	42⅔	5⅓	1¾	1⅛	91

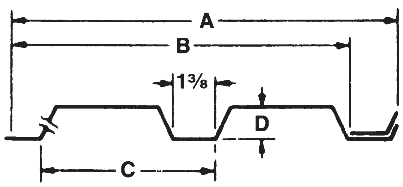
① Applicable prior to painting, corrugating or embossing.
② Based on 1½ corrugations side lap.
③ As measured between the outside surfaces of adjacent corrugations.
④ Based on overall width of formed sheet.
⑤ Based on one corrugation side lap.

TABLE 7.24 Designed Dimensions and Weights for Ribbed Roofing



NOMINAL THICK-NESS ① in.	NOMINAL OVER-ALL WIDTH ④ in.	NOMINAL COVERAGE WIDTH ⑤ in.	NOMINAL PITCH OF CORRUGA-TION in.	NOMINAL DEPTH OF CORRUGA-TION ③ in.	NOMINAL WEIGHT PER 100 SQUARE FEET ④ lb
	DIM. A	DIM B.	DIM C.	DIM D.	
0.036	24.8	24	4.8	1¾	85
0.040	24.8	24	4.8	1¾	95
0.050	24.8	24	4.8	1¾	118

TABLE 7.25 Designed Dimensions and Weights for Ribbed Siding



NOMINAL THICK-NESS ① in.	NOMINAL OVER-ALL WIDTH ④ in.	NOMINAL COVERAGE WIDTH ⑥ in.	NOMINAL PITCH OF CORRUGA-TION in.	NOMINAL DEPTH OF CORRUGA-TION ③ in.	NOMINAL WEIGHT PER 100 SQUARE FEET ④ lb
	DIM. A	DIM B.	DIM C.	DIM D.	
0.032	41⅝	40	4	1	58
0.032	41⅝	40	8	1	52
0.040	41⅝	40	4	1	73
0.040	41⅝	40	8	1	65

TABLE 7.26 Thickness Tolerances ①— Commercial Roofing and Siding

NOMINAL THICKNESS in.	NOMINAL WIDTH—in.	
	Up thru 36	Over 36 thru 54
	TOLERANCE—in. plus and minus	
0.024	.0025	.004
0.032	.0025	.005
0.036	.0025	.005
0.040	.003	.005
0.050	.004	.006

TABLE 7.27 Depth of Corrugation Tolerances— Commercial Roofing and Siding

Allowable deviation from nominal depth of corrugation: ±1/32 in.

TABLE 7.28 Length Tolerances ⑦— Commercial Roofing and Siding

Allowable deviation from specified length: ±½ in.

TABLE 7.29 Parallelness of Corrugations— Commercial Roofing and Siding

PRODUCT	PARALLELNESS OF CORRUGATIONS
Corrugated roofing and siding	Capable of being lapped at either end.
V-beam roofing and siding	Capable of being lapped at either end.
Ribbed roofing	Capable of being lapped at either end and ribs are parallel to each other and to edges of sheet within ±⅛ in.
Ribbed siding	Capable of being lapped at either end.

TABLE 7.30 Squareness Tolerance— Commercial Roofing and Siding

Allowable difference in length of diagonals: ±½ in.

① Applicable to flat sheet prior to painting, corrugating or embossing.
② Based on 1½ corrugations side lap.
③ As measured between the outside surfaces of adjacent corrugations.
④ Based on overall width of formed sheet.
⑤ Based on one corrugation side lap.
⑥ Based on side lap of 1⅝ inches.
⑦ Applicable to lengths of 3 feet through 30 feet for all products except ribbed siding. For ribbed siding, tolerances are applicable to lengths of 3 feet through 36½ feet.

Composition Limits Percent Maximum for Duct Sheet

SILICON	IRON	COPPER	MANGANESE	MAGNESIUM	CHROMIUM	ZINC	TITANIUM	OTHERS		ALUMINUM
								Each	Total	
1.0	1.0	0.40	1.5	0.7	0.20	1.0	0.20	0.05	0.15	Remainder

Mechanical Property Limits ①

Ultimate Strength: 16.0 ksi minimum

Formability

Duct sheet is capable of forming a Pittsburgh Lock Seam.

Standard Sizes

a. **Standard Thicknesses:** 0.016, 0.018, 0.020, 0.022, 0.025, 0.032, 0.040, 0.050, 0.063 in.

b. **Standard Widths for Coiled Duct Sheet, Coiled Duct Sheet Cut to Length and Flat Duct Sheet:** 24, 30, 36 and 48 in.

c. **Standard Lengths for Coiled Duct Sheet Cut to Length, and Flat Duct Sheet:** 72, 96, 120, 144 and 168 in.

d. **Standard Coil Sizes for Coiled Duct Sheet:** Minimum coil size, 35 pounds per inch of width.

① The data base and criteria upon which these mechanical property limits are established are outlined on page 6-1 under "Mechanical Properties."

TABLE 7.31 Thickness Tolerances—Duct Sheet

STANDARD THICKNESS in.	TOLERANCE—in. plus and minus	
	STANDARD WIDTHS—in.	
	24, 30, 36	48
0.016	0.0015	0.002
0.018, 0.020, 0.022, 0.025	0.002	0.0025
0.032	0.002	0.0025
0.040	0.0025	0.003
0.050, 0.063	0.003	0.004

TABLE 7.32 Width Tolerances—Flat Duct Sheet

STANDARD THICKNESS	TOLERANCE—in. plus and minus	
	STANDARD WIDTHS—in.	
	24, 30, 36	48
All	3⁄32	1⁄8

TABLE 7.33 Width Tolerances—Coiled Duct Sheet and Coiled Duct Sheet Cut to Length

STANDARD THICKNESS in.	TOLERANCE—in. plus and minus	
	STANDARD WIDTHS—in.	
	24	30, 36, 48
All	1⁄32	3⁄64

TABLE 7.34 Length Tolerances—Coiled Duct Sheet Cut to Length and Flat Duct Sheet

STANDARD LENGTH	STANDARD WIDTH	TOLERANCE, in.
All	All	±1⁄4

TABLE 7.35 Mechanical Property Limits ① for Tread Plate

ALLOY AND TEMPER	SPECIFIED THICKNESS ② in.	TENSILE STRENGTH—ksi				ELONGATION percent min. in 2 in. or 4D ③
		ULTIMATE		YIELD		
		min.	max.	min.	max.	
6061-O	0.100–0.128	. .	22.0	. .	12.0	16
	0.129–0.499	. .	22.0	. .	12.0	18
	0.500–0.625	. .	22.0	. .	. .	18
6061-T4	0.100–0.249	30.0	. .	16.0	. .	14
	0.250–0.625	30.0	. .	16.0	. .	16
6061-T42 ④	0.100–0.249	30.0	. .	14.0	. .	14
	0.250–0.625	30.0	. .	14.0	. .	16
6061-T6 and T62 ④	0.100–0.188	42.0	. .	35.0	. .	6
	0.189–0.249	42.0	. .	35.0	. .	8
	0.250–0.499	42.0	. .	35.0	. .	10
	0.500–0.625	42.0	. .	35.0	. .	9

① The data base and criteria upon which these mechanical property limits are established are outlined on page 6-1 under "Mechanical Properties."
② For sheet and plate under ½ inch in thickness, the standard ½-inch-wide tension test specimen is used. The raised figures of the pattern are machined off before testing.
③ D represents specimen diameter.
④ This temper is not available from the material producer. These properties can usually be obtained by the user, when the material is properly solution heat treated or solution and precipitation heat treated from the O (annealed) or F (as fabricated) temper. These properties also apply to samples of material in the O or F tempers that are solution heat treated or solution and precipitation treated by the producer to determine that the material will respond to proper heat treatment. Properties attained by the user, however, may be lower than those listed if the material has been formed or otherwise cold or hot worked, particularly in the annealed temper, prior to solution heat treatment.

TABLE 7.36 Weights per Square Foot—Tread Plate

The following nominal weights per square foot are based on alloy 6061, which has a density of 0.098 pounds per cubic inch:

THICKNESS in.	NOMINAL WEIGHT lb/sq. ft
0.100	1.55
0.125	1.90
0.156	2.34
0.188	2.79
0.250	3.67
0.375	5.43
0.500	7.20
0.625	8.96

TABLE 7.37 Thickness Tolerances—Tread Plate

Specified ① Thickness—in.	Tolerances—in.	
	Plus ②	Minus
0.100	0.008	0.012
0.125	0.010	0.015
0.156	0.011	0.019
0.188	0.013	0.023
0.250	0.018	0.030
0.375	0.025	0.045
0.500	0.035	0.060
0.625	0.044	0.075

① Specified thickness does not include height of pattern.
② In case of dispute, allowed plus tolerance shall be determined by weight. The allowed deviation from nominal weight shall not exceed plus 8 percent.

TABLE 7.38 Width Tolerances—Tread Plate

Allowable deviation from specified width: ±⅜ in.

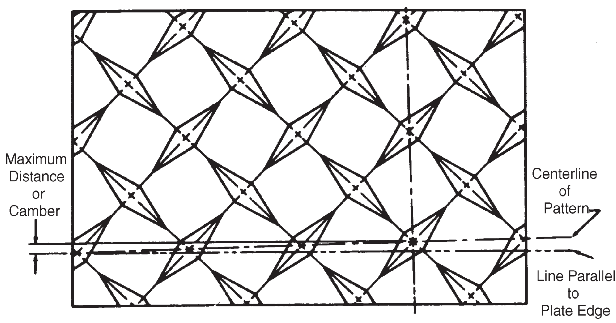
TABLE 7.39 Length Tolerances—Tread Plate

SPECIFIED LENGTH in.	TOLERANCE in.—plus
Up thru 144	⅜
Over 144 thru 240	7⁄16
Over 240	½

TABLE 7.40 Height of Pattern Tolerance—Tread Plate

Minimum height of raised pattern: 0.040 inch.
(Maximum height is controlled by weight tolerance.)

TABLE 7.41 Camber of Pattern Line ④ Tolerances—Tread Plate



SPECIFIED LENGTH in.	TOLERANCE—in.	
	SPECIFIED WIDTH—in.	
	Up thru 48	Over 48 thru 72
Up thru 24	1⁄8	1⁄8
Over 24 thru 72	1⁄2	1⁄2
Over 72 thru 144	3⁄4	1
Over 144	1	1 1⁄2

TABLE 7.42 Lateral Bow ③ Tolerances—Tread Plate

SPECIFIED WIDTH in.	TOLERANCE—IN.
	ALLOWABLE DEVIATION OF A SIDE EDGE FROM A STRAIGHT LINE
	SPECIFIED THICKNESS—in.
	0.100–0.625
Up thru 4	1 in any 10 ft.
Over 4 thru 72	1⁄8 in any 10 ft.

TABLE 7.43 Squareness Tolerances ⑤—Tread Plate

SPECIFIED LENGTH in.	TOLERANCE—in.
	ALLOWABLE DIFFERENCE IN LENGTH OF DIAGONALS
Up thru 144	3⁄8
Over 144 thru 240	7⁄16
Over 240	1⁄2

③ Applicable only to lengths up through 240 inches.
④ The camber of a pattern line is the maximum distance between the center of any figure in a pattern line and a line parallel with the edge of the plate that passes through the center of the figure in the same pattern line nearest to the edge of the floor plate.
⑤ Not resquared.

8. Fin Stock

Introduction

Section 8. of Aluminum Standards and Data covers the mechanical property limits and product dimensional tolerance limits for aluminum alloy fin stock. These limits are statistically based guaranteed limits, and may be used as the basis of design. Note that the limits applicable in any specific situation are those for the specific size of product ordered.

Product Property Limits for Aluminum Alloy Fin Stock

Table 8.1 on page 8-2 provides the specified aluminum industry property limits for aluminum alloy fin stock. Note that the product limits shown are statistically-based guaranteed limits, and are thus suitable for design.

Dimensional Tolerance Limits for Aluminum Alloy Fin Stock

Specific aluminum industry guaranteed dimensional tolerance limits for aluminum alloy fin stock are shown in Tables 8.2 and 8.3, as listed below:

Table 8.2 - Thickness Tolerances
Table 8.3 - Width and Lateral Bow Tolerances

Some general comments on the applicability and methods for calculating tolerances from these tables are given on p. 4-16 of Aluminum Standards and Data. For fin stock, it is appropriate to note that these published tolerance limits represent industry standards that are agreed to and capable of being met by all members of the industry. Thus they represent the maximum tolerances that can be provided by any producer; in no case should tolerance ranges larger than these values be provided.

In some cases, substantially tighter limits (i.e., smaller ranges of thickness, width and/or length) may be obtained from individual producers upon special order. In this regard, for example, it is broadly understood in the industry that it is possible to order fin stock from many suppliers to thickness tolerances that are one-half those in the limit Table 8.2.

For additional information of specific tolerance ranges available, contact producers directly.

Special Note: The applicable limits for any individual product are those that apply to the specified (ordered) dimension.

References to Other Fin Stock Information in Aluminum Standards And Data

TABLE 8.1 Mechanical Property Limits ① ④—Fin Stock

ALLOY AND TEMPER	SPECIFIED THICKNESS in.	TENSILE STRENGTH—ksi				ELONGATION percent min.	
		ULTIMATE		YIELD ②			
		min.	max.	min.	max	in 2 in.	in 5 in. ③
1100-O	0.005–0.019	11.0	15.5	3.5	. .	15	. .
	0.020–0.030	11.0	15.5	3.5	. .	20	. .
1100-H14	0.005–0.012	16.0	21.0	14.0	. .	1	. .
	0.013–0.019	16.0	21.0	14.0	. .	2	. .
	0.020–0.030	16.0	21.0	14.0	. .	3	. .
1100-H18	0.005–0.019	22.0	. .	. .	. .	1	. .
	0.020–0.030	22.0	. .	. .	. .	2	. .
1100-H19	0.005–0.019	24.0	. .	. .	. .	1	. .
1100-H25	0.005–0.019	17.5	23.5	14.5	. .	2	. .
	0.020–0.030	17.5	23.5	14.5	. .	3	. .
1100-H111, H211	0.005–0.012	12.0	17.0	7.0	. .	12	. .
1100-H113	0.005–0.012	11.0	16.0	5.0	. .	15	. .
1145-O	0.005–0.019	8.0	13.0	3.0	. .	15	. .
	0.020–0.030	8.0	13.0	3.0	. .	20	. .
1145-H14	0.005–0.012	14.0	19.0	11.0	. .	1	. .
	0.013–0.019	14.0	19.0	11.0	. .	2	. .
	0.020–0.030	14.0	19.0	11.0	. .	3	. .
1145-H19	0.005–0.019	20.0	. .	. .	. .	1	. .
1145-H25	0.005–0.019	15.0	21.0	11.0	. .	2	. .
	0.020–0.030	15.0	21.0	11.0	. .	3	. .
1145-H111, H211	0.005–0.012	9.0	14.0	5.0	. .	12	. .
1145-H113	0.005–0.012	8.0	14.0	4.0	. .	15	. .
3003-O	0.005–0.007	14.0	19.0	5.0	. .	14	. .
	0.008–0.012	14.0	19.0	5.0	. .	18	. .
	0.013–0.030	14.0	19.0	5.0	. .	20	. .
3003-H14	0.005–0.012	20.0	26.0	17.0	. .	1	. .
	0.013–0.019	20.0	26.0	17.0	. .	2	. .
	0.020–0.030	20.0	26.0	17.0	. .	3	. .
3003-H18	0.005–0.019	27.0	. .	24.0	. .	1	. .
	0.020–0.030	27.0	. .	24.0	. .	2	. .
3003-H19	0.005–0.019	29.0	. .	. .	. .	1	. .
3003-H25	0.005–0.019	22.0	29.0	18.0	. .	2	. .
	0.020–0.030	22.0	29.0	18.0	. .	3	. .
3003-H111, H211	0.005–0.012	15.0	20.0	9.0	. .	12	. .
3003-H113	0.005–0.012	14.0	20.0	6.5	. .	14	. .
7072-O	0.005–0.012	8.0	13.0	3.0	. .	15	. .
	0.013–0.030	8.0	13.0	3.0	. .	20	. .
7072-H12	0.005–0.030	11.0	16.0	8.0	. .	1	. .
7072-H14	0.005–0.012	14.0	19.0	12.0	. .	1	. .
	0.013–0.019	14.0	19.0	12.0	. .	2	. .
	0.020–0.030	14.0	19.0	12.0	. .	3	. .
7072-H16	0.005–0.030	17.0	22.0	. .	. .	1	. .
7072-H18	0.005–0.019	19.0	. .	. .	. .	1	. .
	0.020–0.030	19.0	. .	. .	. .	2	. .
7072-H19	0.005–0.019	21.0	. .	. .	. .	1	. .
7072-H23	0.004–0.007	13.0	19.0	8.0	15.0	17	14
7072-H24	0.004–0.007	14.0	19.0	11.0	17.0	17	14
7072-H241	0.004–0.007	13.5	19.5	10.0	17.0	15	12
7072-H25	0.005–0.019	15.5	21.5	12.0	. .	2	. .
	0.020–0.030	15.5	21.5	12.0	. .	3	. .
7072-H111, H211	0.005–0.012	9.0	14.0	6.0	. .	12	. .
7072-H113	0.005–0.012	8.0	14.0	4.0	. .	15	. .

① Mechanical test specimens are taken as detailed under “Sampling and Testing,” page 4-1.
② Yield strengths not determined unless specifically requested.
③ Tested in accordance with ASTM E345.
④ Processes such as flattening, leveling, or straightening coiled products subsequent to shipment by the producer may alter the mechanical properties of the metal (refer to Certification, page 4-1).

TABLE 8.2 Thickness Tolerances—Fin Stock

SPECIFIED THICKNESS in.	TOLERANCE in. plus and minus
0.004–0.0104	0.0005
0.0105–0.0169	0.001
0.017–0.030	0.0015

TABLE 8.3 Width and Lateral Bow Tolerances①—Fin Stock

Same as for coiled sheet.
See tables 7.11 and 7.12

Note: The Olsen Cup and similar tests frequently used as measures of formability are not sufficiently reproducible to permit the establishment of standards for acceptance or rejection of material. Cup test values, when used, are acceptable only as general guidelines for rating comparative formability.

① Tolerances for thicknesses of 0.004–0.0059 inch are the same as those specified for thickness of 0.006 inch.

9. Foil

Introduction

Section 9. of Aluminum Standards and Data covers the mechanical property limits and product dimensional tolerance limits for aluminum alloy foil. These limits are statistically based guaranteed limits, and may be used as the basis of design. Note that the limits applicable in any specific situation are those for the specific size of product ordered.

Product Property Limits for Aluminum Alloy Foil

Table 9.1 provides the specified aluminum industry mechanical property limits for aluminum alloy foil. Note that the product limits shown are statistically-based guaranteed limits, and are thus suitable for design.

Special Note: The applicable limits for any individual product are those that apply to the specified (ordered) dimension.

Dimensional Tolerance Limits for Aluminum Alloy Foil

Specific aluminum industry guaranteed tolerance limits for aluminum alloy sheet and plate are shown in Tables 9.2 through 9.24, as listed below:

Some general comments on the applicability and methods for calculating tolerances from these tables are given on p. 4-16 of Aluminum Standards and Data. For foil, it is appropriate to note that these published tolerance limits represent industry standards that are agreed to and capable of being met by all members of the industry. Thus they represent the maximum tolerances that can be provided by any producer; in no case should tolerance ranges larger than these values be provided.

In some cases, substantially tighter limits (i.e., smaller ranges of thickness, width and/or length) may be obtained from individual producers upon special order In this regard, for example, it is broadly understood in the industry that it may be possible to order foil from many suppliers to thickness tolerances that are one-half those in the limit tables.

For additional information of specific tolerance ranges available, contact producers directly.

References to Other Foil Information in Aluminum Standards and Data

TABLE 9.1 Mechanical Property Limits—Unmounted Foil ①

SPECIFIED THICKNESS in.	ALLOY AND TEMPER								
	1145 & 1235		1100		3003		5052		5056
	O	H19	O	H19	O	H19	O	H19	H19
	ULTIMATE TENSILE STRENGTH—ksi								
	max.	min.	max.	min.	max.	min.	max.	min.	min.
0.0007–0.0015	14.0	20.0	15.5	24.0	19.0	27.5	31.0	43.0	61.0
0.0016–0.0025	14.0	20.0	15.5	24.0	19.0	27.5	31.0	42.0	57.0
0.0026–0.0040	14.0	20.0	15.5	24.0	19.0	27.5	31.0	41.0	53.0
0.0041–0.0059	14.0	20.0	15.5	24.0	19.0	27.5	31.0	36.0	52.0

① See pages 4-4 and 4-5 for recommended test conditions and practices. The data base and criteria upon which these mechanical property limits are established are outlined on page 6-1 under "Mechanical Properties."

TABLE 9.2 Covering Area—Unmounted Foil

SPECIFIED THICKNESS in.	COVERING AREA—×10³ sq. in. per lb. ① ②			SPECIFIED THICKNESS in.	COVERING AREA—×10³ sq. in. per lb. ① ②		
	Nominal	Minimum ③	Maximum ③		Nominal	Minimum ③	Maximum ③
0.00017	60.3	54.8	67.0	0.00095	10.8	9.81	12.0
0.00020	51.3	46.6	57.0	0.0010	10.3	9.32	11.4
0.00025	41.0	37.3	45.6	0.0015	6.84	6.22	7.60
0.00030	34.2	31.1	38.0	0.0020	5.13	4.66	5.70
0.00035	29.3	26.6	32.6	0.0025	4.10	3.73	4.56
0.00040	25.6	23.3	28.5	0.0030	3.42	3.11	3.80
0.00045	22.8	20.7	25.3	0.0035	2.93	2.66	3.26
0.00050	20.5	18.6	22.8	0.0040	2.56	2.33	2.85
0.00055	18.6	17.0	20.7	0.0045	2.28	2.07	2.53
0.00060	17.1	15.5	19.0	0.0050	2.05	1.86	2.28
0.00065	15.8	14.3	17.5	0.0055	1.86	1.70	2.07
0.00070	14.7	13.3	16.3	0.0060	1.71	1.55	1.90
0.00075	13.7	12.4	15.2	0.0065	1.58	1.43	1.75
0.00080	12.8	11.7	14.2	0.0070	1.47	1.33	1.63
0.00085	12.1	11.0	13.4	0.0075	1.37	1.24	1.52
0.00090	11.4	10.4	12.7	0.0079	1.28	1.17	1.42

① The nominal covering area for 0.00017 inch thick foil is $60.3 \cdot 10^3$ or 60,300 sq. in. per lb.
② Based on a density of 0.0975 lb/cu in., the density of 1145 and 1235 aluminum. Covering area in sq. in./lb is calculated using the following formula:

$$\text{Covering Area} = \frac{1}{\text{thickness in in. x density in lb./in.}^3}$$

See Table 2.4 for other density values.
③ Based on the standard thickness tolerance of plus and minus 10% per roll or shipment.

TABLE 9.3 Roll Width—Unmounted Foil

SPECIFIED WIDTH in.	TOLERANCE—in. plus and minus	
	Unmounted Foil	Colored, Embossed and Coated Foil
Up thru 12	1/64	1/32
Over 12	1/32	1/32

TABLE 9.4 Inside Diameter—Core, Unmounted Foil

SPECIFIED INSIDE DIAMETER in.	TOLERANCE—in. plus and minus	
	Fiber Cores	Metal Cores
1 5/16	1/32	0.012
3.000	1/32	0.015

TABLE 9.5 Length and Width—Flat Sheets of Unmounted Foil

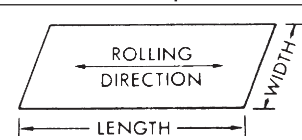
SPECIFIED LENGTH OR WIDTH in.	TOLERANCE—in. plus and minus
	
All	1/32

TABLE 9.6 Splices—① Unmounted Foil, Maximum Number Per Roll

ROLL DIAMETER in.	FOIL THICKNESS—in.			
	0.00035–0.001		Over 0.001	
	FOIL WIDTH—in.			
	Up thru 52½ ②	Over 52½	Up thru 52½ ②	Over 52½
Up thru 9½	3	4	1	1
Over 9½–13½	5	7	2	3
Over 13½–18	8	11	4	5
Over 18–22	10	13	6	7
Maximum Average Number Per Roll in Total Shipment				
Up thru 9½	2	2	½	½
Over 9½–13½	3	5	1	1
Over 13½–18	5	8	2	2
Over 18–22	7	10	3	4

① Standard splices are lap or butt made with foil or plastic tape. Other types are subject to special inquiry.

② Maximum for 90% of shipment: remainder will not exceed maximums listed for widths over 52½ inches.

TABLE 9.7 Coating Weights—Unmounted Foil

COATING TYPE	TOLERANCE percent plus and minus
Heat seal, Clear	20 or ¼ lb ①
Polyethylene	15
Elvax	30

① Whatever is greater.

TABLE 9.8 Quantity Tolerance—Unmounted Foil

SPECIFIED QUANTITY Per Item or Order	TOLERANCE percent plus and minus
All	10

LAMINATED FOIL

TABLE 9.9 Roll Width—Laminated Foil

SPECIFIED WIDTH in.	TOLERANCE—in. plus and minus	
	Laminated Foil	Colored, Embossed and Coated Foil
Up thru 12	1/64	1/32
Over 12	1/32	1/32

TABLE 9.10 Inside Diameter—Core, Laminated Foil

SPECIFIED INSIDE DIAMETER in.	TOLERANCE—in. plus and minus	
	Fiber Cores	Metal Cores
1 5/16	1/32	0.012
3.000	1/32	0.015

TABLE 9.11 Length and Width—Flat Sheets of Unmounted Foil

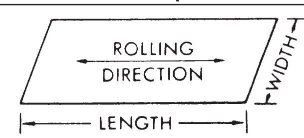
SPECIFIED LENGTH OR WIDTH in.	TOLERANCE—in. plus and minus
	
All	1/32

TABLE 9.12 Coating Weights—Laminated Foil

COATING TYPE	TOLERANCE percent plus and minus
Heat seal, Clear	20 or ¼ lb ①
Polyethylene	15
Elvax	30

① Whatever is greater.

TABLE 9.13 Covering Area (Yield)—Laminated Foil

NOMINAL COVERING AREA sq. in. per lb.	TOLERANCE ① percent plus and minus
All	10

① Average per roll or shipment.

TABLE 9.14 Adhesive Weight—Laminated Foil

ADHESIVE TYPE	TOLERANCE percent plus and minus
Solid Glue, Asphalt Thermoplastic	20 or ¼ lb ①
Wax	20
Polyethylene	15

① Whatever is greater.

TABLE 9.15 Paper Weight (Ream Basis) ①—Laminated Foail

PAPER TYPE ②	TOLERANCE percent plus and minus
All	5

① Standard ream is 500 sheets 24 in. · 36 in.
② Some papers may require a greater tolerance.

TABLE 9.16 Quantity Tolerance—Laminated Foil

SPECIFIED QUANTITY Per Item or Order	TOLERANCE percent plus and minus
All	10

PRINTED FOIL

TABLE 9.17 Border Width—Cut Labels

TYPE OF CUT	NOMINAL BORDER WIDTH in., min.
Rectangular Rhomboid or Die	⅛

TABLE 9.18 Overall Size—Cut Labels

SPECIFIED SIZE in.	TOLERANCE—in. plus and minus	
	Within a Shipment	Within a Pack
All	1/32	1/64

TABLE 9.19 Border Variation—Cut Labels

TYPE OF LABEL	TOLERANCE in. plus and minus
Unembossed or Full Embossed	1/32
Embossed to Register	3/64

TABLE 9.20 Width—Rolls

SPECIFIED WIDTH in.	TOLERANCE in. plus and minus
All	1/32

TABLE 9.21 Minimum Type Size—Rotogravure

TYPE	LINE CYLINDER	TONE OR PROCESS
Relief	4 point	6 point
Reverse	6 point	8 point

TABLE 9.22 Quantity Tolerance①

SPECIFIED QUANTITY Million Sq. Inches	TOLERANCE Percent
Up to 1	+100, –50
1 to 10	±40
10 to 20	±30
20 to 35	±20
35 to 50	±15
50 and over	±10

① For body and neck labels ordered in equal sets and produced on combination cylinders see Table 9.24 for additional tolerance.

TABLE 9.23 Covering Area (Yield)①

NOMINAL COVERING AREA sq. in. per lb.	TOLERANCE percent plus and minus
All	10

① Average per roll or shipment

TABLE 9.24 Quantity Variation Between Body and Neck Labels

When ordered in equal sets, the allowable deviation in the number of body and neck labels when produced on combination cylinders is 10 percent.

10. Wire, Rod and Bar—Rolled and Cold-finished

Introduction

Section 10. of Aluminum Standards and Data covers the mechanical property limits and product dimensional tolerance limits for aluminum alloy rolled or cold finished wire, rod and bar. These limits are statistically based guaranteed limits, and may be used as the basis of design. Note that the limits applicable in any specific situation are those for the specific size of product ordered.

Product Property Limits for Aluminum Alloy Wire, Rod and Bar—Rolled or Cold-finished

Tables 10.1 through 10.4 provide the specified aluminum industry mechanical property limits for rolled or cold-finished aluminum alloy wire, rod and bar, as follows:

Table 10.1 - Mechanical Property Limits - Wire, Rod and Bar - Rolled or Cold-Finished - Non-Heat-Treatable Alloys
Table 10.2 - Mechanical Property Limits - Wire, Rod and Bar - Rolled or Cold-Finished - Heat-Treatable Alloys
Table 10.3 - Mechanical Property Limits - Rivet and Cold Heading Wire and Rod
Table 10.3 - Mechanical Property Limits - Rivet and Cold Heading Wire and Rod after Heat Treatment

Note that the product limits shown are statistically-based guaranteed limits, and are thus suitable for design.

Special Note: The applicable limits for any individual product are those that apply to the specified (ordered) dimension.

Dimensional Tolerance Limits for Aluminum Alloy Wire, Rod And Bar

Specific aluminum industry guaranteed tolerance limits for aluminum alloy sheet and plate are shown in Tables 10.5 through 10.20, as listed below:

Table 10.5 - Diameter - Round Wire and Rod
Table 10.6 - Diameter - Centerless Ground Round Wire and Rod
Table 10.7 - Diameter - Rivet and Cold Heading Wire and Rod
Table 10.8 - Diameter - Drawing Stock
Table 10.9 - Thickness and Width - Rectangular Wire and Bar
Table 10.10 - Distance Across Flats - Square, Hexagonal, and Octagonal Wire and Bar
Table 10.11 - Thickness and Width - Flattened Wire (Round Edge)
Table 10.12 - Thickness and Width - Flattened and Slit Wire
Table 10.13 - Length - Specific and Multiple
Table 10.14 - Twist - Bar in Straight Lengths
Table 10.15 - Straightness - Rod and Bar in Straight Lengths, Other than Screw Machine Stock
Table 10.16 - Straightness - Screw Machine Stock
Table 10.17 - Flatness - Flat Surfaces
Table 10.18 - Angularity
Table 10.19 - Squareness of Saw Cuts
Table 10.20 - Corner Radii Bar

Some general comments on the applicability and methods for calculating tolerances from these tables are given on page 4-16 of Aluminum Standards and Data. For wire, rod and bar, it is appropriate to note that these published tolerance limits represent industry standards that are agreed to and capable of being met by all members of the industry. Thus they represent the maximum tolerances that can be provided by any producer; in no case should tolerance ranges larger than these values be provided.

In some cases, substantially tighter limits (i.e., smaller ranges of thickness, width and/or length) may be obtained from individual producers upon special order. In this regard, for example, it is broadly understood in the industry that it may be possible to order wire, rod and bar from many suppliers to dimensional tolerances that are one-half those in the limit tables.

For additional information of specific tolerance ranges available, contact producers directly.

References to Other Wire, Road and Bar Information in Aluminum Standards And Data

TABLE 10.1 Mechanical Property Limits—Wire, Rod and Bar—Rolled or Cold Finished—Non-Heat-Treatable Alloys ① ⑯

ALLOY AND TEMPER	SPECIFIED DIAMETER OR THICKNESS in.	TENSILE STRENGTH—ksi			ELONGATION ② percent min. in 2 in. or 4D ③
		ULTIMATE		YIELD ② ⑪	
		min.	max.		
1100					
1100-O	All	11.0	15.5	3.0	25
1100-H112	All	11.0	. .	3.0	. .
1100-H12	Up thru 0.374	14.0	. .	. .	. .
1100-H14	Up thru 0.374	16.0	. .	. .	. .
1100-H16	Up thru 0.374	19.0	. .	. .	. .
1100-H18	Up thru 0.374	22.0	. .	. .	. .
1100-F ⑫	0.375 and over	. .	. .	. .	. .
1345					
1345-O	Up thru 0.374	. .	14.0	. .	25
1345-H12	Up thru 0.374	13.0	. .	. .	. .
1345-H14	Up thru 0.314	15.0	. .	. .	. .
1345-H16	Up thru 0.314	17.0	. .	. .	. .
1345-H18	Up thru 0.314	19.0	. .	. .	. .
1345-H19	Up thru 0.204	21.0	. .	. .	. .
3003					
3003-O	All	14.0	19.0	5.0	25
3003-H112	All	14.0	. .	5.0	. .
3003-H12	Up thru 0.374	17.0	. .	. .	. .
3003-H14	Up thru 0.374	20.0	. .	. .	. .
3003-H16	Up thru 0.374	24.0	. .	. .	. .
3003-H18	Up thru 0.374	27.0	. .	. .	. .
3003-F ⑫	0.375 and over	. .	. .	. .	. .
5050					
5050-O	All	18.0	26.0	. .	25
5050-H32	Up thru 0.374	22.0	. .	. .	. .
5050-H34	Up thru 0.374	25.0	. .	. .	. .
5050-H36	Up thru 0.374	27.0	. .	. .	. .
5050-H38	Up thru 0.374	29.0	. .	. .	. .
5050-F ⑫	0.375 and over	. .	. .	. .	. .
5052					
5052-O	All	25.0	32.0	9.5	25
5052-H32	Up thru 0.374	31.0	. .	23.0	. .
5052-H34	Up thru 0.374	34.0	. .	26.0	. .
5052-H36	Up thru 0.374	37.0	. .	29.0	. .
5052-H38	Up thru 0.374	39.0	. .	. .	. .
5052-F ⑫	0.375 and over	. .	. .	. .	. .
5056					
5056-O	All	. .	46.0	. .	20
5056-H111	Up thru 0.374	44.0	. .	. .	. .
5056-H12	Up thru 0.374	46.0	. .	. .	. .
5056-H32	Up thru 0.374	44.0	. .	. .	. .
5056-H14	Up thru 0.374	52.0	. .	. .	. .
5056-H34	Up thru 0.374	50.0	. .	. .	. .
5056-H18	Up thru 0.374	58.0	. .	. .	. .
5056-H38	Up thru 0.374	55.0	. .	. .	. .
5056-H192	Up thru 0.374	60.0	. .	. .	. .
5056-H392	Up thru 0.374	58.0	. .	. .	. .
5056-F ⑫	0.375 and over	. .	. .	. .	. .
5154					
5154-O	All	30.0	41.0	11.0	25
5154-H112	All	30.0	41.0	11.0	. .
5154-H32	Up thru 0.374	36.0	. .	. .	. .
5154-H34	Up thru 0.374	39.0	. .	. .	. .
5154-H36	Up thru 0.374	42.0	. .	. .	. .
5154-H38	Up thru 0.374	45.0	. .	. .	. .
5154-F ⑫	0.375 and over	. .	. .	. .	. .

For all numbered footnotes, see page 10-4.

Footnotes Tables 10.1 through 10.4

① Mechanical test specimens are taken as detailed under "Sampling and Testing," page 4-1. The data base and criteria upon which these mechanical property limits are established are outlined on page 6-1 under "Mechanical Properties."

② The measurement of elongation and yield strength is not required for wire less than 0.125 inch in thickness or diameter.

③ D represents specimen diameter.

④ Properties listed for this full size increment are applicable to rod. Properties listed are only applicable for square, rectangular, hexagonal or octagonal bar having a maximum thickness of 4 in. and a maximum cross-sectional area of 36 square inches.

⑤ Properties listed for this full size increment are applicable to rod. Properties listed are only applicable for square, hexagonal or octagonal bar having a maximum thickness of 3½ inches; for rectangular bar having a maximum thickness of 3 inches with corresponding maximum width of 6 inches. For rectangular bar less than 3 inches in thickness, maximum width is 10 inches.

⑥ For bar maximum cross-sectional area is 50 square inches.

⑦ Rivet and cold heading wire and rod, and the fasteners produced from it, shall upon proper heat treatment (T4 and T42 tempers) or heat treatment and aging (T6, T61, T7 and T73 tempers) be capable of developing the properties presented in Table 10.4. Tensile tests are preferred for the rivet and cold heading wire and rod, and shear tests for the fasteners made from it.

⑧ For stress-relieved tempers the characteristics and properties other than those specified may differ somewhat from the corresponding characteristics and properties of material in the basic temper.

⑨ Material in this temper, 0.750 inch and thicker, when tested in accordance with ASTM G47 in the short transverse direction at a stress level of 75 percent of the specified minimum yield strength, will exhibit no evidence of stress corrosion cracking. Capability of individual lots to resist stress corrosion is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined on pages 6-7 and 6-8.

⑩ These properties can usually be obtained by the user when the material is properly solution heat treated or solution and precipitation heat treated from the O (annealed) or F (as fabricated) temper. These properties also apply to samples of material in the O or F tempers that are solution heat treated or solution and precipitation treated by the producer to determine that the material will respond to proper heat treatment. Properties attained by the user, however, may be lower than those listed if the material has been formed or otherwise cold or hot worked, particularly in the annealed temper, prior to solution heat treatment.

⑪ These yield strengths determined only when specifically requested.

⑫ Except in the annealed (O temper) condition, the temper of nonheat-treatable alloy rod and bar cannot be closely controlled and will vary according to size.

⑬ Minimum yield strength for 2024-T4 wire and rod, produced in coil form for both straight length and colied products, is 40.0 ksi.

⑭ Applicable to rod only.

⑮ This temper is not available from the material producer.

⑯ Processes such as flattening, leveling, or straightening coiled products subsequent to shipment by the producer may alter the mechanical properties of the metal (refer to Certification Documentation, page 4-12).

TABLE 10.2 Mechanical Property Limits—Wire, Rod and Bar—Rolled or Cold Finished—Heat-Treatable Alloys ① ⑯

ALLOY AND TEMPER	SPECIFIED DIAMETER OR THICKNESS OR MINIMUM DISTANCE ACROSS FLATS in.	TENSILE STRENGTH—ksi			ELONGATION ② percent min. in 2 in. or 4D ③
		ULTIMATE		YIELD ②	
		min.	max.		
2011					
2011-T3	0.125–1.500	45.0	. .	38.0	10
	1.501–2.000	43.0	. .	34.0	12
	2.001–3.500	42.0	. .	30.0	12
2011-T4 and T451 ⑧	0.375–8.000	40.0	. .	18.0	16
2011-T8	0.125–3.250	54.0	. .	40.0	10
2014					
2014-O	Up thru 8.000	. .	35.0	. .	12
2014-T4, T42 ⑩ ⑮ and T451 ⑧	Up thru 8.000 ④	55.0	. .	32.0	16
2014-T6, T62 ⑩ ⑮ and T651 ⑧	Up thru 8.000 ④	65.0	. .	55.0	8
2017					
2017-O	Up thru 8.000	. .	35.0	. .	16
2017-T4, T42 ⑩ ⑮ and T451 ⑧	Up thru 8.000 ⑥	55.0	. .	32.0	12
2024					
2024-O	Up thru 8.000	. .	35.0	. .	16
2024-T36	Up thru 0.375	69.0	. .	52.0	10
2024-T4	Up thru 0.499	62.0	. .	45.0 ⑬	10
	0.500–4.500 ④	62.0	. .	42.0 ⑬	10
	4.501–6.500 ⑭	62.0	. .	40.0	10
	6.501–8.000 ⑭	58.0	. .	38.0	10
2024-T42 ⑩ ⑮	Up thru 0.124	62.0	. .	. .	. .
	0.125–1.000	62.0	. .	40.0	10
	1.001–6.500 ④	62.0	. .	40.0	10
2024-T351	0.500–6.500 ④	62.0	. .	45.0	10
2024-T6	Up thru 6.500 ④	62.0	. .	50.0	5
2024-T62 ⑩ ⑮	Up thru 6.500 ④	60.0	. .	46.0	5
2024-T851	0.500–6.500 ④	66.0	. .	58.0	5
2219					
2219-T851	0.500–2.000	58.0	. .	40.0	4
	2.001–4.000	57.0	. .	39.0	4
6061					
6061-O	Up thru 8.000	. .	22.0	. .	18
6061-T4 and T451 ⑧	Up thru 8.000 ⑥	30.0	. .	16.0	18
6061-T42 ⑩ ⑮	Up thru 8.000 ⑥	30.0	. .	14.0	18
6061-T6, T62 ⑩ ⑮ and T651 ⑧	Up thru 8.000 ⑥	42.0	. .	35.0	10
6061-T89	Up thru 0.374	54.0	. .	47.0	. .
6061-T913	Up thru 0.374	63.0	. .	. .	. .
6061-T94	Up thru 0.374	54.0	. .	47.0	. .
6262					
6262-T6 and T651 ⑧	Up thru 8.000 ④	42.0	. .	35.0	10
6262-T9	0.125–2.000	52.0	. .	48.0	5
	2.001–3.000	50.0	. .	46.0	5
7075					
7075-O	Up thru 8.000	. .	40.0	. .	10
7075-T6 and T62 ⑩ ⑮	Up thru 4.000 ⑤	77.0	. .	66.0	7
7075-T651 ⑧	Up thru 4.000 ⑤	77.0	. .	66.0	7
	4.001–6.000	75.0	. .	64.0	7
	6.001–7.000	73.0	. .	62.0	7
7075-T73 ⑨ and T7351 ⑧ ⑨	Up thru 4.000	68.0	. .	56.0	10
	4.001–5.000	66.0	. .	55.0	8
	5.001–6.000	64.0	. .	52.0	8

For all numbered footnotes, see page 10-4.

TABLE 10.3 Rivet and Cold Heading Wire and Rod ① ⑦ ⑯

ALLOY AND TEMPER	SPECIFIED DIAMETER in.	ULTIMATE STRENGTH ksi	
		min.	max.
1100-O	Up thru 1.000	. .	15.5
1100-H14, H24	Up thru 1.000	16.0	21.0
2017-O	Up thru 1.000	. .	35.0
2017-H13, H23	Up thru 1.000	30.0	40.0
2024-O	Up thru 1.000	. .	35.0
2024-H13, H23	Up thru 1.000	32.0	42.0
2117-O	Up thru 1.000	. .	25.0
2117-H15, H25	Up thru 1.000	28.0	35.0
2117-H13, H23	Up thru 1.000	25.0	32.0
2219-O	Up thru 1.000	. .	32.0
2219-H13, H23	Up thru 1.000	28.0	38.0
3003-O	Up thru 1.000	. .	19.0
3003-H14, H24	Up thru 1.000	20.0	26.0
5005-O	Up thru 1.000	. .	20.0
5005-H22, H32	Up thru 1.000	17.0	23.0
5052-O	Up thru 1.000	. .	32.0
5052-H22, H32	Up thru 1.000	31.0	37.0
5056-O	Up thru 1.000	. .	46.0
5056-H22, H32	Up thru 1.000	44.0	52.0
6053-O	Up thru 1.000	. .	19.0
6053-H13, H23	Up thru 1.000	19.0	26.0
6061-O	Up thru 1.000	. .	22.0
6061-H13, H23	Up thru 1.000	22.0	30.0
7050-H13	Up thru 1.000	34.0	44.0
7075-O	Up thru 1.000	. .	40.0
7075-H13, H23	Up thru 1.000	36.0	46.0
7178-O	Up thru 1.000	. .	40.0
7178-H13	Up thru 1.000	36.0	46.0

Computation of Weight Per Foot

Weight per foot in pounds of wire, rod and bar may be computed by determining the cross-sectional area in square inches and multiplying this by 12 (inches in one foot) and by the density of the alloy in pounds per cubic inch. Values of the latter for the various alloys are given on page 2-14.

Examples:

1. Alloy 2011 rod 0.375 in. in diameter:

   Cross-sectional area $= \frac{\pi(0.375)^2}{4}$

   = 0.1104 sq. in.

   Density of alloy 2011 = 0.102 lb. per cu. in.

   Weight per foot = 0.1104 · 12 · 0.102

   = 0.135 lb.

2. Alloy 6061 square bar 0.5 in. wide:

   Cross-sectional area = 0.5 · 0.5 = 0.25 sq. in.

   Density of alloy 6061 = 0.098 lb. per cu. in.

   Weight per foot = 0.25 · 12 · 0.098

   = 0.294 lb.

3. Alloy 2017 rectangular bar 0.5 in. by 1.0 in.:

   Cross-sectional area = 0.5 · 1.0 = 0.5 sq. in.

   Density of alloy 2017 = 0.101 lb. per cu. in.

   Weight per foot = 0.5 · 12 · 0.101

   = 0.606 lb.

4. Alloy 6262 hexagonal bar 0.750 in. across flats:

   Cross-sectional area = 0.8660 (0.750)2

   = 0.4871 sq. in.

   Density of alloy 6262 = 0.098 lb. per cu. in.

   Weight per foot = 0.4871 · 12 · 0.098

   = 0.573 lb.

TABLE 10.4 Mechanical Property Limits for Rivet and Cold Heading Wire ⑦

ALLOY AND TEMPER	SPECIFIED DIAMETER in.	TENSILE STRENGTH ksi min.		ELONGATION ② percent min. in. 2 in. or 4D ③	ULTIMATE SHEARING STRENGTH ksi min.
		ULTIMATE	YIELD ②		
2017-T4	0.063–1.000	55.0	32.0	12	33.0
2024-T42	0.063–0.124	62.0	. .	. .	37.0
	0.125–1.000	62.0	40.0	10	37.0
2117-T4	0.063–1.000	38.0	18.0	18	26.0
2219-T6	0.063–1.000	55.0	35.0	6	30.0
6053-T61	0.063–1.000	30.0	20.0	14	20.0
6061-T6	0.063–1.000	42.0	35.0	10	25.0
7050-T7	0.063–1.000	70.0	58.0	10	39.0
7075-T6	0.063–1.000	77.0	66.0	7	42.0
7075-T73	0.063–1.000	68.0	56.0	10	41.0
7178-T6	0.063–1.000	84.0	73.0	5	46.0

For all numbered footnotes, see page 10-4.

TABLE 10.5 Diameter—Round Wire and Rod

SPECIFIED DIAMETER in.	TOLERANCE—in. plus and minus Except as noted — ALLOWABLE DEVIATION FROM SPECIFICED DIAMETER			
	Drawn Wire	Cold Finished Rod	Rolled Rod	
			Plus	Minus
Up thru 0.035	.0005	. . .	. . .	. . .
0.036–0.064	.001	. . .	. . .	. . .
0.065–0.374	.0015	. . .	. . .	. . .
0.375–0.500	. . .	.0015	.020	.020
0.501–1.000	. . .	.002	.025	.025
1.001–1.500	. . .	.0025	. . .	. . .
1.501–2.000	. . .	.004	. . .	. . .
2.001–3.000	. . .	.006	. . .	. . .
3.001–3.499	. . .	.008	. . .	. . .
3.500–5.000	. . .	.012	. . .	. . .
5.001–6.000	. . .	.020	. . .	. . .
6.001–7.000	. . .	.025	. . .	. . .
7.001–8.000	. . .	.030	. . .	. . .

TABLE 10.6 Diameter—Centerless Ground Round Wire and Rod

SPECIFIED DIAMETER in.	TOLERANCE in. plus and minus — ALLOWABLE DEVIATION FROM SPECIFIED DIAMETER
0.125–0.625	.0005
0.626–1.500	.0010
1.501–2.000	.0025

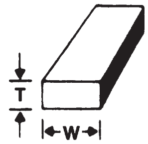
TABLE 10.7 Diameter—Rivet and Cold Heading Wire and Rod

SPECIFIED DIAMETER in.	TOLERANCE — ALLOWABLE DEVIATION FROM SPECIFIED DIAMETER			
	Rivet Wire		Rivet Rod	
	in. plus	in. minus	in. plus	in. minus
Up thru 0.061	.0005	.0005	. . .	. . .
0.062–0.123	.001	.0005	. . .	. . .
0.124–0.154	.001	.001	. . .	. . .
0.155–0.374	.002	.001	. . .	. . .
0.375–0.500	. . .	. . .	.002	.001
0.501–1.000	. . .	. . .	.003	.001

TABLE 10.8 Diameter—Drawing Stock

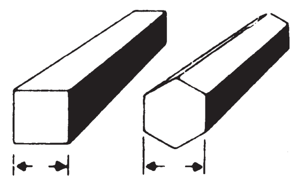
SPECIFIED DIAMETER in.	TOLERANCE—in. plus and minus — ALLOWABLE DEVIATION FROM SPECIFIED DIAMETER
0.375–0.500	.020
0.501–1.000	.025

TABLE 10.9 Thickness and Width—Rectangular Wire and Bar



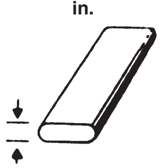
SPECIFIED THICKNESS OR WIDTH in.	TOLERANCE in. plus and minus — ALLOWABLE DEVIATION FROM SPECIFIED THICKNESS AND WIDTH			
	Drawn Wire and Cold Finished Bar		Rolled Bar	
	Thickness	Width	Thickness	Width
Up thru 0.035	.001	. .	. .	. .
0.036–0.064	.0015	. .	. .	. .
0.065–0.500	.002	.002	.006	. .
0.501–0.750	.0025	.0025	.008	.016
0.751–1.000	.0025	.0025	.012	.016
1.001–1.500	.003	.003	.016	.016
1.501–2.000	.005	.003	.016	.031
2.001–3.000	.008	.008	.020	.031
3.001–4.000	. .	.010	.020	.031
4.001–6.000	. .	. .	. .	.047
6.001–10.000	. .	. .	. .	.062

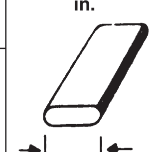
TABLE 10.10 Distance across Flats—Square, Hexagonal and Octagonal Wire and Bar



SPECIFIED DISTANCE ACROSS FLATS in.	TOLERANCE in. plus and minus — ALLOWABLE DEVIATION FROM SPECIFIED DISTANCE ACROSS FLATS		
	Drawn Wire	Cold Finished Bar	Rolled Bar
Up thru 0.035	.001	. .	. .
0.036–0.064	.0015	. .	. .
0.065–0.374	.002	. .	. .
0.375–0.500	. .	.002	. .
0.501–1.000	. .	.0025	. .
1.001–1.500	. .	.003	. .
1.501–2.000	. .	.005	.016
2.001–3.000	. .	.008	.020
3.001–4.000	. .	. .	.020

TABLE 10.11 Thickness and Width—Flattened Wire (Round Edge)





SPECIFIED THICKNESS in.	TOLERANCE in. plus and minus — ALLOWABLE DEVIATION FROM SPECIFIED THICKNESS	SPECIFIED WIDTH in.	TOLERANCE in. plus and minus — ALLOWABLE DEVIATION FROM SPECIFIED THICKNESS
Up thru 0.020	.001	Up thru 0.875	.007
0.021–0.060	.0015	0.876–2.000	.010
0.061–0.187	.002		

TABLE 10.12 Thickness and Width—Flattened and Slit Wire

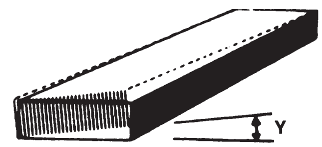
SPECIFIED THICKNESS in.	TOLERANCE in. plus and minus — ALLOWABLE DEVIATION FROM SPECIFIED THICKNESS	SPECIFIED WIDTH in.	TOLERANCE in. plus and minus — ALLOWABLE DEVIATION FROM SPECIFIED WIDTH
0.018–0.020	0.001	0.500–0.625	0.0025
0.021–0.060	0.0015	0.626–1.500	0.004
0.061–0.080	0.002	1.501–4.750	0.006

TABLE 10.13 Length—Specific and Multiple—Rolled or Cold Finished Wire, Rod, and Bar

SPECIFIED DIAMETER, WIDTH OR DISTANCE ACROSS FLATS in.	TOLERANCE ⑤—in. plus — ALLOWABLE DEVIATION FROM SPECIFIED LENGTH — SPECIFIED LENGTH—ft.			
	Up thru 12	Over 12 thru 30	Over 30 thru 50	Over 50
Up thru 2.999	⅛	¼	⅜	1
3.000–7.999	3⁄16	5⁄16	7⁄16	1
8.000 and over	¼	⅜	½	1

TABLE 10.14 Twist④—Rolled or Cold Finished Bar and Straight Lengths

PRODUCT	TEMPER	SPECIFIED WIDTH (RECTANGLES): SPECIFIED DISTANCE ACROSS FLATS: (SQUARES, HEXAGONS AND OCTAGONS) in.	TOLERANCE ① ③—DEGREES — ALLOWABLE DEVIATION FROM STRAIGHT — Y (max.) in degrees — IN TOTAL LENGTH OR IN ANY MEASURED SEGMENT OF ONE FT. OR MORE OF TOTAL LENGTH	MAXIMUM FOR TOTAL LENGTH
Square, Rectangular and Octagonal Bar	All except O and TX51 ②	Up thru 1.499	1 · Measured length, ft	7
		1.500–2.999	½ · Measured length, ft	5
		3.000 and over	¼ · Measured length, ft	3
	TX51 ②	0.500–2.999	1½ · Measured length, ft	7
		3.000 and over	½ · Measured length, ft	5
Hexagonal Bar	All except O	Up thru 1.499	1 · Measured length, ft	7
		1.500–2.999	½ · Measured length, ft	5
		3.000 and over	¼ · Measured length, ft	3



① For TX51 tempers, tolerance is applicable only to thicknesses of 0.500 in. and over.
② TX51 is a general designation for the following stress-relieved tempers: T351, T451, T651, T851, and T7351.
③ When weight of piece on flat surface minimizes deviation.
④ Twist is normally measured by placing the bar on a flat surface and at any point along its length measuring the maximum distance between the bottom surface of the bar and the flat surface. From this measurement, the actual deviation from straightness of the bar at that point is subtracted. The remainder is the twist. To convert the standard twist tolerance (degrees) to an equivalent linear value, the sine of the standard tolerance is multiplied by the width of the surface of the section that is on the flat surface. The following values are used to convert angular tolerances to linear deviation:

Tolerance, degrees	Maximum allowable linear deviation inch per inch of width
¼	0.004
½	0.009
1	0.017
1½	0.026
3	0.052
5	0.087
7	0.122
9	0.156
15	0.259
21	0.358

⑤ For wire, rod and bar ordered as standard screw machine stock, the length tolerance is plus ⅜ in.

TABLE 10.15 Straightness—Rolled or Cold Finished Rod and Bar in Straight Lengths Other than Screw Machine Stock

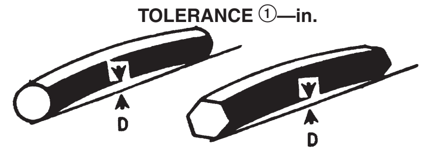
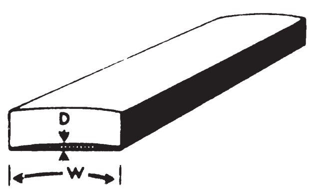
PRODUCT	TEMPER	SPECIFIED DIAMETER (ROD): SPECIFIED DISTANCE ACROSS FLATS: (SQUARES, HEXAGONS AND OCTAGONS) SPECIFIED THICKNESS (RECTANGLES) in.	TOLERANCE ①—in.  IN TOTAL LENGTH OR IN ANY MEASURED SEGMENT OF ONE FT. OR MORE OF TOTAL LENGTH
ROLLED			
Rod and Hexagonal, Square, Rectangular and Octagonal Bar	All except O	All	0.050 · Measured length, ft.
COLD FINISHED			
Rod and Hexagonal Bar	All except O and TX51 ②	All	0.025 · Measured length, ft.
	TX51 ②	0.500 and over	0.025 · Measured length, ft.
Square, Rectangular and Octagonal Bar	All except O and TX51 ②	All	0.025 · Measured length, ft.
	TX51 ②	0.500 and over	0.050 · Measured length, ft.

TABLE 10.16 Straightness—Screw Machine Stock

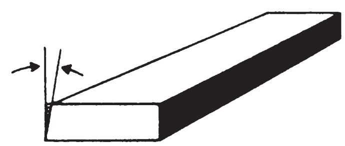
SPECIFIED DIAMETER, (ROD); SPECIFIED DISTANCE ACROSS FLATS (HEXAGONAL BAR) in.	TEMPER	TOLERANCE ① in. ALLOWABLE DEVIATION FROM STRAIGHT	
		In any foot or less of length	In 12 feet
All	All Except TX51 ②	0.0125	0.100
0.500 and over	TX51 ②	0.0125	0.100

TABLE 10.17 Flatness—Flat Surfaces—Rolled or Cold Finished Rod and Bar

SURFACE WIDTH in.	TOLERANCE, in.  Maximum Allowable Deviation D
Up thru 1	0.004
Over 1	0.004 · W (inches)
In any 1 in. of width	0.004

① When weight of piece on flat surface minimizes deviation.
② TX51 is a general designation for the following stress-relieved tempers: T351, T451, T851, and T7351.

TABLE 10.18 Angularity—Rolled or Cold Finished Rod and Bar



Allowable deviation from nominal angle: ±1 degree

TABLE 10.19 Squareness of Saw Cuts—Rolled or Cold Finished Rod and Bar

Allowable deviation from square: 1 degree

TABLE 10.20 Corner Radii Bar—Rolled or Cold Finished Rod and Bar

Thickness, inches	Corner Radii inches, max.
Up thru 0.500	0.016
0.501–2.000	0.032
2.001 and thicker	0.050

11. Wire, Rod, Bar and Profiles — Extruded

Introduction

Section 11. of Aluminum Standards and Data covers the mechanical property limits and product dimensional tolerances for aluminum alloy extruded wire, rod, bar, and profiles.

Mechanical Property Limits for Aluminum Alloy Wire, Rod, Bar and Profiles — Extruded

Table 11.1 provides the specified aluminum industry mechanical property limits for extruded aluminum alloy wire, rod, bar, and profiles. Note that the limits shown are statistically-based guaranteed limits, and are thus suitable for design.

Special Note: The applicable limits for any individual product are those that apply to the specified (ordered) dimension.

Dimensional Tolerances for Aluminum Alloy Wire, Rod, Bar and Profiles — Extruded

Specific aluminum industry tolerances for aluminum alloy extruded wire, rod, bar and profiles are shown in Tables 11.2 through 11.14, as listed below:

Table 11.2, 3 and 4 - Cross-Sectional Dimension Tolerances
Table 11.5 - Length
Table 11.6 - Straightness
Table 11.7 - Twist
Table 11.8 - Flatness (Flat Surfaces) - Bar, Solid and Semihollow Profiles
Table 11.9 - Flatness (Flat Surfaces) - Hollow Profiles
Table 11.10 - Surface Roughness
Table 11.11 - Contour (Curved Surfaces)
Table 11.12 - Squareness of Cut Ends
Table 11.13 - Corner and Fillet Radii
Table 11.14 - Angularity

Some general comments on the applicability and methods for calculating tolerances from these tables are given on page 4-16 of Aluminum Standards and Data. Precision tolerances may be obtained from individual producers upon request. Aggressive profile characteristics may require wider than standard tolerances. In other cases, substantially tighter tolerances can be achieved.

For additional information of specific tolerances available, contact producers directly.

References to other Wire, Rod, Bar and Profiles — Extruded information found in Aluminum Standards and Data

TABLE 11.1 Mechanical Property Limits—Extruded Wire, Rod, Bar and Profiles ⑥

ALLOY AND TEMPER	SPECIFIED DIAMETER OR THICKNESS ① OR MINIMUM DISTANCE ACROSS FLATS in.	AREA sq. in.	TENSILE STRENGTH—ksi ULTIMATE min.	TENSILE STRENGTH—ksi ULTIMATE max.	TENSILE STRENGTH—ksi YIELD min.	TENSILE STRENGTH—ksi YIELD max.	ELONGATION ② percent min. in 2 in. or 4D ③
1100							
1100-O	All	All	11.0	15.5	3.0	..	25
1100-H112	All	All	11.0	..	3.0	..	..
2014							
2014-O	All	All	..	30.0	..	18.0	12
2014-T4, T4510 ⑤ ⑦ and T4511 ⑤ ⑦	All	All	50.0	..	35.0	..	12
2014-T42 ④ ⑧	All	All	50.0	..	29.0	..	12
2014-T6, T6510 ⑤ and T6511 ⑤	Up thru 0.499	All	60.0	..	53.0	..	7
	0.500–0.749	All	64.0	..	58.0	..	7
	0.750 and over	Up thru 25	68.0	..	60.0	..	7
	0.750 and over	Over 25 thru 32	68.0	..	58.0	..	6
2014-T62 ④ ⑧	Up thru 0.749	All	60.0	..	53.0	..	7
	0.750 and over	Up Thru 25	60.0	..	53.0	..	7
	0.750 and over	Over 25 thru 32	60.0	..	53.0	..	6
2024							
2024-O	All	All	..	35.0	..	19.0	12
2024-T3, T3510 ⑤ ⑦ and T3511 ⑤ ⑦	Up thru 0.249	All	57.0	..	42.0	..	12
	0.250–0.749	All	60.0	..	44.0	..	12
	0.750–1.499	All	65.0	..	46.0	..	10
	1.500 and over	Up thru 25	70.0	..	52.0	..	10
	1.500 and over	Over 25 thru 32	68.0	..	48.0	..	8
2024-T42 ④ ⑧	Up thru 0.749	All	57.0	..	38.0	..	12
	0.750–1.499	All	57.0	..	38.0	..	10
	1.500 and over	Up thru 25	57.0	..	38.0	..	10
	1.500 and over	Over 25 thru 32	57.0	..	38.0	..	8
2024-T81, T8510 ⑤ and T8511 ⑤	0.050–0.249	All	64.0	..	56.0	..	4
	0.250–1.499	All	66.0	..	58.0	..	5
	1.500 and over	Up thru 32	66.0	..	58.0	..	5
2219							
2219-O	All	All	..	32.0	..	18.0	12
2219-T31, T3510 ⑤ ⑦ and T3511 ⑤ ⑦	Up thru 0.499	Up thru 25	42.0	..	26.0	..	14
	0.500–2.999	Up thru 25	45.0	..	27.0	..	14
2219-T62 ④ ⑧	Up thru 0.999	Up thru 25	54.0	..	36.0	..	6
	1.000 and over	Up thru 32	54.0	..	36.0	..	6
2219-T81, T8510 ⑤ and T8511 ⑤	Up thru 2.999	Up thru 25	58.0	..	42.0	..	6
3003							
3003-O	All	All	14.0	19.0	5.0	..	25
3003-H112	All	All	14.0	..	5.0	..	..
5083							
5083-O	Up thru 5.000	Up thru 32	39.0	51.0	16.0	..	14
5083-H111	Up thru 5.000	Up thru 32	40.0	..	24.0	..	12
5083-H112	Up thru 5.000	Up thru 32	39.0	..	16.0	..	12
5086							
5086-O	Up thru 5.000	Up thru 32	35.0	46.0	14.0	..	14
5086-H111	Up thru 5.000	Up thru 32	36.0	..	21.0	..	12
5086-H112	Up thru 5.000	Up thru 32	35.0	..	14.0	..	12
5154							
5154-O	All	All	30.0	41.0	11.0	..	..
5154-H112	All	All	30.0	..	11.0	..	..
5454							
5454-O	Up thru 5.000	Up thru 32	31.0	41.0	12.0	..	14
5454-H111	Up thru 5.000	Up thru 32	33.0	..	19.0	..	12
5454-H112	Up thru 5.000	Up thru 32	31.0	..	12.0	..	12
6005							
6005-T1	Up thru 0.500	All	25.0	..	15.0	..	16
6005-T5	Up thru 0.124	All	38.0	..	35.0	..	8
	0.125–1.000	All	38.0	..	35.0	..	10

For all numbered footnotes, see page 11-5.

TABLE 11.1 Mechanical Property Limits—Extruded Wire, Rod, Bar and Profiles ⑥ (continued)

ALLOY AND TEMPER	SPECIFIED DIAMETER OR THICKNESS ① OR MINIMUM DISTANCE ACROSS FLATS in.	AREA sq. in.	TENSILE STRENGTH—ksi ULTIMATE		YIELD		ELONGATION ② percent min. in 2 in. or 4D ③
			min.	max.	min.	max.	
6005A							
6005A-T1	Up thru 0.249	All	25.0	. .	14.5	. .	15
6005A-T5	Up thru 0.249	All	38.0	. .	31.0	. .	7
	0.250-0.999	All	38.0	. .	31.0	. .	9
6005A-T61	Up thru 0.249	All	38.0	. .	35.0	. .	8
	0.250-1.000	All	38.0	. .	35.0	. .	10
6061							
6061-O	All	All	. .	22.0	. .	16.0	16
6061-T1	Up thru 0.625	All	26.0	. .	14.0	. .	16
6061-T4, T4510 ⑤ ⑦ and T4511 ⑤⑦	All	All	26.0	. .	16.0	. .	16
6061-T42 ④ ⑧	All	All	26.0	. .	12.0	. .	16
6061-T51	Up thru 0.625	All	35.0	. .	30.0	. .	8
6061-T6, T62 ④ ⑧, T6510 ⑤	Up thru 0.249	All	38.0	. .	35.0	. .	8
andT6511 ⑤	0.250 and over	All	38.0	. .	35.0	. .	10
6063							
6063-O	All	. .	. .	19.0	. .		18
6063-T1	Up thru 0.500	All	17.0	. .	9.0	. .	12
	0.501–1.000	All	16.0	. .	8.0	. .	12
6063-T4 and T42 ④ ⑧	Up thru 0.500	All	19.0	. .	10.0	. .	14
	0.501–1.000	All	18.0	. .	9.0	. .	14
6063-T5	Up thru 0.500	All	22.0	. .	16.0	. .	8
	0.501–1.000	All	21.0	. .	15.0	. .	8
6063-T52 ⑭	Up thru 1.000	All	22.0	30.0	16.0	25.0	8
6063-T6 and T62 ④ ⑧	Up thru 0.124	All	30.0	. .	25.0	. .	8
	0.125–1.000	All	30.0	. .	25.0	. .	10
6066							
6066-O	All	All	. .	29.0	. .	18.0	16
6066-T4, T4510 ⑤ ⑦ and T4511 ⑤ ⑦	All	All	40.0	. .	25.0	. .	14
6066-T42 ④ ⑧	All	All	40.0	. .	24.0	. .	14
6066-T6, T6510 ⑤ and T6511 ⑤	All	All	50.0	. .	45.0	. .	8
6066-T62 ④ ⑧	All	All	50.0	. .	42.0	. .	8
6070							
6070-T6 and T62 ④ ⑧	Up thru 2.999	Up thru 32	48.0	. .	45.0	. .	6
6082							
6082-T6, T6511	0.200-0.750	All	45.0	. .	38.0	. .	6
	0.751-6.000	All	45.0	. .	38.0	. .	8
	6.001-8.000	All	41.0	. .	35.0	. .	6
6105							
6105-T1	Up thru 0.500	All	25.0	. .	15.0	. .	16
6105-T5	Up thru 0.500	All	38.0	. .	35.0	. .	8
6162							
6162-T5, T5510 ⑤ and T5511 ⑤	Up thru 1.000	All	37.0	. .	34.0	. .	7
6162-T6, T6510 ⑤	Up thru 0.249	All	38.0	. .	35.0	. .	8
and T6511 ⑤	0.250–0.499	All	38.0	. .	35.0	. .	10
6262							
6262-T6, T62 ④ ⑧, T6510 ⑤ and T6511 ⑤	All	All	38.0	. .	35.0	. .	10
6351							
6351-T1	Up thru 0.499	Up thru 20	26.0	. .	13.0	. .	15
6351-T4	Up thru 0.749	All	32.0	. .	19.0	. .	16
6351-T5	Up thru 0.249	All	38.0	. .	35.0	. .	8
	0.250–1.000	All	38.0	. .	35.0	. .	10
6351-T51	0.125–1.000	Up thru 20	36.0	. .	33.0	. .	10
6351-T54	Up thru 0.500	Up thru 20	30.0	. .	20.0	. .	10
6351-T6	Up thru 0.124	All	42.0	. .	37.0	. .	8
	0.125–0.749	All	42.0	. .	37.0	. .	10

For all numbered footnotes, see page 11-5.

TABLE 11.1 Mechanical Property Limits—Extruded Wire, Rod, Bar and Profiles ⑥ (concluded)

ALLOY AND TEMPER	SPECIFIED DIAMETER OR THICKNESS ① OR MINIMUM DISTANCE ACROSS FLATS in.	AREA sq. in.	TENSILE STRENGTH—ksi				ELONGATION ② percent min. in 2 in. or 4D ③
			ULTIMATE		YIELD		
			min.	max.	min.	max.	
6463							
6463-T1	Up thru 0.500	Up thru 20	17.0	. .	9.0	. .	12
6463-T5	Up thru 0.500	Up thru 20	22.0	. .	16.0	. .	8
6463-T6 and T62 ④ ⑧	Up thru 0.124	Up thru 20	30.0	. .	25.0	. .	8
	0.125–0.500	Up thru 20	30.0	. .	25.0	. .	10
7005							
7005-T53	Up thru 0.750	All	50.0	. .	44.0	. .	10
7050							
7050-T73510 ⑤ ⑨ and T73511 ⑤ ⑨	Up thru 5.000	Up thru 32	70.0	. .	60.0	. .	8
7050-T74510 ⑤ ⑪ ⑬ and T74511 ⑤ ⑪ ⑬	Up thru 5.000	Up thru 32	73.0	. .	63.0	. .	7
7050-T76510 ⑫ and T76511 ⑫	Up thru 0.499	Up thru 32	77.0	. .	68.0	. .	7
	0.500–5.000	Up thru 32	79.0	. .	69.0	. .	7
7075							
7075-O	All	All	. .	40.0	. .	24.0	10
7075-T6, T62 ④ ⑧, T6510 ⑤ and T6511 ⑤	Up thru 0.249	All	78.0	. .	70.0	. .	7
	0.250–0.499	All	81.0	. .	73.0	. .	7
	0.500–1.499	All	81.0	. .	72.0	. .	7
	1.500–2.999	All	81.0	. .	72.0	. .	7
	3.000–4.499	Up thru 20	81.0	. .	71.0	. .	7
	3.000–4.499	Over 20 thru 32	78.0	. .	70.0	. .	6
	4.500–5.000	Up thru 32	78.0	. .	68.0	. .	6
7075-T73 ⑨, T73510 ⑤ ⑨ and T73511 ⑤ ⑨	0.062–0.249	Up thru 20	68.0	. .	58.0	. .	7
	0.250–1.499	Up thru 25	70.0	. .	61.0	. .	8
	1.500–2.999	Up thru 25	69.0	. .	59.0	. .	8
	3.000–4.499	Up thru 20	68.0	. .	57.0	. .	7
	3.000-4.499	Over 20 thru 32	65.0	. .	55.0	. .	7
	4.500-5.000	Up thru 36	65.0	. .	53.0	. .	7
7075-T76 ⑩, T76510 ⑤ ⑩ and T76511 ⑤ ⑩	Up thru 0.049	All	73.0	. .	63.0	. .	7
	0.050–0.124	All	74.0	. .	64.0	. .	7
	0.125–0.249	Up thru 20	74.0	. .	64.0	. .	7
	0.250–0.499	Up thru 20	75.0	. .	65.0	. .	7
	0.500–1.000	Up thru 20	75.0	. .	65.0	. .	7
	1.001–2.000	Up thru 20	75.0	. .	65.0	. .	7
	2.001–3.000	Up thru 20	74.0	. .	64.0	. .	7
	3.001–4.000	Up thru 20	74.0	. .	63.0	. .	7
7178							
7178-O	All	Up thru 32	. .	40.0	. .	24.0	10
7178-T6, T6510 ⑤ and T6511 ⑤	Up thru 0.061	All	82.0	. .	76.0	. .	. .
	0.062–0.249	Up thru 20	84.0		76.0	. .	5
	0.250-1.499	Up thru 25	87.0	. .	78.0	. .	5
	1.500–2.499	Up thru 25	86.0	. .	77.0	. .	5
	1.500–2.499	Over 25 thru 32	84.0	. .	75.0	. .	5
	2.500–2.999	Up thru 32	82.0	. .	71.0	. .	5
7178-T62 ④ ⑧	Up thru 0.061	All	79.0	. .	73.0	. .	. .
	0.062–0.249	Up thru 20	82.0	. .	74.0	. .	5
	0.250–1.499	Up thru 25	86.0	. .	77.0	. .	5
	1.500–2.499	Up thru 25	86.0	. .	77.0	. .	5
	2.500–2.999	Up thru 32	82.0	. .	71.0	. .	7
7178-T76 ⑩, T76510 ⑤ ⑩ and T76511 ⑤ ⑩	0.125–0.249	Up thru 20	76.0	. .	66.0	. .	7
	0.250–0.499	Up thru 20	77.0	. .	67.0	. .	7
	0.500–1.000	Up thru 20	77.0	. .	67.0	. .	7
7475							
7475-T62	1.001–2.000	All	75.0	. .	66.0	. .	7

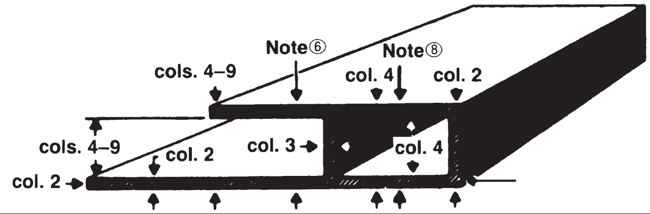
For all numbered footnotes, see page 11-5.

Footnotes for Table 11.1

① The thickness of the cross section from which the tension test specimen is taken determines the applicable mechanical properties. The data base and criteria upon which these mechanical property limits are established are outlined on page 6-1 under "Mechanical Properties."
② For material of such dimensions that a standard test specimen cannot be taken, or for profiles thinner than 0.062 inch, the test for elongation is not required.
③ D represents specimen diameter.
④ These properties can usually be obtained by the user when the material is properly solution heat treated or solution and precipitation heat treated from the O (annealed) or F (as fabricated) temper. These properties also apply to samples of material in the O or F tempers that are solution heat treated or solution and precipitation treated by the producer to determine that the material will respond to proper heat treatment. Properties attained by the user, however, may be lower than those listed if the material has been formed or otherwise cold or hot worked, particularly in the annealed temper, prior to solution heat treatment.
⑤ For stress-relieved tempers the characteristics and properties other than those specified may differ somewhat from the corresponding characteristics and properties of material in the basic temper.
⑥ Processes such as flattening, leveling, or straightening coiled products subsequent to shipment by the producer may alter the mechanical properties of the metal (refer to Certification Documentation, Section 4).
⑦ Upon artificial aging, T31, T3510, T3511, T4, T4510 and T4511 temper material shall be capable of developing the mechanical properties applicable to the T81, T8510, T8511, T6, T6510 and T6511 tempers, respectively.
⑧ This temper is not available from the material producer.
⑨ Material in this temper, 0.750 inch and thicker, when tested in accordance with ASTM G47 in the short transverse direction at a stress level of 75 percent of the specified minimum yield strength, will exhibit no evidence of stress corrosion cracking. Capability of individual lots to resist stress corrosion is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined on pages 6-7 through 6-10.
⑩ Material in this temper, when tested in accordance with ASTM G34, will exhibit exfoliation less than that shown in Photo EB, Figure 2 of ASTM G34. Also, material 0.750 inch and thicker, when tested in accordance with ASTM G47 in the short transverse direction at a stress level of 25 ksi, will exhibit no evidence of stress corrosion cracking. Capability of individual lots to resist exfoliation corrosion and stress corrosion cracking is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined on pages 6-7 through 6-10.
⑪ Material in this temper, when tested at the t/10 plane in accordance with ASTM G34, will exhibit exfoliation less than that shown in Photo EB, Figure 2 of ASTM G34. Also, material 0.750 inch and thicker, when tested in accordance with ASTM G47 in the short transverse direction at a stress level of 35 ksi, will exhibit no evidence of stress corrosion cracking. Capability of individual lots to resist exfoliation corrosion and stress corrosion cracking is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined on pages 6-7 through 6-10.
⑫ Material in this temper, when tested at the t/10 plane in accordance with ASTM G34, will exhibit exfoliation less than that shown in Photo EB, Figure 2 of ASTM G34. Also, material 0.750 inch and thicker, when tested in accordance with ASTM G47 in the short transverse direction at a stress level of 17 ksi, will exhibit no evidence of stress corrosion cracking. Capability of individual lots to resist exfoliation corrosion and stress corrosion cracking is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined on pages 6-7 through 6-10.
⑬ T74 type tempers, although not previously registered, have appeared in the literature and in some specifications as T736 type tempers.
⑭ 6063-T52 is a producer temper and is an exception to ANSI H35.1/H35.1(M) paragraphs A2.2 Temper Designation for Purchaser/User Heat-Treatment, A2.3 Temper Designations for Producer/Supplier Demonstration of Response to Temper Conversion, and A2.4 Temper Designation for Purchaser/User Heat-Treatment.

TABLE 11.2 Cross-Sectional Dimension Tolerances—Profiles ①

EXCEPT FOR T3510, T4510, T6510, T73510, T76510 AND T8510 TEMPERS ⑦



SPECIFIED DIMENSION in.	TOLERANCE ② ③—in. plus and minus															
	METAL DIMENSIONS				SPACE DIMENSIONS											
	ALLOWABLE DEVIATION FROM SPECIFIED DIMENSION WHERE 75 PERCENT OR MORE OF THE DIMENSION IS METAL ⑨ ⑩				ALLOWABLE DEVIATION FROM SPECIFIED DIMENSION WHERE MORE THAN 25 PERCENT OF THE DIMENSION IS SPACE ⑥ ⑧											
	All Except Those Covered by Column 3		Wall Thickness ④ Completely ⑤ Enclosing Space 0.11 sq. in. and Over (Eccentricity)		At Dimensioned Points 0.250–0.624 inches from Base of Leg		At Dimensioned Points 0.625–1.249 inches from Base of Leg		At Dimensioned Points 1.250–2.499 inches from Base of Leg		At Dimensioned Points 2.500–3.999 inches from Base of Leg		At Dimensioned Points 4.000–5.999 inches from Base of Leg		At Dimensioned Points 6.000–8.000 inches from Base of Leg	
Col. 1	Col. 2		Col. 3		Col.4		Col. 5		Col. 6		Col. 7		Col. 8		Col. 9	
	Standard Tolerance, All Except 5XXX Alloys ⑪	Precision Tolerance, All Except 5XXX Alloys	Standard Tolerance, All Except 5XXX Alloys ⑪	Precision Tolerance, All Except 5XXX Alloys	Standard Tolerance, All Except 5XXX Alloys ⑪	Precision Tolerance, All Except 5XXX Alloys	Standard Tolerance, All Except 5XXX Alloys ⑪	Precision Tolerance, All Except 5XXX Alloys	Standard Tolerance, All Except 5XXX Alloys ⑪	Precision Tolerance, All Except 5XXX Alloys	Standard Tolerance, All Except 5XXX Alloys ⑪	Precision Tolerance, All Except 5XXX Alloys	Standard Tolerance, All Except 5XXX Alloys ⑪	Precision Tolerance, All Except 5XXX Alloys	Standard Tolerance, All Except 5XXX Alloys ⑪	Precision Tolerance, All Except 5XXX Alloys
CIRCUMSCRIBING CIRCLE SIZES LESS THAN 10 INCHES IN DIAMETER																
Up thru 0.124	0.006	0.004	±10% of specified dimension; ±.060 max. ±.010 min.	±10% of specified dimension; ±.060 max. ±.010 min.	0.010	0.007	0.012	0.008	. .	. .	. .	. .	. .	. .	. .	. .
0.125–0.249	0.007	0.005			0.012	0.008	0.014	0.009	0.016	0.011	. .	. .	. .	. .	. .	. .
0.250–0.499	0.008	0.005			0.014	0.009	0.016	0.011	0.018	0.012	0.020	0.013	. .	. .	. .	. .
0.500–0.749	0.009	0.006			0.016	0.011	0.018	0.012	0.020	0.013	0.022	0.015	. .	. .	. .	. .
0.750–0.999	0.010	0.007			0.018	0.012	0.020	0.013	0.022	0.015	0.025	0.017	0.030	0.020	. .	. .
1.000–1.499	0.012	0.008			0.021	0.014	0.023	0.015	0.026	0.017	0.030	0.020	0.035	0.023	. .	. .
1.500–1.999	0.014	0.009			0.024	0.016	0.026	0.017	0.031	0.020	0.036	0.024	0.042	0.028	0.050	0.033
2.000–3.999	0.024	0.016			0.034	0.022	0.038	0.025	0.048	0.032	0.057	0.038	0.068	0.045	0.080	0.053
4.000–5.999	0.034	0.022			0.044	0.029	0.050	0.033	0.064	0.042	0.078	0.051	0.094	0.062	0.110	0.073
6.000–7.999	0.044	0.029			0.054	0.036	0.062	0.041	0.082	0.054	0.099	0.065	0.120	0.079	0.140	0.092
8.000–9.999	0.054	0.036			0.064	0.042	0.074	0.049	0.100	0.066	0.120	0.079	0.145	0.096	0.170	0.112
CIRCUMSCRIBING CIRCLE SIZES 10 INCHES IN DIAMETER AND OVER																
Up thru 0.124	0.014	0.009	±15% of specified dimension; ±.090 max. ±.025 min.	±15% of specified dimension; ±.090 max. ±.015 min.	0.018	0.012	0.020	0.013	. .	. .	. .	. .	. .	. .	. .	. .
0.125–0.249	0.015	0.010			0.019	0.013	0.022	0.015	0.028	0.018	. .	. .	. .	. .	. .	. .
0.250–0.499	0.016	0.011			0.020	0.013	0.024	0.016	0.030	0.020	0.050	0.033	. .	. .	. .	. .
0.500–0.749	0.017	0.011			0.022	0.015	0.027	0.018	0.040	0.026	0.060	0.040	. .	. .	. .	. .
0.750–0.999	0.018	0.012			0.023	0.015	0.030	0.020	0.050	0.033	0.070	0.046	0.090	0.059	. .	. .
1.000–1.499	0.019	0.013			0.024	0.016	0.034	0.022	0.060	0.040	0.080	0.053	0.100	0.066	. .	. .
1.500–1.999	0.024	0.016			0.034	0.022	0.044	0.029	0.070	0.046	0.090	0.059	0.110	0.073	0.170	0.112
2.000–3.999	0.034	0.022			0.044	0.029	0.054	0.036	0.080	0.053	0.100	0.066	0.120	0.079	0.180	0.119
4.000–5.999	0.044	0.029			0.054	0.036	0.064	0.042	0.090	0.059	0.110	0.073	0.130	0.086	0.190	0.125
6.000–7.999	0.054	0.036			0.064	0.042	0.074	0.049	0.100	0.066	0.120	0.079	0.140	0.092	0.200	0.132
8.000–9.999	0.064	0.042			0.074	0.049	0.084	0.055	0.110	0.073	0.130	0.086	0.150	0.099	0.210	0.139
10.000–11.999	0.074	0.049			0.084	0.055	0.094	0.062	0.120	0.079	0.140	0.092	0.160	0.106	0.220	0.145
12.000–13.999	0.084	0.055			0.094	0.062	0.104	0.069	0.130	0.086	0.150	0.099	0.170	0.112	0.230	0.152
14.000–15.999	0.094	0.062			0.104	0.069	0.114	0.075	0.140	0.092	0.160	0.106	0.180	0.119	0.240	0.158
16.000–17.999	0.104	0.069			0.114	0.075	0.124	0.082	0.150	0.099	0.170	0.112	0.190	0.125	0.250	0.165
18.000–19.999	0.114	0.075			0.124	0.082	0.134	0.088	0.160	0.106	1.800	1.188	0.200	0.132	0.260	0.172
20.000–21.999	0.124	0.082			0.134	0.088	0.144	0.095	0.170	0.112	0.190	0.125	0.210	0.139	0.270	0.178
22.000–24.000	0.134	0.088			0.144	0.095	0.154	0.102	0.180	0.119	0.200	0.132	0.220	0.145	0.280	0.185

Footnotes for Tables 11.2 through 11.4

① These Standard and Precision Tolerances are applicable to the average profile. The extrusion conditions required to produce the wide variety of alloy-temper and profile combinations require close review between customer and producer to determine critical characteristics and tolerance capability. Agressive profile characteristics may require wider than standard tolerance and closer than precision tolerance may be feasible for other characteristics.

② The tolerance applicable to a dimension composed of two or more component dimensions is the sum of the tolerances of the component dimensions if all of the component dimensions are indicated.

③ When a dimension tolerance is specified other than as an equal bilateral tolerance, the value of the standard tolerance is that which applies to the mean of the maximum and minimum dimensions permissible under the tolerance for the dimension under consideration.

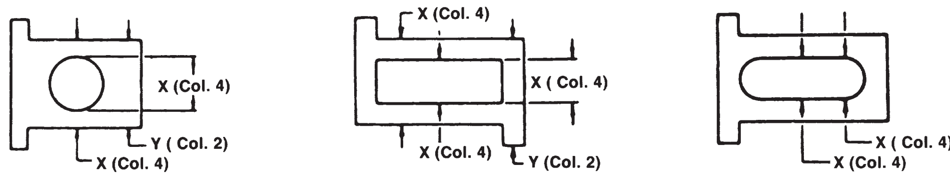
④ Where dimensions specified are outside and inside, rather than wall thickness itself, the allowable deviation (eccentricity) given in Column 3 applies to mean wall thickness. (Mean wall thickness is the average of two wall thickness measurements taken at opposite sides of the void.)

⑤ In the case of Class 1 Hollow Profiles the standard wall thickness tolerance for extruded round tube is applicable. (A Class 1 Hollow Profile is one whose void is round and one inch or more in diameter and whose weight is equally distributed on opposite sides of two or more equally spaced axes.)

(Continued on bottom of next page)

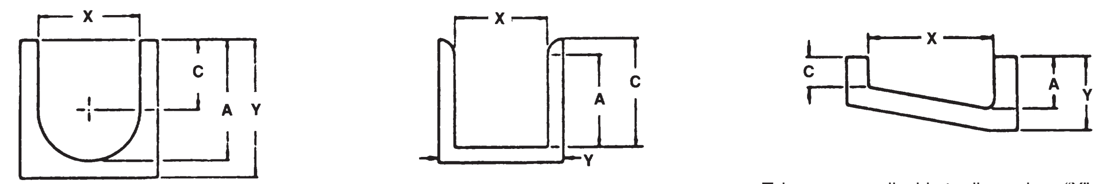
Examples Illustrating Use of Table 11.2

Closed-Space Dimensions



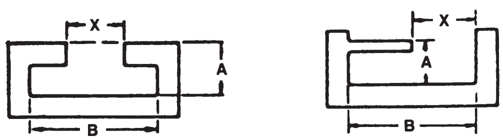
All dimensions designated “Y” are classed as “metal dimensions,” and tolerances are determined from column 2.
Dimensions designated “X” are classed as “space dimensions through an enclosed void,” and the tolerances applicable are determined from column 4 unless 75 percent or more of the dimension is metal, in which case column 2 applies.

Open-Space Dimensions



Tolerances applicable to dimensions “X” are determined as follows:
 1. Locate dimension “X” in column 1.
 2. Determine which of columns 4–9 is applicable, dependent on distance “A.”
 3. Locate proper tolerance in column 4, 5, 6, 7, 8 or 9 in the same line as dimension “X.”

Dimensions “Y” are “metal dimensions”; tolerances are determined from column 2.
Distances “C” are shown merely to indicate incorrect values for determining which of columns 4–9 apply.

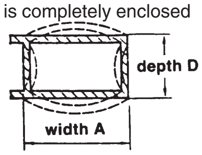


Tolerances applicable to dimensions “X” are determined as follows:
 1. Locate distance “B” in column 1.
 2. Determine which of columns 4–9 is applicable, dependent on distance “A.”
 3. Locate proper tolerance in column 4, 5, 6, 7, 8 or 9 in the same line as value chosen in column 1.

Tolerances applicable to dimensions “X” are not determined from Table 11.2; tolerances are determined by standard tolerances applicable to angles “A.”

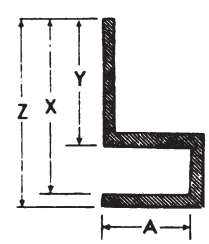
Footnotes for Tables 11.2 through 11.4 (Continued)

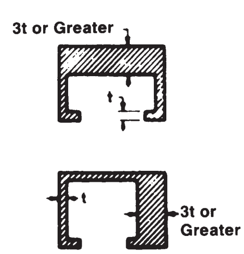
⑥ At points less than 0.250 inch from base of leg the tolerances in Col. 2 are applicable.
⑦ Tolerances for extruded profiles in T3510, T4510, T6510, T73510, T76510 and T8510 tempers shall be as agreed upon between purchaser and vendor at the time the contract or order is entered.
⑧ The following tolerances apply where the space is completely enclosed (hollow profiles); For the width (A), the balance is the value shown in Col. 4 for the depth dimension (D). For the depth (D), the tolerance is the value shown in Col. 4 for the width dimension (A). In no case is the tolerance for either width or depth less than the metal dimensions (Col. 2) at the corners.



Example—Alloy 6061 hollow profile having 1 · 3 rectangular outside dimensions; width tolerance is ±0.021 inch and depth tolerance ±.034 inch. (Tolerances at corners, Col. 2, metal dimensions, are ±0.024 inch for the width and ±0.012 inch for the depth.) Note that the Col. 4 tolerance of 0.021 inch must be adjusted to 0.024 inch so that it is not less than the Col. 2 tolerance.

⑨ These tolerances do not apply to space dimensions such as dimensions “X” and “Z” of the example (right), even when “Y” is 75 percent or more of “X.” For the tolerance applicable to dimensions “X” and “Z,” use Col. 4, 5, 6, 7, 8 or 9, dependent on distance “A.”





⑩ The wall thickness tolerance for hollow or semihollow profiles shall be as agreed upon between purchaser and vendor at the time the contract or order is entered when the nominal thickness of one wall is three times or greater than that of the opposite wall.
⑪ For those 5xxx alloys with a magnesium content of greater than or equal to 4.0% nominal, tolerances are 150% of those values shown in the standard tolerance columns.

TABLE 11.3 Diameter or Distance Across Flats—Round Wire and Rod - Square, Hexagonal and Octagonal Wire and Bar①

	TOLERANCE ③—in. plus and minus							
	ALLOWABLE DEVIATION FROM SPECIFIED DIMENSION ACROSS FLATS OR DIAMETER							
SPECIFIED DIMENSION	ROUND WIRE AND ROD		SQUARE WIRE AND BAR		HEXAGONAL WIRE AND BAR		OCTAGONAL WIRE AND BAR	
in.	Standard Tolerance, All Except 5XXX Alloys ⑪	Precsion Tolerance, All Except 5XXX Alloys	Standard Tolerance, All Except 5XXX Alloys ⑪	Precision Tolerance, All Except 5XXX Alloys	Standard Tolerance, All Except 5XXX Alloys ⑪	Precision Tolerance, All Except 5XXX Alloys	Standard Tolerance, All Except 5XXX Alloys ⑪	Precision Tolerance, All Except 5XXX Alloys
Up thru 0.124	0.006	0.004	0.006	0.004	0.006	0.004	0.006	0.004
0.125–0.249	0.007	0.005	0.007	0.005	0.007	0.005	0.007	0.005
0.250–0.499	0.008	0.005	0.008	0.005	0.008	0.005	0.008	0.005
0.500–0.749	0.009	0.006	0.009	0.006	0.009	0.006	0.009	0.006
0.750–0.999	0.010	0.007	0.010	0.007	0.010	0.007	0.010	0.007
1.000–1.499	0.012	0.008	0.012	0.008	0.012	0.008	0.012	0.008
1.500–1.999	0.014	0.009	0.014	0.009	0.014	0.009	0.014	0.009
2.000–3.999	0.024	0.016	0.024	0.016	0.024	0.016	0.024	0.016
4.000–5.999	0.034	0.022	0.034	0.022	0.034	0.022	0.034	0.022
6.000–7.070	0.044	0.029	0.044	0.029	0.044	0.029	0.044	0.029
7.071–7.999	0.044	0.029	0.054	0.036	0.044	0.029	0.044	0.029
8.000–8.659	0.054	0.036	0.064	0.042	0.054	0.036	0.054	0.036
8.660–8.999	0.054	0.036	0.064	0.042	0.064	0.042	0.054	0.036
9.000–9.238	0.054	0.036	0.064	0.042	0.064	0.042	0.054	0.036
9.239–9.999	0.054	0.036	0.064	0.042	0.064	0.042	0.064	0.042
10.000–11.999	0.074	0.049	0.074	0.049	0.074	0.049	0.074	0.049
12.000–13.999	0.084	0.055	0.084	0.055	0.084	0.055	0.084	0.055
14.000–15.999	0.094	0.062	0.094	0.062	0.094	0.062	0.094	0.062

Note: Shaded tolerances denote products with a circumscribing circle size of 10 inches in diameter and over.

For numbered footnotes, see two preceding pages.

TABLE 11.4 Thickness or Width (Distance Across Flats)—Rectangular Wire and Bar①

	TOLERANCE—in. plus and minus			
	ALLOWABLE DEVIATION FROM SPECIFIED WIDTH OR THICKNESS ACROSS FLATS			
SPECIFIED DEIMENSION IN.	Standard Tolerance, All Except, 5XXX Alloys ⑪	Precision Tolerance, All Except, 5XXX Alloys	Standard Tolerance, All Except, 5XXX Alloys ⑪	Precision Tolerance, All Except, 5XXX Alloys
Up thru 0.124	0.006	0.004	0.014	0.009
0.125–0.249	0.007	0.005	0.015	0.010
0.250–0.499	0.008	0.005	0.016	0.011
0.500–0.749	0.009	0.006	0.017	0.011
0.750–0.999	0.010	0.007	0.018	0.012
1.000–1.499	0.012	0.008	0.019	0.013
1.500–1.999	0.014	0.009	0.024	0.016
2.000–3.999	0.024	0.016	0.034	0.022
4.000–5.999	0.034	0.022	0.044	0.029
6.000–7.999	0.044	0.029	0.054	0.036
8.000–9.999	0.054	0.036	0.064	0.042
10.000–11.999	. .	. .	0.074	0.049
12.000–13.999	. .	. .	0.084	0.055
14.000–15.999	. .	. .	0.094	0.062
16.000–17.999	. .	. .	0.104	0.069
18.000–19.999	. .	. .	0.114	0.075
20.000–21.999	. .	. .	0.124	0.082
22.000–24.000	. .	. .	0.134	0.088

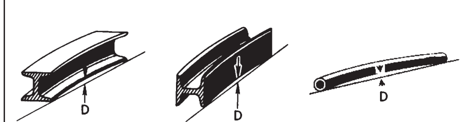
Note: Shaded tolerances denote products with a circumscribing circle size of 10 inches in diameter and over.

For all numbered footnotes, see two preceding pages.

TABLE 11.5 Length①—Wire, Rod, Bar and Profiles

SPECIFIED DIAMETER (WIRE AND ROD): SPECIFIED WIDTH (BAR): CIRCUMSCRIBING CIRCLE DIAMETER ④: (PROFILES) in.	TOLERANCE—in. plus ALLOWABLE DEVIATION FROM SPECIFIED LENGTH SPECIFIED LENGTH—ft.			
	Up thru 12	Over 12 thru 30	Over 30 thru 50	Over 50
Up thru 2.999	⅛	¼	⅜	1
3.000–7.999	3⁄16	5⁄16	7⁄16	1
8.000 and over	¼	⅜	½	1

TABLE 11.6 Straightness①—Rod, Bar and Profiles



PRODUCT	TEMPER	SPECIFIED DIAMETER (ROD): SPECIFIED WIDTH (BAR): CIRCUMSCRIBING CIRCLE DIAMETER ④: (PROFILES) in.	SPECIFIED THICKNESS (RECTANGLES): MINIMUM THICKNESS: (PROFILES) in.	TOLERANCE ③—in. ALLOWABLE DEVIATION (D) FROM STRAIGHT ⑨ IN TOTAL LENGTH OR IN ANY MEASURED SEGMENT OF ONE FT. OR MORE OF TOTAL LENGTH
Rod and Square, Hexagonal and Octagonal Bar	All except O TX510 ② TX511 ②	All	. .	.0125 · Measured length, ft.
	O	0.500 and over	. .	.050 · Measured length, ft.
	TX510 ②	0.500 and over	. .	.050 · Measured length, ft.
	TX511 ②	0.500 and over	. .	.0125 · Measured length, ft.
Rectangular Bar	All except O TX510 ② TX511 ②	Up thru 1.499	Up thru 0.094 ⑦ 0.095 and over	.050 · Measured length, ft. .0125 · Measured length, ft.
		1.500 and over	All	.0125 · Measured length, ft.
	O	Over 0.500	0.500 and over	.050 · Measured length, ft.
	TX510 ②	Over 0.500	0.500 and over	.050 · Measured length, ft.
	TX511 ②	Over 0.500	0.500 and over	.0125 · Measured length, ft.
Profiles	All except O TX510 ② ⑤ TX511 ②	Up thru 1.499	Up thru 0.094 ⑦ 0.095 and over	.050 · Measured length, ft. .0125 · Measured length, ft.
		1.500 and over	All	.0125 · Measured length, ft.
	O	0.500 and over	Up thru 0.094 ⑦ 0.095 and over	.200 · Measured length, ft. .050 · Measured length, ft.
	TX511 ②	0.500 and over	Up thru 0.094 ⑦ 0.095 and over	.050 · Measured length, ft. .0125 · Measured length, ft.

Footnotes for Tables 11.5 through 11.8

① These Standard Tolerances are applicable to the average profile; wider tolerances may be required for some profiles, and closer tolerances may be possible for others.

② TX510 and TX511 are general designations for the following stress relieved tempers: T3510, T4510, T61510, T6510, T8510, T73510, T76510 and T3511, T4511, T61511, T6511, T8511, T73511, T76511, respectively.

③ When weight of piece on the flat surface minimizes deviation.

④ The circumscribing circle diameter is the diameter of the smallest circle that will completely enclose the cross section of the extruded product.

⑤ Tolerances for T3510, T4510, T6510, T73510, T76510, and T8510 tempers shall be as agreed upon between purchaser and vendor at the time the contract or order is entered.

⑥ Twist is normally measured by placing the extruded section on a flat surface and at any point along its length measuring the maximum distance between the bottom surface of the extruded section and the flat surface. From this measurement, the actual deviation from straightness of the extruded section at that point is subtracted. The remainder is the twist.
To convert the standard twist tolerance (degrees) to an equivalent linear value, the sine of the standard tolerance is multiplied by the width of the surface of the section that is on the flat surface. The following values are used to convert angular tolerances to linear deviation:

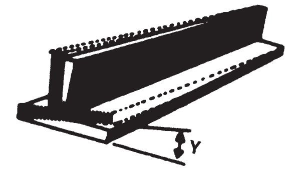
Tolerance, degrees	Maximum allowable linear deviation inch per inch of width
¼	0.004
½	0.009
1	0.017
1½	0.026
3	0.052
5	0.087
7	0.122
9	0.156
15	0.259
21	0.358

⑦ Applies only if the thickness along at least ⅓ of the total perimeter is 0.094 or less. Otherwise use the tolerance shown for 0.095 and over.

⑧ Tolerance for “O” temper material is four times the standard tolerances shown.

⑨ Straightness must be met in all orientations, including orientations which are not self-supporting.

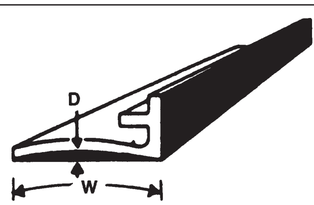
TABLE 11.7 Twist [1] [6]—Bar and Profiles



PRODUCT	TEMPER	SPECIFIED WIDTH (BAR): CIRCUMSCRIBING CIRCLE DIAMETER [4]: (PROFILES) in.	SPECIFIED THICKNESS (RECTANGLES): MINIMUM THICKNESS: (PROFILES) in.	TOLERANCE [3]—Degrees ALLOWABLE DEVIATION FROM STRAIGHT: IN TOTAL LENGTH OR IN ANY MEASURED SEGMENT OF ONE FT. OR MORE OF TOTAL LENGTH	MAXIMUM FOR TOTAL LENGTH
Bar	All except O	Up thru 1.499	All	1 · Measured length, ft.	7
	TX510 [2]	1.500–2.999	All	½ · Measured length, ft.	5
	TX511 [2]	3.000 and over	All	¼ · Measured length, ft.	3
	O	0.500–1.499	0.500 and over	3 · Measured length, ft.	21
		1.500–2.999	0.500 and over	1½ · Measured length, ft.	15
		3.000 and over	0.500 and over	¾ · Measured length, ft.	9
	TX510 [2]	0.500–2.999	0.500 and over	1½ · Measured length, ft.	7
		3.000 and over	0.500 and over	½ · Measured length, ft.	5
	TX511 [2]	0.500–1.499	0.500 and over	1 · Measured length, ft.	7
		1.500–2.999	0.500 and over	½ · Measured length, ft.	5
		3.000 and over	0.500 and over	¼ · Measured length, ft.	3
Profiles	All except O	Up thru 1.499	All	1 · Measured length, ft.	7
	TX510 [2] [5]	1.500–2.999	All	½ · Measured length, ft.	5
	TX511 [2]	3.000 and over	All	¼ · Measured length, ft.	3
	O	0.500 and over	Up thru 0.094 [7]	3 · Measured length, ft.	21
		0.500–1.499	0.095 and over	3 · Measured length, ft.	21
		1.500–2.999	0.095 and over	1½ · Measured length, ft.	15
		3.000 and over	0.095 and over	¾ · Measured length, ft.	9
	TX511 [2]	0.500 and over	Up thru 0.094 [7]	1 · Measured length, ft.	7
		0.500–1.499	0.095 and over	1 · Measured length, ft.	7
		1.500–2.999	0.095 and over	½ · Measured length, ft.	5
		3.000 and over	0.095 and over	¼ · Measured length, ft.	3

TABLE 11.8 Flatness (Flat Surfaces)[1]—Bar, Solid Profiles and Semihollow Profiles

EXCEPT FOR PROFILES IN O [8], T3510, T4510, T6510, T73510, T76510 and T8510 TEMPERS [5]



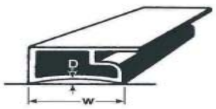
SURFACES WIDTHS UP THRU 1 INCH OR ANY 1 INCH INCREMENT OF WIDER SURFACES
Maximum Allowable Deviation D = TOLERANCE FACTOR (in.)

WIDTHS OVER 1 INCH
Maximum Allowable Deviation D = TOLERANCE FACTOR · W (in.)

MINIMUM THICKNESS OF METAL FORMING THE SURFACE in.	SURFACE WIDTH—in. UP TO 5.999	6.000 TO 7.999	8.000 TO 9.999	10.000 TO 11.999	12.000 TO 13.999	14.000 TO 15.999	16.000 TO 17.999	18.000 TO 19.999	20.000 TO 21.999	22.000 TO 23.999	24.000 AND UP
	TOLERANCE FACTOR										
Up thru 0.124	.004	.006	.010	.014	. .	. .	. .	. .	. .	. .	. .
0.125–0.187	.004	.006	.008	.012	.014	.014	.014	. .	. .	. .	. .
0.188–0.249	.004	.006	.008	.010	.012	.012	.012	.014	.014	. .	. .
0.250–0.374	.004	.006	.006	.008	.010	.010	.012	.012	.012	.014	. .
0.375–0.499	.004	.004	.006	.008	.008	.008	.010	.010	.010	.012	.014
0.500–0.749	.004	.004	.006	.006	.008	.008	.008	.008	.010	.010	.012
0.750–0.999	.004	.004	.006	.006	.008	.008	.008	.008	.008	.008	.010
1.000–1.499	.004	.004	.004	.006	.006	.008	.008	.008	.008	.008	.008
1.500–1.999	.004	.004	.004	.004	.006	.006	.006	.008	.008	.008	.008
2.000 and up	.004	.004	.004	.004	.004	.006	.006	.006	.008	.008	.008

For all numbered footnotes, see page 11-9.

TABLE 11.9 Flatness (Flat Surfaces) ①—Hollow Profiles (EXCEPT FOR PROFILES IN O ⑩, T3510, T4510, T6510, T73510, T76510 and T8510 TEMPERS ④)



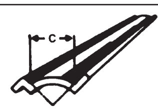
SURFACES WIDTHS UP THRU 1 INCH OR ANY 1 INCH INCREMENT OF WIDER SURFACES	Maximum Allowable Deviation D = TOLERANCE FACTOR (in.)
WIDTHS OVER 1 INCH	Maximum Allowable Deviation D = TOLERANCE FACTOR · W (in.)

MINIMUM THICKNESS OF METAL FORMING THE SURFACE in.	SURFACE WIDTH—in.										
	UP TO 5.999	6.000 TO 7.999	8.000 TO 9.999	10.000 TO 11.999	12.000 TO 13.999	14.000 TO 15.999	16.000 TO 17.999	18.000 TO 19.999	20.000 TO 21.999	22.000 TO 23.999	24.000 AND UP
	TOLERANCE FACTOR										
Up thru 0.124	.006	.008	.012	.016	. .	. .	. .	. .	. .	. .	. .
0.125–0.187	.006	.008	.010	.014	.016	. .	. .	. .	. .	. .	. .
0.188–0.249	.004	.006	.010	.012	.014	.014	.014	.016	. .	. .	. .
0.250–0.374	.004	.006	.008	.010	.012	.012	.012	.014	.014	.016	. .
0.375–0.499	.004	.006	.008	.010	.010	.010	.012	.012	.012	.014	.016
0.500–0.749	.004	.004	.006	.008	.008	.008	.010	.010	.012	.012	.014
0.750–0.999	.004	.004	.006	.006	.008	.008	.008	.008	.010	.010	.012
1.000 and up	.004	.004	.004	.006	.006	.008	.008	.008	.008	.008	.008

TABLE 11.10 Surface Roughness ① ⑧—Extruded Wire, Rod, Bar and Profiles

SPECIFIED SECTION THICKNESS in.	ALLOWABLE DEPTH OF CONDITIONS ② in. max.
Up thru 0.063	0.0015
0.064–0.125	0.002
0.126–0.188	0.0025
0.189–0.250	0.003
0.251–0.500	0.004
0.501- and over	0.008

TABLE 11.11 Contour (Curved Surfaces) ①③—Extruded Profiles

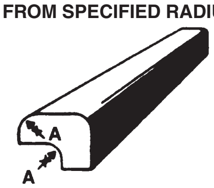


Temper	
All except O, TX510 ④	**Allowable deviation from specified contour: 0.005 inch per inch of chord length; 0.005 inch minimum. Not applicable to contours with chord length 6 inch and over.**
O	**Allowable deviation from specified contour: 0.015 inch per inch of chord length; 0.015 inch minimum. Not applicable to contours with chord length 6 inches and over.**

TABLE 11.12 Squareness of Cut Ends ①—Extruded Rod, Bar and Profiles

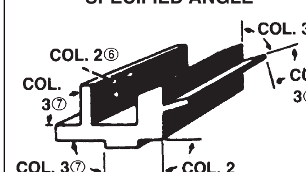
Allowable deviation from square: 1 degree

TABLE 11.13 Corner and Fillet Radii ①—Extruded Bar and Profiles



SPECIFIED RADIUS ⑨ in.	TOLERANCE—in. ALLOWABLE DEVIATION FROM SPECIFIED RADIUS (Difference between radius A and specified radius)
Sharp corners	+1⁄64
0.016–0.187	±1⁄64
0.188 and over	±10%

TABLE 11.14 Angularity ① ⑤—Extruded Bar and Profiles

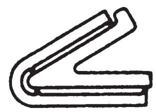


TEMPER	MINIMUM SPECIFIED LEG THICKNESS in.	TOLERANCE Degrees plus and minus — ALLOWABLE DEVIATION FROM SPECIFIED ANGLE — RATIO: ⑥ ⑦ LEG OR SURFACE LENGTH TO LEG OR METAL THICKNESS	
		1 and less	Over 1 thru 40
	Col. 1	Col.2	Col.3
All except O, TX510 ④	Up thru 0.187	1	2
	0.188–0.749	1	1½
	0.750 and over	1	1
O	Up thru 0.187	3	6
	0.188–0.749	3	4½
	0.750 and over	3	3

For all numbered footnotes, see page 11-12.

Footnotes for Tables 11.9 through 11.14

① These Standard Tolerances are applicable to the average profile; wider tolerances may be required for some profiles, and closer tolerances may be possible for others.
② Conditions include die lines and handling marks.
③ As measured with a contour gauge whose surface is limited to a maximum subtended angle of 90 degrees. Extruded curved surfaces comprising more than a 90-degree subtended angle are checked by sliding the gauge across the surface, thus checking two or more 90-degree portions of the surface. Extruded profile surfaces comprising arcs formed by two or more radii require the use of a separate contour gauge for each portion of the surface formed by an individual radius.
④ Tolerances for T3510, T4510, T6510, T73510, T76510 and T8510 tempers shall be as agreed upon between the purchaser and vendor and at the time the contract or order is entered.
⑤ Angles are measured with protractors or with gauges. As illustrated, a four-point contact system is used, two contact points being as close to the angle vertex as practical, and the others near the ends of the respective surfaces forming the angle. Between these points of measurement surface flatness is the controlling tolerance.



⑥ When the area between the surface forming an angle is all metal, values in column 2 apply if the larger surface length to metal thickness ratio is 1 or less.
⑦ When two legs are involved the one having the larger ratio determines the applicable column.
⑧ Not applicable to 2219 alloy extrusions. Most profiles in 2219 alloy will have die lines about twice the depth shown in the table; however, for each profile the supplier should be contacted for the roughness value to apply.
⑨ If unspecified, the radius shall be $1/32$ in. maximum including tolerances.
⑩ Tolerance for "O" temper material is four times the standard tolerances shown.

12. Tube and Pipe

Introduction

Section 12. of Aluminum Standards and Data covers the mechanical property limits and product dimensional tolerance limits for aluminum alloy tube and pipe. These limits are statistically based guaranteed limits, and may be used as the basis of design. Note that the limits applicable in any specific situation are those for the specific size of product ordered.

Mechanical Property Limits For Aluminum Alloy Tube and Pipe

The specified aluminum industry mechanical property limits for aluminum alloy tube and pipe are provided in the following tables:

Note that the limits shown are statistically-based guaranteed limits, and are thus suitable for design.

Special Note: The applicable limits for any individual product are those that apply to the specified (ordered) dimension.

Dimensional Tolerance Limits for Aluminum Alloy Tube and Pipe

Specific aluminum industry guaranteed tolerance limits for aluminum alloy tube and pipe are shown in the following tables:

Some general comments on the applicability and methods for calculating tolerances from these tables are given on p. 4-16 of Aluminum Standards and Data. For pipe, it is appropriate to note that these published tolerance limits represent industry standards that are agreed to and capable of being met by all members of the industry. Thus they represent the maximum tolerances that can be provided by any producer; in no case should tolerance ranges larger than these values be provided.

In some cases, substantially tighter limits (i.e., smaller ranges of thickness, width and/or length) may be obtained from individual producers upon special order. In this regard, for example, it is broadly understood in the industry that it may be possible to order product from many suppliers to dimensional tolerances that are one-half those in the limit tables.

For additional information of specific tolerance ranges available, contact producers directly.

References to Other Tube and Pipe Information in Aluminum Standards and Data

TABLE 12.1 Mechanical Property Limits—Extruded Tube

ALLOY AND TEMPER	SPECIFIED WALL THICKNESS ① in.	AREA sq. in.	TENSILE STRENGTH—ksi				ELONGATION percent min. in 2 in. or 4D ②
			ULTIMATE		YIELD		
			min.	max.	min.	max.	
1060							
1060-O	All	All	8.5	14.0	2.5	. .	25
1060-H112	All	All	8.5	. .	2.5	. .	25
1100							
1100-O	All	All	11.0	15.5	3.0	. .	25
1100-H112	All	All	11.0	. .	3.0	. .	25
2014							
2014-O	All	All	. .	30.0	. .	18.0	12
2014-T4, T4510 ④ and T4511 ④	All	All	50.0	. .	35.0	. .	12
2014-T42 ③ ⑤	All	All	50.0	. .	29.0	. .	12
2014-T6, T6510 ④ and T6511 ④	Up thru 0.499	All	60.0	. .	53.0	. .	7
	0.500–0.749	All	64.0	. .	58.0	. .	7
	0.750 and over	Up thru 25	68.0	. .	60.0	. .	7
	0.750 and over	Over 25 thru 32	68.0	. .	58.0	. .	6
2014-T62 ③ ⑤	Up thru 0.749	All	60.0	. .	53.0	. .	7
	0.750 and over	Up thru 25	60.0	. .	53.0	. .	7
	0.750 and over	Over 25 thru 32	60.0	. .	53.0	. .	6
2024							
2024-O	All	All	. .	35.0	. .	19.0	12
2024-T3, T3510 ④ and T3511 ④	Up thru 0.249	All	57.0	. .	42.0	. .	10
	0.250–0.749	All	60.0	. .	44.0	. .	10
	0.750–1.499	All	65.0	. .	46.0	. .	10
	1.500 and over	Up thru 25	70.0	. .	48.0	. .	10
	1.500 and over	Over 25 thru 32	68.0	. .	46.0	. .	8
2024-T42 ③ ⑤	Up thru 0.749	All	57.0	. .	38.0	. .	12
	0.750–1.499	All	57.0	. .	38.0	. .	10
	1.500 and over	Up thru 25	57.0	. .	38.0	. .	10
	1.500 and over	Over 25 thru 32	57.0	. .	38.0	. .	8
2024-T81, T8510 ④ and T8511 ④	0.050–0.249	All	64.0	. .	56.0	. .	4
	0.250–1.499	All	66.0	. .	58.0	. .	5
	1.500 and over	Up thru 32	66.0	. .	58.0	. .	5
2219							
2219-O	All	All	. .	32.0	. .	18.0	12
2219-T31, T3510 ④ and T3511 ④	Up thru 0.499	Up thru 25	42.0	. .	26.0	. .	14
	0.500–2.999	Up thru 25	45.0	. .	27.0	. .	14
2219-T62 ③ ⑤	Up thru 0.999	Up thru 25	54.0	. .	36.0	. .	6
	1.000 and over	Up thru 32	54.0	. .	36.0	. .	6
2219-T81, T8510 ④, and T8511 ④	Up thru 2.999	Up thru 25	58.0	. .	42.0	. .	6
3003							
3003-O	All	All	14.0	19.0	5.0	. .	25
3003-H112	All	All	14.0	. .	5.0	. .	25
ALCLAD 3003							
ALCLAD 3003-O	All	All	13.0	18.0	4.5	. .	25
ALCLAD 3003-H112	All	All	13.0	. .	4.5	. .	25
3004							
3004-O	All	All	23.0	29.0	8.5	. .	. .

For all numbered footnotes, see page 12-5.

TABLE 12.1 Mechanical Property Limits—Extruded Tube (continued)

ALLOY AND TEMPER	SPECIFIED WALL THICKNESS ① in.	AREA sq. in.	TENSILE STRENGTH—ksi ULTIMATE min.	TENSILE STRENGTH—ksi ULTIMATE max.	TENSILE STRENGTH—ksi YIELD min.	TENSILE STRENGTH—ksi YIELD max.	ELONGATION percent min. in 2 in. or 4D ②
5083							
5083-O	All	Up thru 32	39.0	51.0	16.0	. .	14
5083-H111	All	Up thru 32	40.0	. .	24.0	. .	12
5083-H112	All	Up thru 32	39.0	. .	16.0	. .	12
5086							
5086-O	All	Up thru 32	35.0	46.0	14.0	. .	14
5086-H111	All	Up thru 32	36.0	. .	21.0	. .	12
5086-H112	All	Up thru 32	35.0	. .	14.0	. .	12
5154							
5154-O	All	All	30.0	41.0	11.0	. .	. .
5154-H112	All	All	30.0	. .	11.0	. .	. .
5454							
5454-O	All	Up thru 32	31.0	41.0	12.0	. .	14
5454-H111	All	Up thru 32	33.0	. .	19.0	. .	12
5454-H112	All	Up thru 32	31.0	. .	12.0	. .	12
6005							
6005-T1	Up thru 0.500	All	25.0	. .	15.0	. .	16
	Up thru 0.124	All	38.0	. .	35.0	. .	8
6005-T5	0.125–1.000	All	38.0	. .	35.0	. .	10
6005A							
6005A-T1	Up thru 0.249	All	25.0	. .	14.5	. .	15
6005A-T5	Up thru 0.249	All	38.0	. .	31.0	. .	7
	0.250-0.999	All	38.0	. .	31.0	. .	9
6005A-T61	Up thru 0.249	All	38.0	. .	35.0	. .	8
	0.250-1.000	All	38.0	. .	35.0	. .	10
6061							
6061-O	All	All	. .	22.0	. .	16.0	16
6061-T1	Up thru 0.625	All	26.0	. .	14.0	. .	16
6061-T4, T4510 ④ and T4511 ④	All	All	26.0	. .	16.0	. .	16
6061-T42 ③ ⑤	All	All	26.0	. .	12.0	. .	16
6061-T51	Up thru 0.625	All	35.0	. .	30.0	. .	8
6061-T6, T62 ③ ⑤, T6510 ④	Up thru 0.249	All	38.0	. .	35.0	. .	8
and T6511 ④	0.250 and over	All	38.0	. .	35.0	. .	10
6063							
6063-O	All	All	. .	19.0	. .	. .	18
6063-T1	Up thru 0.500	All	17.0	. .	9.0	. .	12
	0.501–1.000	All	16.0	. .	8.0	. .	12
6063-T4 and T42 ③ ⑤	Up thru 0.500	All	19.0	. .	10.0	. .	14
	0.501–1.000	All	18.0	. .	9.0	. .	14
6063-T5	Up thru 0.500	All	22.0	. .	16.0	. .	8
	0.501–1.000	All	21.0	. .	15.0	. .	8
6063-T52 ⑦	Up thru 1.000	All	22.0	30.0	16.0	25.0	8
6063-T6 and T62 ③ ⑤	Up thru 0.124	All	30.0	. .	25.0	. .	8
	0.125–1.000	All	30.0	. .	25.0	. .	10
6066							
6066-O	All	All	. .	29.0	. .	18.0	16
6066-T4, T4510 ④, and T4511 ④	All	All	40.0	. .	25.0	. .	14
6066-T42 ③ ⑤	All	All	40.0	. .	24.0	. .	14
6066-T6, T6510 ④ and T6511 ④	All	All	50.0	. .	45.0	. .	8
6066-T62 ③ ⑤	All	All	50.0	. .	42.0	. .	8
6070							
6070-T6 and T62 ③ ⑤	Up thru 2.999	Up thru 32	48.0	. .	45.0	. .	6

For all numbered footnotes, see page 12-5.

TABLE 12.1 Mechanical Property Limits—Extruded Tube (concluded)

ALLOY AND TEMPER	SPECIFIED WALL THICKNESS ① in.	AREA sq. in.	TENSILE STRENGTH—ksi ULTIMATE min.	TENSILE STRENGTH—ksi ULTIMATE max.	TENSILE STRENGTH—ksi YIELD min.	TENSILE STRENGTH—ksi YIELD max.	ELONGATION percent min. in 2 in. or 4D ②
6082							
6082-T6	0.200–1.000	All	45.0	. .	38.0	. .	8
6105							
6105-T1	Up thru 0.500	All	25.0	. .	15.0	. .	16
6105-T5	Up thru 0.500	All	38.0	. .	35.0	. .	8
6162							
6162-T5, T5510 ④ and T5511 ④	Up thru 1.000	All	37.0	. .	34.0	. .	7
6162-T6, T6510 ④ and T6511 ④	Up thru 0.249	All	38.0	. .	35.0	. .	8
	0.250–0.499	All	38.0	. .	35.0	. .	10
6262							
6262-T6, T62 ③ ⑤, T6510 ④ and T6511 ④	All	All	38.0	. .	35.0	. .	10
6351							
6351-T4	Up thru 0.749	All	32.0	. .	19.0	. .	16
6351-T6	Up thru 0.124	All	42.0	. .	37.0	. .	8
	0.125–0.749	All	42.0	. .	37.0	. .	10
7075							
7075-O	All	All	. .	40.0	. .	24.0	10
7075-T6, T62 ③ ⑤, T6510 ④ and T6511 ④	Up thru 0.249	All	78.0	. .	70.0	. .	7
	0.250–0.499	All	81.0	. .	73.0	. .	7
	0.500–1.499	All	81.0	. .	72.0	. .	7
	1.500–2.999	All	81.0	. .	72.0	. .	7
7075-T73 ⑥, T73510 ④ ⑥ and T73511 ④ ⑥	0.062–0.249	All	68.0	. .	58.0	. .	7
	0.250–1.499	Up thru 25	70.0	. .	61.0	. .	8
	1.500–2.999	Up thru 25	69.0	. .	59.0	. .	8

Footnotes for Table 12.1

① The thickness of the cross-section from which the tension test specimen is taken determines the applicable mechanical properties. The data base and criteria upon which these mechanical property limits are established are outlined on page 6-1 under "Mechanical Properties."

② D represents specimen diameter.

③ These properties can usually be obtained by the user when the material is properly solution heat treated or solution and precipitation heat treated from the O (annealed) or F (as fabricated) temper. These properties also apply to samples of material in the O or F tempers that are solution heat treated and precipitation treated by the producer to determine that the material will respond to proper heat treatment. Properties attained by the user, however, may be lower than those listed if the material has been formed or otherwise cold or hot worked, particularly in the annealed temper, prior to solution heat treatment.

④ For stress-relieved tempers the characteristics and properties other than those specified may differ somewhat from the corresponding characteristics and properties of material in the basic temper.

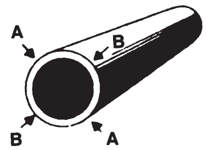
⑤ This temper is not available from the material producer.

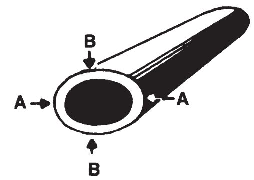
⑥ Material in this temper, 0.750 inch and thicker, when tested in accordance with ASTM G47 in the short transverse direction at a stress level of 75 percent of the specified minimum yield strength, will exhibit no evidence of stress corrosion cracking. Capability of individual lots to resist stress corrosion is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined on pages 6-7 through 6-10.

⑦ 6063-T52 is a producer temper and is an exception to ANSI H35.1/H35.1(M) paragraphs A2.2 Temper Designation for Purchaser/User Heat -Treatment, A2.3 Temper Designations for Producer/Supplier Demonstration of Response to Temper Conversion and A2.4 Temper Designation for Purchaser/User Heat-Treatment.

TABLE 12.2 Diameter—Round Tube

EXCEPT FOR T3510, T4510, T6510, T73510, T76510 AND T8510 TEMPERS ⑦

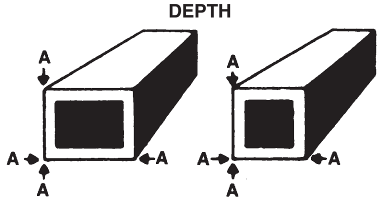


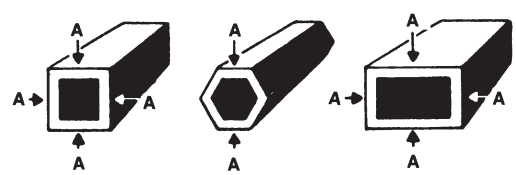


SPECIFIED DIAMETER ① in.	TOLERANCE ②—in. plus and minus			
	ALLOWABLE DEVIATION OF MEAN DIAMETER ③ FROM SPECIFIED DIAMETER (Size) — Difference between ½ (AA+BB) and specified diameter		ALLOWABLE DEVIATION OF DIAMETER AT ANY POINT FROM SPECIFIED DIAMETER ④ — Difference between AA or BB and specified diameter	
Col. 1	Col. 2		Col. 3	
	5xxx 4.0 nominal Mg ⑯	Other Alloys	5xxx 4.0 nominal Mg ⑯	Other Alloys
0.500–0.999	.015	.010	.030	.020
1.000–1.999	.018	.012	.038	.025
2.000–3.999	.023	.015	.045	.030
4.000–5.999	.038	.025	.075	.050
6.000–7.999	.053	.035	.113	.075
8.000–9.999	.068	.045	.150	.100
10.000–11.999	.083	.055	.188	.125
12.000–13.999	.098	.065	.225	.150
14.000–15.999	.113	.075	.263	.175
16.000–17.999	.128	.085	.300	.200
18.000–19.999	.143	.095	.338	.225
20.000–21.999	.158	.105	.375	.250
22.000–23.999	.173	.115	.413	.275

TABLE 12.3 Width and Depth—Square, Rectangular, Hexagonal and Octagonal Tube

EXCEPT FOR T3510, T4510, T6510, T73510, T76510 AND T8510 TEMPERS ⑦





SPECIFIED WIDTH OR DEPTH in.	TOLERANCE ②—in. plus and minus				
	ALLOWABLE DEVIATION OF WIDTH OR DEPTH AT CORNERS FROM SPECIFIED WIDTH OR DEPTH — Difference between AA and specified width or depth		ALLOWABLE DEVIATION OF WIDTH OR DEPTH NOT AT CORNERS FROM SPECIFIED WIDTH OR DEPTH ④ — Difference between AA and specified width, depth, or distance across flats		
	SQUARE, RECTANGULAR		SQUARE HEXAGONAL, OCTAGONAL		RECTANGULAR
Col. 1	Col. 2		Col. 3		Col. 4
	5xxx 4.0 nominal Mg ⑯	Other Alloys	5xxx 4.0 nominal Mg ⑯	Other Alloys	All Alloys
0.500–0.749	.018	.012	.030	.020	The tolerance for the width is the value in the previous column for a dimension equal to the depth, and conversely, but in no case is the tolerance less than at the corners. Example: The width tolerance of a 1 3 inch alloy 6061 rectangular tube is ±0.025 inch and the depth tolerance ±0.035 inch.
0.750–0.999	.021	.014	.030	.020	
1.000–1.999	.027	.018	.038	.025	
2.000–3.999	.038	.025	.053	.035	
4.000–4.999	.053	.035	.068	.045	
5.000–5.999	.068	.045	.083	.055	
6.000–6.999	.083	.055	.098	.065	
7.000–7.999	.098	.065	.108	.075	
8.000–8.999	.113	.075	.123	.085	
9.000–9.999	.128	.085	.143	.095	
10.000–10.999	.143	.095	.158	.105	
11.000–12.999	.158	.105	.173	.115	

For all numbered footnotes, see page 12-9.

TABLE 12.4 Wall Thickness—Round Extruded Tube

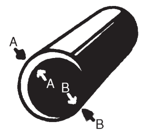
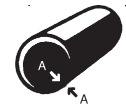
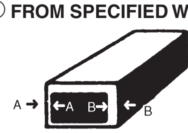
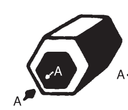
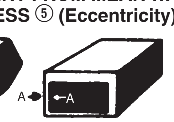
SPECIFIED WALL THICKNESS ⑥ in.	TOLERANCE ① ②—in. plus and minus								
	ALLOWABLE DEVIATION OF MEAN WALL THICKNESS ⑤ FROM SPECIFIED WALL THICKNESS  Difference between ½ (AA + BB) and specified wall thickness								ALLOWABLE DEVIATION OF WALL THICKNESS AT ANY POINT FROM MEAN WALL THICKNESS ⑤ (Eccentricity)  Difference between AA and mean wall thickness
	OUTSIDE DIAMETER—IN.								
	Under 1.250		1.250–2.999		3.000–4.999		5.000 and over		
Col. 1	Col. 2		Col. 3		Col. 4		Col. 5		Col. 6
	5xxx 4.0 nominal Mg ⑯	Other Alloys	5xxx 4.0 nominal Mg ⑯	Other Alloys	5xxx 4.0 nominal Mg ⑯	Other Alloys	5xxx 4.0 nominal Mg ⑯	Other Alloys	All Alloys
Under 0.047	.009	.006	. .	. .	. .	. .	. .	. .	Plus and minus 10% of mean wall thickness max ±0.060 min ±0.010
0.047–0.061	.011	.007	.012	.008	.012	.008	.015	.010	
0.062–0.077	.012	.008	.012	.008	.014	.009	.018	.012	
0.078–0.124	.014	.009	.014	.009	.015	.010	.023	.015	
0.125–0.249	.014	.009	.014	.009	.020	.013	.030	.020	
0.250–0.374	.017	.011	.017	.011	.024	.016	.038	.025	
0.375–0.499	. .	. .	.023	.015	.032	.021	.053	.035	
0.500–0.749	. .	. .	.030	.020	.042	.028	.068	.045	
0.750–0.999	. .	. .	. .	. .	.053	.035	.083	.055	
1.000–1.499	. .	. .	. .	. .	.068	.045	.098	.065	
1.500–2.000	. .	. .	. .	. .	. .	. .	.113	.075	
2.001–2.499	. .	. .	. .	. .	. .	. .	.128	.085	±0.120
2.500–2.999	. .	. .	. .	. .	. .	. .	.143	.095	
3.000–3.499	. .	. .	. .	. .	. .	. .	.158	.105	
3.500–4.000	. .	. .	. .	. .	. .	. .	.173	.115	

TABLE 12.5 Wall Thickness—Other-Than-Round Extruded Tube

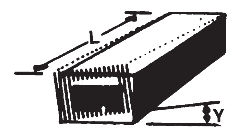
SPECIFIED WALL THICKNESS ⑥ in.	TOLERANCE ① ②—in. plus and minus					
	ALLOWABLE DEVIATION OF MEAN WALL THICKNESS ⑤ FROM SPECIFIED WALL THICKNESS  Difference between ½ (AA + BB) and specified wall thickness				ALLOWABLE DEVIATION OF WALL THICKNESS AT ANY POINT FROM MEAN WALL THICKNESS ⑤ (Eccentricity)   Difference between AA and mean wall thickness	
	CIRCUMSCRIBING CIRCLE DIAMETER ⑩—in.					
	Under 5.000		5.000 and over		Under 5.000	5.000 and over
Col. 1	Col. 2		Col. 3		Col. 4	Col. 5
	5xxx4.0 nominal Mg ⑯	Other Alloys	5xxx4.0 nominal Mg ⑯	Other Alloys	All Alloys	All Alloys
Under 0.047	.008	.005	.012	.008	.005	Plus and minus 10% of mean wall thickness max ±0.060 min ±0.010
0.047–0.061	.009	.006	.014	.009	.007	
0.062–0.124	.011	.007	.015	.010	.010	
0.125–0.249	.012	.008	.023	.015	.015	
0.250–0.374	.017	.011	.030	.020	.025	
0.375–0.499	.021	.014	.045	.030	.030	
0.500–0.749	.038	.025	.060	.040	.040	
0.750–0.999	.053	.035	.075	.050	.050	
1.000–1.499	.068	.045	.090	.060	.060	
1.500–2.000	. .	. .	.105	.070	. .	

For all numbered footnotes, see page 12-9.

TABLE 12.6 Length—Extruded Tube

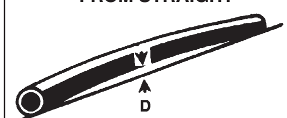
SPECIFIED OUTSIDE DIAMETER OR WIDTH in.	TOLERANCE—in. plus excepted as noted							
	ALLOWABLE DEVIATION FROM SPECIFIED LENGTH							
	STRAIGHT				COILED			
	SPECIFIED LENGTH—ft.							
	Up thru 12	Over 12 thru 30	Over 30 thru 50	Over 50	Up thru 100	Over 100 thru 250	Over 250 thru 500	Over 500
0.500–1.249	⅛	¼	⅜	1	+5%, –0%	±10%	±15%	±20%
1.250–2.999	⅛	¼	⅜	1	. .	. .	. .	. .
3.000–7.999	3⁄16	5⁄16	7⁄16	1	. .	. .	. .	. .
8.000 and over	¼	⅜	½	1	. .	. .	. .	. .

TABLE 12.7 Twist [11]—Other-than-Round Extruded Tube



TEMPER	SPECIFIED WIDTH in.	SPECIFIED THICKNESS in.	TOLERANCE [9]—Degrees ALLOWABLE DEVIATION FROM STRAIGHT Y (max.) in degrees	
			IN TOTAL LENGTH OR IN ANY SEGMENT OF ONE FT. OR MORE OF TOTAL LENGTH	MAXIMUM FOR TOTAL LENGTH
All except O, TX510, TX511 [8]	0.500 thru 1.499 1.500–2.999 3.000 and over	All All All	1 · Measured length, ft. ½ · Measured length, ft. ¼ · Measured length, ft.	7 5 3
O, TX510 [8]	0.500 and over	0.095 and over	[7]	[7]
TX511 [8]	0.500–1.499 1.500–2.999 3.000 and over	0.095 and over 0.095 and over 0.095 and over	1 · Measured length, ft. ½ · Measured length, ft. ¼ · Measured length, ft.	7 5 3

TABLE 12.8 Straightness—Extruded Tube in Straight Lengths

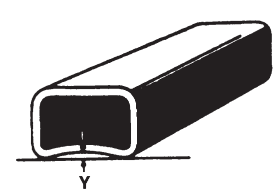


TEMPER	SPECIFIED WIDTH in.	TOLERANCE [9] [12]—in. ALLOWABLE DEVIATION (D) FROM STRAIGHT
		IN TOTAL LENGTH OR IN ANY SEGMENT OF ONE FT. OR MORE OF TOTAL LENGTH
All except O, TX510 [8]	0.500–5.999 6.000 and over	.010 · Measured length, ft. .020 · Measured length, ft.
O, TX510 [8]	0.500 and over	[7]

For all numbered footnotes, see page 12-9.

TABLE 12.9 Flatness (Flat Surfaces)—Extruded Tube

EXCEPT FOR O, T3510, T4510, T6510, T73510, T76510 AND T8510 TEMPERS [7]



MINIMUM THICKNESS OF METAL FORMING THE SURFACE in.	TOLERANCE—in. Maximum Allowable Deviation Y	
	WIDTHS UP THRU 1 IN. OR ANY 1 IN. INCREMENT OF WIDER SURFACES	WIDTHS OVER 1 IN. THRU 5.999 IN.
Up thru 0.187	0.006	0.006 · W (inches)
0.188 and over	0.004	0.004 · W (inches)

TABLE 12.10 Squareness of Cut Ends—Extruded Tube

Allowable deviation from square: 1 degree.

TABLE 12.11 Corner and Fillet Radii—Extruded Tube

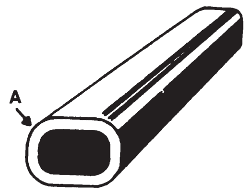
SPECIFIED RADIUS ⑱ in.	TOLERANCE—in. ALLOWABLE DEVIATION FROM SPECIFIED RADIUS
	 Difference between radius A and specified radius
Sharp corners	+1⁄64
0.016–0.187	±1⁄64
0.188 and over	±10%

TABLE 12.12 Angularity—Extruded Tube

Allowable deviation from square: ±2 degrees.

TABLE 12.13 Surface Roughness ⑭ ⑰—Extruded Tube

Specified Outside Diameter in.	Specified Wall Thickness in.	Allowable Depth of Conditions ⑬ in., max.
Up thru 12.750	Up thru 0.063	0.0025
	0.064–0.125	0.003
	0.126–0.188	0.0035
	0.189–0.250	0.004
	0.251–0.500	0.005
	0.501 and over	0.008
12.751–15.000	Up thru 0.500	0.010
	0.501 and over	0.012
15.001–20.000	Up thru 0.500	0.012
	0.501 and over	0.015
20.001 and over	Up thru 0.500	0.015
	0.501 and over	0.020

TABLE 12.14 Dents ⑮—Extruded Tube

Depth of dents shall not exceed twice the tolerances specified in Table 12.2 for diameter at any point from specified diameter, except for tube having a wall thickness less than 2.5 percent of the outside diameter, in which case the following multipliers apply:

2% to 2½% exclusive—2.5 · tolerance (max.)
1½% to 2% exclusive—3.0 · tolerance (max.)
1% to 1½% exclusive—4.0 · tolerance (max.)

Footnotes for Tables 12.2 through 12.14

① When outside diameter, inside diameter, and wall thickness (or their equivalent dimensions in other than round tube) are all specified, standard tolerances are applicable to any two of these dimensions, but not to all three. When both outside and inside diameters or inside diameter and wall thickness are specified, the tolerance applicable to the specified or calculated O.D. dimension shall also apply to the I.D. dimension.
② When a dimension tolerance is specified other than as an equal bilateral tolerance, the value of the standard tolerance is that which applied to the mean of the maximum and minimum dimensions permissible under the tolerance for the dimension under consideration.
③ Mean diameter is the average of two diameter measurements taken at right angles to each other at any point along the length.
④ Not applicable in the annealed (O) temper of if wall thickness is less than 2½ percent of outside diameter of a circle having a circumference equal to the perimeter of the tube.
⑤ The mean wall thickness of round tube is the average of two measurements taken opposite each other. The mean wall thickness of other-than-round tube is the average of two measurements taken opposite each other at approximate center line of tube and perpendicular to the longitudinal axis of the cross section.
⑥ When dimensions specified are outside and inside, rather than wall thickness itself, allowable deviation at any point (eccentricity) applies to mean wall thickness.
⑦ Tolerances for O, T3510, T4510, T6510, T73510, T76510 and T8510 tempers shall be as agreed upon between purchaser and vendor at the time the contract or order is entered.
⑧ TX510 and TX511 are general designations for the following stress-relieved tempers: T3510, T4510, T6510, T8510, T73510, T76510; and T3511, T4511, T6511, T8511, T73511, T76511, respectively.
⑨ When weight of piece on flat surface minimizes deviation.
⑩ The circumscribing circle diameter is the diameter of the smallest circle that will completely enclose the cross section of the extruded product.
⑪ Twist is normally measured by placing the extruded tube on a flat surface and at any point along its length measuring the maximum distance between the bottom surface of the extruded tube and the flat surface. From this measurement, the actual deviation from straightness of the extruded tube at that point is subtracted. The remainder is the twist. To convert the standard twist tolerance (degrees) to an equivalent linear value, the sine of the standard tolerance is multiplied by the width of the surface of the section that is on the flat surface. The following values are used to convert angular tolerances to linear deviation:

Tolerance, degrees	Maximum allowable linear deviation inch per inch of width
¼	0.004
½	0.009
1	0.017
1½	0.026
3	0.052
5	0.087
7	0.122
9	0.156
15	0.259
21	0.358

⑫ Tolerances not applicable to TX510, or TX511 temper tube having a wall thickness less than 0.095 in.
⑬ Conditions include die lines, mandrel lines and handling marks.
⑭ For tube over 12.750 in. O.D. the 2000 and 7000 series alloys and 5000 series alloys with nominal magnesium content of 3 percent or more are excluded.
⑮ Not applicable to O temper tube.
⑯ Tolerances apply to 5xxx alloys with 4.0% Mg.
⑰ Not applicable to 2219 alloy tube. Most tubes in 2219 alloy will have die lines about twice the depth shown in the table; however, for each tube size the supplier should be contacted for the roughness value to apply.
⑱ If unspecified, the radius shall be 1⁄32 in. maximum including tolerances.

Application

Extruded round coiled tube is produced by bridge or porthole die extrusion methods and is intended for general purpose applications such as refrigeration units, oil lines and instrument lines.

Internal Cleanliness

The tube shall be capable of meeting an inside cleanliness requirement of no more residue than 0.002 g of residue per square foot ($0.139 \cdot 10^{-4}$g per sq. in.) of internal surface when tested in accordance with the following paragraph. Tube ends are sealed by crimping or by other suitable means to maintain cleanliness during shipping and storage.

Test Method—A measured quantity of solvent (125 ml minimum of inhibited 1,1,1 trichloroethane, trichloroethylene or equal) is pumped or aspirated through a test sample of tube into the flask. The test sample shall have a minimum internal area of 375 sq. in. except that no more than 50 ft. of length shall be required. The solvent is then transferred to a preweighed container such as a crucible, evaporating dish or beaker, and completely evaporated on a low temperature hot plate. After solvent evaporation the container is dried in a furnace or over for at least 10 minutes at 212–230°F, cooled in a desiccator, then weighed.

A blank determination is made on the measured quantity of solvent, and the gain in weight for the blank is subtracted from the weight of the residue sample. The corrected weight is then calculated in grams of residue per internal area of tube.

Note: The quantity of solvent used for the blank run is the same as that used for the actual examination of the tube sample. The sample is prepared so that there is no inclusion of chips, dust, and so forth, resulting from the sample preparation.

Leak Test

The tube is capable of withstanding an internal air pressure of 250 psi with no evidence of leakage, or pressure loss.

Formability

The tube ends are capable of being expanded by forcing a steel pin having an included angle of 60 degrees into them until the outside diameter is increased 40 percent. The expansion shall not cause cracks, ruptures or other defects visible to the unaided eye.

TABLE 12.15 Mechanical Property Limits ① ③—Extruded Coiled Tube

ALLOY AND TEMPER ②	SPECIFIED WALL THICKNESS in.	TENSILE STRENGTH—ksi			ELONGATION percent min. in 2 in.
		ULTIMATE		YIELD	FULL-SECTION SPECIMEN
		min.	max.	min.	
1050-H112	0.032–0.050	8.5	14.5	2.5	25
1100-H112	0.032–0.050	11.0	17.0	3.0	25
1200-H112	0.032–0.050	10.0	16.0	3.0	25
1235-H112	0.032–0.050	9.0	15.0	3.0	25
3003-H112	0.032–0.050	14.0	20.0	5.0	25

① The data base and criteria upon which these mechanical property limits are established are outlined on page 6-1 under “Mechanical Properties.”
② Also available in F (as extruded temper), for which no mechanical properties are specified or guaranteed.
③ Processes such as flattening, leveling or straightening coiled products subsequent to shipment by the producer may alter the mechanical properties of the metal (refer to Certification Documentation, Section 4).

TABLE 12.16 Outside Diameter—Extruded Coiled Tube

SPECIFIED OUTSIDE DIAMETER in.	TOLERANCE—in. plus and minus	
	ALLOWABLE DEVIATION OF MEAN DIAMETER FROM SPECIFIED DIAMETER	ALLOWABLE DEVIATION OF DIAMETER AT ANY POINT FROM SPECIFIED DIAMETER
0.250–0.625	0.004	0.006

TABLE 12.17 Wall Thickness—Extruded Coiled Tube

SPECIFIED WALL THICKNESS, in.	TOLERANCE—in. plus and minus	
	ALLOWABLE DEVIATION OF MEAN WALL THICKNESS FROM SPECIFIED WALL THICKNESS	ALLOWABLE DEVIATION OF WALL THICKNESS AT ANY POINT FROM SPECIFIED WALL THICKNESS
0.032–0.050	0.003	0.004

TABLE 12.18 Coil Length ①—Extruded Coiled Tube

PERCENT OF COILS IN SHIPMENT	RANGE OF LENGTH
70 min.	80 to 120 percent of nominal
30 max.	60 to 80 percent of nominal

① Coil size shall be as agreed upon between supplier and purchaser.

TABLE 12.19 Mechanical Property Limits ① ⑦—Drawn Tube

ALLOY AND TEMPER	SPECIFIED WALL THICKNESS in.	TENSILE STRENGTH—ksi				ELONGATION percent min. in 2 in. or 4D ②	
		ULTIMATE		YIELD		FULL-SECTION SPECIMEN ③	CUT-OUT SPECIMEN ④
		min.	max.	min.	max.		
1060 ⑤							
1060-O	0.010–0.500	8.5	13.5	2.5	. .	. .	. .
1060-H12	0.010–0.500	10.0	. .	4.0	. .	. .	. .
1060-H14	0.010–0.500	12.0	. .	10.0	. .	. .	. .
1060-H18	0.010–0.500	16.0	. .	13.0	. .	. .	. .
1060-H113 ⑪	0.010–0.500	8.5	. .	2.5	. .	. .	. .
1100 ⑤							
1100-O	0.014–0.500	11.0	15.5	3.5	. .	. .	. .
1100-H12	0.014–0.500	14.0	. .	11.0	. .	. .	. .
1100-H14	0.014–0.500	16.0	. .	14.0	. .	. .	. .
1100-H16	0.014–0.500	19.0	. .	17.0	. .	. .	. .
1100-H18	0.014–0.500	22.0	. .	20.0	. .	. .	. .
1100-H113 ⑪	0.014–0.500	11.0	. .	3.5	. .	. .	. .
2011							
2011-T3	0.018–0.049	47.0	. .	40.0	. .	. .	. .
	0.050–0.500	47.0	. .	40.0	. .	10	8
2011-T4511	0.018–0.049	44.0	. .	25.0	. .	. .	. .
	0.050–0.259	44.0	. .	25.0	. .	20	18
	0.260–0.500	44.0	. .	25.0	. .	20	20
2011-T8	0.018–0.500	58.0	. .	46.0	. .	10	8
2014							
2014-O	0.018–0.500	. .	32.0	. .	16.0	. .	. .
2014-T4 and T42 ⑥ ⑧	0.018–0.024	54.0	. .	30.0	. .	10	. .
	0.025–0.049	54.0	. .	30.0	. .	12	10
	0.050–0.259	54.0	. .	30.0	. .	14	10
	0.260–0.500	54.0	. .	30.0	. .	16	12
2014-T6 and T62 ⑥ ⑧	0.018–0.024	65.0	. .	55.0	. .	7	. .
	0.025–0.049	65.0	. .	55.0	. .	7	6
	0.050–0.259	65.0	. .	55.0	. .	8	7
	0.260–0.500	65.0	. .	55.0	. .	9	8
2024							
2024-O	0.018–0.500	. .	32.0	. .	15.0	. .	. .
2024-T3	0.018–0.024	64.0	. .	42.0	. .	10	. .
	0.025–0.049	64.0	. .	42.0	. .	12	10
	0.050–0.259	64.0	. .	42.0	. .	14	10
	0.260–0.500	64.0	. .	42.0	. .	16	12
2024-T42 ⑥ ⑧	0.018–0.024	64.0	. .	40.0	. .	10	. .
	0.025–0.049	64.0	. .	40.0	. .	12	10
	0.050–0.259	64.0	. .	40.0	. .	14	10
	0.260–0.500	64.0	. .	40.0	. .	16	12
3003 ⑤							
3003-O	0.010–0.024	14.0	19.0	5.0	. .	. .	. .
	0.025–0.049	14.0	19.0	5.0	. .	30	20
	0.050–0.259	14.0	19.0	5.0	. .	35	25
	0.260–0.500	14.0	19.0	5.0	. .	. .	30
3003-H12	0.010–0.500	17.0	. .	12.0	. .	. .	. .
3003-H14	0.010–0.024	20.0	. .	17.0	. .	3	. .
	0.025–0.049	20.0	. .	17.0	. .	5	3
	0.050–0.259	20.0	. .	17.0	. .	8	4
	0.260–0.500	20.0	. .	17.0	. .	. .	. .
3003-H16	0.010–0.024	24.0	. .	21.0	. .	. .	. .
	0.025–0.049	24.0	. .	21.0	. .	3	2
	0.050–0.259	24.0	. .	21.0	. .	5	4
	0.260–0.500	24.0	. .	21.0	. .	. .	. .
3003-H18	0.010–0.024	27.0	. .	24.0	. .	2	. .
	0.025–0.049	27.0	. .	24.0	. .	3	2
	0.050–0.259	27.0	. .	24.0	. .	5	3
	0.260–0.500	27.0	. .	24.0	. .	. .	. .
3003-H113 ⑪	0.010–0.500	14.0	. .	5.0	. .	. .	. .

For all numbered footnotes, see page 12-14.

TABLE 12.19 Mechanical Property Limits ① ⑦—Drawn Tube (continued)

ALLOY AND TEMPER	SPECIFIED WALL THICKNESS in.	TENSILE STRENGTH—ksi ULTIMATE min.	ULTIMATE max.	YIELD min.	YIELD max.	ELONGATION percent min. in 2 in. or 4D ② FULL-SECTION SPECIMEN ③	CUT-OUT SPECIMEN ④
ALCLAD 3003 ⑤							
Alclad 3003-O	0.010–0.024	13.0	19.0	4.5	. .	. .	. .
	0.025–0.049	13.0	19.0	4.5	. .	30	20
	0.050–0.259	13.0	19.0	4.5	. .	35	25
	0.260–0.500	13.0	19.0	4.5	. .	. .	30
Alclad 3003-H14	0.010–0.024	19.0	. .	16.0	. .	. .	. .
	0.025–0.049	19.0	. .	16.0	. .	5	3
	0.050–0.259	19.0	. .	16.0	. .	8	4
	0.260–0.500	19.0	. .	16.0	. .	. .	. .
Alclad 3003-H18	0.010–0.500	26.0	. .	23.0	. .	. .	. .
Alclad 3003-H113 ⑪	0.010–0.500	13.0	. .	4.5	. .	. .	. .
3004 ⑤							
3004-O	0.018–0.450	23.0	29.0	8.5	. .	. .	. .
3004-H34	0.018–0.450	32.0	. .	25.0	. .	. .	. .
3004-H36	0.018–0.450	35.0	. .	28.0	. .	. .	. .
3004-H38	0.018–0.450	38.0	. .	30.0	. .	. .	. .
5050 ⑤							
5050-O	0.010–0.500	18.0	24.0	6.0	. .	. .	. .
5050-H32	0.010–0.500	22.0	. .	16.0	. .	. .	. .
5050-H34	0.010–0.500	25.0	. .	20.0	. .	. .	. .
5050-H36	0.010–0.500	27.0	. .	22.0	. .	. .	. .
5050-H38	0.010–0.500	29.0	. .	24.0	. .	. .	. .
5052 ⑤							
5052-O	0.010–0.450	25.0	35.0	10.0	. .	. .	. .
5052-H2	0.010–0.450	31.0	. .	23.0	. .	. .	. .
5052-H34	0.010–0.450	34.0	. .	26.0	. .	. .	. .
5052-H36	0.010–0.450	37.0	. .	29.0	. .	. .	. .
5052-H38	0.010–0.450	39.0	. .	31.0	. .	. .	. .
5086 ⑤							
5086-O	0.010–0.450	35.0	46.0	14.0	. .	. .	. .
5086-H32	0.010–0.450	40.0	. .	28.0	. .	. .	. .
5086-H34	0.010–0.450	44.0	. .	34.0	. .	. .	. .
5086-H36	0.010–0.450	47.0	. .	38.0	. .	. .	. .
5154 ⑤							
5154-O	0.010–0.500	30.0	41.0	11.0	. .	10	10
5154-H34	0.010–0.500	39.0	. .	29.0	. .	5	5
5154-H38	0.010–0.250	45.0	. .	34.0	. .	. .	. .
6061							
6061-O	0.018–0.500	. .	22.0	. .	14.0	15	15
6061-T4	0.025–0.049	30.0	. .	16.0	. .	16	14
	0.050–0.259	30.0	. .	16.0	. .	18	16
	0.260–0.500	30.0	. .	16.0	. .	20	18
6061-T42 ⑥ ⑧	0.025–0.049	30.0	. .	14.0	. .	16	14
	0.050–0.259	30.0	. .	14.0	. .	18	16
	0.260–0.500	30.0	. .	14.0	. .	20	18
6061-T6 and T62 ⑥ ⑧	0.025–0.049	42.0	. .	35.0	. .	10	8
	0.050–0.259	42.0	. .	35.0	. .	12	10
	0.260–0.500	42.0	. .	35.0	. .	14	12
6063							
6063-O	0.018–0.500	. .	19.0	. .	. .	. .	. .
6063-T4 and T42 ⑥ ⑧	0.025–0.049	22.0	. .	10.0	. .	16	14
	0.050–0.259	22.0	. .	10.0	. .	18	16
	0.260–0.500	22.0	. .	10.0	. .	20	18

For all numbered footnotes, see page 12-14.

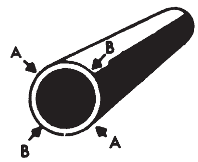
TABLE 12.19 Mechanical Property Limits ① ⑦—Drawn Tube (concluded)

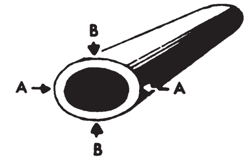
ALLOY AND TEMPER	SPECIFIED WALL THICKNESS in.	TENSILE STRENGTH—ksi				ELONGATION percent min. in 2 in. or 4D ②	
		ULTIMATE		YIELD		FULL-SECTION SPECIMEN ③	CUT-OUT SPECIMEN ④
		min.	max.	min.	max.		
6063 (Continued)							
6063-T6 and T62 ⑥ ⑧	0.025–0.049	33.0	. .	28.0	. .	12	8
	0.050–0.259	33.0	. .	28.0	. .	14	10
	0.260–0.500	33.0	. .	28.0	. .	16	12
6063-T83	0.025–0.259	33.0	. .	30.0	. .	5	. .
6063-T831	0.025–0.259	28.0	. .	25.0	. .	5	. .
6063-T832	0.025–0.049	41.0	. .	36.0	. .	8	5
	0.050–0.259	40.0	. .	35.0	. .	8	5
6066							
6066-O	0.018–0.500	. .	28.0	. .	18.0	16	16
6066-T4 and T42 ⑥ ⑧	0.025–0.500	40.0	. .	25.0	. .	14	12
6066-T6 and T62 ⑥ ⑧	0.025–0.050	50.0	. .	45.0	. .	8	8
	0.051–0.500	50.0	. .	45.0	. .	10	8
6262							
6262-T6 and T62 ⑥ ⑧	0.025–0.049	42.0	. .	35.0	. .	10	8
	0.050–0.259	42.0	. .	35.0	. .	12	10
	0.260–0.500	42.0	. .	35.0	. .	14	12
6262-T9	0.025–0.375	48.0	. .	44.0	. .	5	4
7075							
7075-O	0.025–0.049	. .	40.0	. .	21.0 ⑨	10	8
	0.050–0.500	. .	40.0	. .	21.0 ⑨	12	10
7075-T6 and T62 ⑥ ⑧	0.025–0.259	77.0	. .	66.0	. .	8	7
	0.260–0.500	77.0	. .	66.0	. .	9	8
7075-T73 ⑩	0.025–0.259	66.0	. .	56.0	. .	10	8
	0.260–0.500	66.0	. .	56.0	. .	12	10

Footnotes for Table 12.19

① The data base and criteria upon which these mechanical property limits are established are outlined on page 6-1 under "Mechanical Properties."
② D represents diameter of cut-out specimen.
③ Round tube 2 inches or less in outside diameter and square tube 1½ inches or less on a side are tested in full section unless the limitations of the testing machine precludes the use of such a specimen.
④ For round tube over 2 inches in diameter, for square tube over 1½ inches on a side, for all sizes of tube other than round or square, or in those cases when a full-section specimen cannot be used, a cut-out specimen is used.
⑤ In this alloy, tube other than round is produced only in the O, F and H113 tempers. Properties for the F temper are not specified or guaranteed.
⑥ These properties can usually be obtained by the user when the material is properly solution heat treated or solution and precipitation heat treated from the O (annealed) or F (as fabricated) temper. These properties also apply to samples of material in the O or F tempers, which are solution heat treated or solution and precipitation treated by the producer to determine that the material will respond to proper heat treatment. Properties attained by the user, however, may be lower than those listed if the material has been formed or otherwise cold or hot worked, particularly in the annealed temper, prior to solution heat treatment.
⑦ Processes such as flattening, levelling or straightening coiled products subsequent to shipment by the producer may alter the mechanical properties of the metal (refer to Certification Documentation, Section 4).
⑧ This temper is not available from the material producer.
⑨ Applicable only to round tube. The maximum yield strength for other-than-round tube shall be negotiated.
⑩ Material in this temper, 0.750 inch and thicker, when tested in accordance with ASTM G47 in the short transverse direction at a stress level of 75 percent of the specified minimum yield strength, will exhibit no evidence of stress corrosion cracking. Capability of individual lots to resist stress corrosion is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined on page 6-8.
⑪ This temper applies to other than round tube that is fabricated from the annealed round tube.

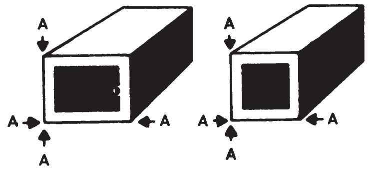
TABLE 12.20 Diameter—Drawn Round Tube

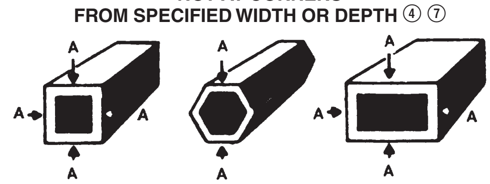




SPECIFIED DIAMETER in.	TOLERANCE ②—in. plus and minus			
	ALLOWABLE DEVIATION OF MEAN DIAMETER ③ FROM SPECIFIED DIAMETER (Size)	ALLOWABLE DEVIATION OF DIAMETER AT ANY POINT FROM SPECIFIED DIAMETER④		
	Difference between ½ (AA + BB) and specified diameter	Difference between AA or BB and specified diameter		
		NON-ANNEALED AND NON-HEAT-TREATED TUBE	HEAT-TREATED TUBE ⑤	ANNEALED TUBE
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5
Up thru 0.500	.003	.003	.006	.018
0.501–1.000	.004	.004	.008	.024
1.001–2.000	.005	.005	.010	.030
2.001–3.000	.006	.006	.012	.036
3.001–5.000	.008	.008	.016	.048
5.001–6.000	.010	.010	.020	.060
6.001–8.000	.015	.015	.030	.090
8.001–10.000	.020	.020	.040	.120
10.001–12.000	.025	.025	.050	.150

TABLE 12.21 Width and Depth—Drawn Square, Rectangular, Hexagonal and Octagonal Tube





SPECIFIED WIDTH OR DEPTH ① in.	TOLERANCE ②—in. plus and minus		
	ALLOWABLE DEVIATION OF WIDTH OR DEPTH AT CORNERS FROM SPECIFIED WIDTH OR DEPTH	ALLOWABLE DEVIATION OF WIDTH OR DEPTH NOT AT CORNERS FROM SPECIFIED WIDTH OR DEPTH ④ ⑦	
	Difference between AA and specified width or depth	Difference between AA and specified width, depth, or distance across flats	
	SQUARE, RECTANGULAR	SQUARE, HEXAGONAL, OCTAGONAL	RECTANGULAR
Col. 1	Col. 2	Col. 3	Col. 4
Up thru 0.500	.003	.006	The tolerance for the width is the value in Col. 3 for the dimension equal to the depth, and conversely, but in no case is the tolerance less than at the corners. ⑥
0.501–1.000	.004	.008	
1.001–2.000	.005	.010	
2.001–3.000	.006	.012	
3.001–5.000	.008	.016	
5.001–6.000	.010	.020	
6.001–8.000	.015	.030	
8.001–10.000	.020	.040	
10.001–12.000	.025	.050	

Footnotes for Tables 12.20 and 12.21

① When outside diameter, inside diameter, and wall thickness (or their equivalent dimensions in other than round tube) are all specified, standard tolerances are applicable to any two of these dimensions, but not to all three. When both outside and inside diameters or inside diameter and wall thickness are specified, the tolerance applicable to the specified or calculated O.D. dimension shall also apply to the I.D. dimension.

② When a dimension tolerance is specified other than as an equal bilateral tolerance, the value of the standard tolerance is that which applies to the mean of the maximum and minimum dimensions permissible under the tolerance of the dimension under consideration.

③ Mean diameter is the average of two diameter measurements taken at right angles to each other at the same longitudinal location on the tube.

④ Not applicable to coiled tube or tube having a wall thickness less than 2½ percent of the specified outside diameter. The tolerance for tube with wall thickness less than 2½ percent of the specified outside diameter is determined by multiplying the applicable tolerance in columns 3 thru 5 as follows:
2% to 2½% exclusive—1.5 · tolerance
1½% to 2% exclusive—2.0 · tolerance
1% to 1½% exclusive—3.0 · tolerance
½% to 1% exclusive—4.0 · tolerance

⑤ For the T8 tempers of 6063 the tolerance in Column 3 apply.

⑥ Example: The width tolerance of 1 · 3 inch rectangular tube is plus and minus 0.008 inch, and the depth tolerance is plus and minus 0.012 in.

⑦ Not applicable to annealed (O temper) tube.

TABLE 12.22 Diameter—Drawn Oval, Eliptical and Streamline Tube

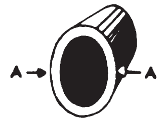
EQUIVALENT ROUND DIAMETER ⑤ in.	TOLERANCE ① ②—in.			
	LENGTH OF MAJOR AXIS, in.  Difference between AA and specified length		LENGTH OF MAJOR AXIS, in.  Difference between AA and specified length	
Col. 1	Col. 2		Col. 3	
Up thru 2.500	+.040	.025	+.025	.015
2.501–4.250	+.050	.035	+.035	.025
4.251–6.000	+.070	.050	+.055	.040
6.001–8.000	+.100	.085	+.080	.060
8.001–10.000	+.160	.140	+.115	.085

TABLE 12.23 Corner Radii—Drawn Tube

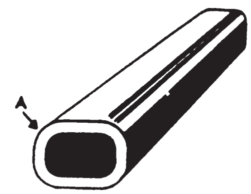
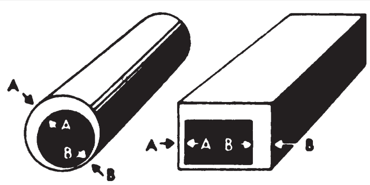
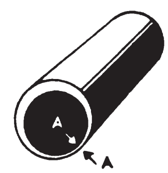
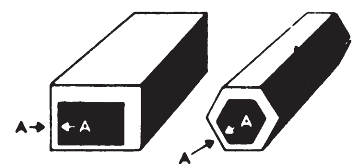
SPECIFIED ⑦ RADIUS in.	TOLERANCE ②—in.
	ALLOWABLE DEVIATION FROM SPECIFIED RADIUS  Difference between radius A and specified radius
Sharp Corners	+1/64
0.016–0.187	±1/64
0.188 and over	±10%

TABLE 12.24 Wall Thickness—Drawn Round and Other-Than-Round Tube

SPECIFIED THICKNESS ④ in	TOLERANCE ① ②—in. plus and minus		
	ALLOWABLE DEVIATION OF MEAN WALL THICKNESS ③ FROM SPECIFIED WALL THICKNESS	ALLOWABLE DEVIATION OF WALL THICKNESS AT ANY POINT FROM SPECIFIED WALL THICKNESS (Eccentricity)	
	 Difference between ½(AA+BB) and specified wall thickness	ROUND, NON-HEAT-TREATABLE ALLOYS ⑥ 	ROUND, HEAT-TREATABLE ALLOYS AND OTHER THAN ROUND, ALL ALLOYS 
Col. 1	Col. 2	Col. 3	Col. 4
0.010–0.035	.002	.002	Plus and minus 10% of specified wall thickness, min ±0.003
0.036–0.049	.003	.003	
0.050–0.083	.004	.004	
0.084–0.120	.005	.006	
0.121–0.203	.006	.008	
0.204–0.300	.008	.012	
0.301–0.375	.015	.020	
0.376–0.500	.020	.030	

Footnotes for Tables 12.22 Through 12.24

① When outside diameter, inside diameter, and wall thickness (or their equivalent dimensions in other-than-round tube) are all specified, standard tolerances are applicable to any two of these dimensions, but not to all three. When both outside and inside diameters or inside diameter and wall thickness are specified, the tolerance applicable to the specified or calculated O.D. dimension shall also apply to the I.D. dimension.

② When a dimension tolerance is specified other than as an equal bilateral tolerance, the value of the standard tolerance is that which applies to the mean of the maximum and minimum dimensions permissible under the tolerance for the dimension under consideration.

③ The mean wall thickness of round tube is the average of two measurements taken opposite each other. The mean wall thickness of other-than-round tube is the average of two measurements taken opposite each other at approximate center line of tube and perpendicular to the longitudinal axis of the cross section.

④ When dimensions specified are outside and inside, rather than wall thickness itself, allowable deviation at any point (eccentricity) is plus and minus 10 percent of the mean wall thickness but not less than ±0.003 inch.

⑤ Equivalent round diameter is the diameter of the circle having a circumference equal to the perimeter of the tube.

⑥ For coiled tube, values in Column 4 apply.

⑦ If unspecified, the radius shall be 1/32 in. maximum including tolerances.

TABLE 12.25 Straightness—Drawn Tube

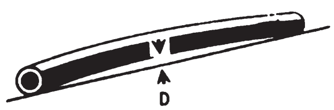
SPECIFIED OUTSIDE DIAMETER OR WIDTH in.	TOLERANCE ① ②—in. ALLOWABLE DEVIATION FROM STRAIGHT  D(max) IN TOTAL LENGTH OR IN ANY MEASURED SEGMENT OF ONE FT. OR MORE OF TOTAL LENGTH
Up thru 0.374	.500 · Measured length, ft.
0.375–5.999	.010 · Measured length, ft.
6.000 and over	.020 · Measured length, ft.

TABLE 12.26 Twist ④—Drawn Tube

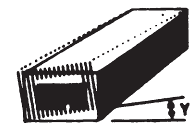
SPECIFIED WIDTH in.	TOLERANCE ① ②—Degree ALLOWABLE DEVIATION FROM STRAIGHT  Y (max) in degrees	
	IN TOTAL LENGTH OR IN ANY MEASURED SEGMENT OF ONE FT. OR MORE OF TOTAL LENGTH	MAXIMUM FOR TOTAL LENGTH
Up thru 1.499	1 · Measured length, ft.	7
1.500–2.999	½ · Measured length, ft.	5
3.000 and over	¼ · Measured length, ft.	3

TABLE 12.27 Length—Drawn Tube

SPECIFIED OUTSIDE DIAMETER OR WIDTH in.	TOLERANCE—in. plus except as noted							
	ALLOWABLE DEVIATION FROM SPECIFIED LENGTH							
	STRAIGHT				COILED			
	SPECIFIED LENGTH—ft.							
	Up thru 12	Over 12 thru 30	Over 30 thru 50	Over 50	Up thru 100	Over 100 to 250	250 to 500	500 and over
Up thru 0.249	¼	⅜	½	. .	+5%, –0%	±10%	±15%	±20%
0.250–1.249	⅛	¼	⅜	1	+5%, –0%	±10%	±15%	±20%
1.250–2.999	⅛	¼	⅜	1	. .	. .	. .	. .
3.000–7.999	3⁄16	5⁄16	7⁄16	1	. .	. .	. .	. .
8.000 and over	¼	⅜	½	1	. .	. .	. .	. .

TABLE 12.28 Flatness (Flat Surfaces)—Other-Than-Round Drawn Tube

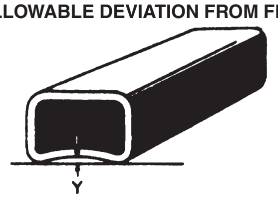
SPECIFIED WIDTH OR DEPTH in.	TOLERANCE ③—in. ALLOWABLE DEVIATION FROM FLAT  Maximum allowable distance Y
Up thru 0.500	.003
0.501–1.000	.004
1.001–2.000	.005
2.001–3.000	.006
3.001–5.000	.008
5.001–6.000	.010
6.001–8.000	.015
8.001–10.000	.020
10.001–12.000	.025

TABLE 12.29 Squareness of Cut Ends—Drawn Tube

Allowable deviation from square: 1 degree

TABLE 12.30 Angularity—Drawn Tube

Allowable deviation from specified angle: ±2 degrees

Footnotes for Tables 12.25 Through 12.30

① Tolerance is applicable when weight of tube on flat surface minimizes deviation.

② Not applicable to annealed (O temper) tube.

③ Not applicable to annealed (O temper) tube, coiled tube, or tube having a wall thickness less than 0.020 inch or less than 2½% of the equivalent round diameter. Equivalent round diameter is the diameter of a circle having a circumferance equal to the perimeter of the tube.

④ Twist is normally measured by placing the drawn tube on a flat surface and at any point along its length measuring the maximum distance between the bottom surface of the drawn tube and the flat surface. From this measurement, the actual deviation from straightness of the drawn tube at that point is subtracted. The remainder is the twist. To convert the standard twist tolerance (degrees) to an equivalent linear value, the sine of the standard tolerance is multiplied by the width of the surface of the section that is on the flat surface. The following values are used to convert angular tolerances to linear deviation:

Tolerance, degrees	Maximum allowable linear deviation inch per inch of width
¼	0.004
½	0.009
1	0.017
1½	0.026
3	0.052
5	0.087
7	0.122
9	0.156
15	0.259
21	0.358

TABLE 12.31 Surface Roughness—Drawn Tube ②

Depth of surface conditions shall not exceed 10% of the smaller (or nominal) wall thickness or 0.005 inch, whichever is smaller.

② Not applicable to annealed (O Temper) tube

TABLE 12.32 Dents—Drawn Tube

SPECIFIED DIAMETER in.	TOLERANCES—in.		
	NON-ANNEALED AND NON-HEAT-TREATED TUBE	HEAT-TREATED TUBE ⑤	ANNEALED TUBE
Col. 1	Col. 2	Col. 3	Col. 4
Up thru 0.500	.006	.012	.036
0.501–1.000	.008	.016	.048
1.001–2.000	.010	.020	.060
2.001–3.000	.012	.024	.072
3.001–5.000	.016	.032	.096
5.001–6.000	.020	.040	.120
6.001–8.000	.030	.060	.180
8.001–10.000	.040	.080	.240
10.001–12.000	.050	.100	.300

For tube having a wall thickness less than 2½ percent of the outside diameter, the following multipliers of the above tolerances apply.

Percent of Wall Thickness

2% to 2.5% exclusive—1.25 · tolerance (max.)
1.5% to 2% exclusive—1.50 · tolerance (max.)
1% to 1.5% exclusive—2.0 · tolerance (max.)
0.5% to 1% exclusive—2.5 · tolerance (max.)

⑤ For the T8 tempers of 6063 the tolerances of Column 2 apply.

TABLE 12.33 Mechanical Property Limits ①—Heat-Exchanger Tube

ALLOY AND TEMPER	SPECIFIED WALL THICKNESS in.	TENSILE STRENGTH—ksi				ELONGATION percent min. in 2 in. or 4D ②	
		ULTIMATE		YIELD		FULL-SECTION SPECIMEN ③	CUT-OUT SPECIMEN ④
		min.	max.	min.	max.		
1060							
1060-H14	0.010–0.200	12.0	. .	10.0	. .	. .	. .
3003							
3003-H14	0.010–0.024	20.0	. .	17.0	. .	3	. .
	0.025–0.049	20.0	. .	17.0	. .	5	3
	0.050–0.200	20.0	. .	17.0	. .	8	4
3003-H25	0.010–0.200	22.0	. .	19.0	. .	. .	. .
ALCLAD 3003							
Alclad 3003-H14	0.010–0.024	19.0	. .	16.0	. .	. .	. .
	0.025–0.049	19.0	. .	16.0	. .	5	3
	0.050–0.200	19.0	. .	16.0	. .	8	4
Alclad 3003-H25	0.010–0.200	21.0	. .	18.0	. .	. .	. .
5052							
5052-H32	0.010–0.200	31.0	. .	23.0	. .	. .	. .
5052-H34	0.010–0.200	34.0	. .	26.0	. .	. .	. .
5454							
5454-H32	0.010–0.050	36.0	. .	26.0	. .	. .	5
	0.051–0.200	36.0	. .	26.0	. .	. .	8
5454-H34	0.010–0.050	39.0	. .	29.0	. .	. .	4
	0.051–0.200	39.0	. .	29.0	. .	. .	6
6061							
6061-T4	0.025–0.049	30.0	. .	16.0	. .	16	14
	0.050–0.200	30.0	. .	16.0	. .	18	16
6061-T6	0.025–0.049	42.0	. .	35.0	. .	10	8
	0.050–0.200	42.0	. .	35.0	. .	12	10

① The data base and criteria upon which these mechanical property limits are established are outlined on page 6-1 under "Mechanical Properties."
② D represents diameter of cut-out specimens.
③ Tube 2 in. or less in outside diameter is tested in full section unless the limitations of the testing machine preclude the use of such specimen.
④ In those cases when a full-section specimen cannot be used, cut-out specimen is used.

TABLE 12.34 Outside Diameter Tolerances—Heat-Treatable Heat Exchanger Tube

SPECIFIED OUTSIDE DIAMETER, in.	TOLERANCE ① in. plus and minus
Up thru 0.500	.003
0.501–1.000	.004
1.001–1.500	.005
1.501–2.000	.006

TABLE 12.35 Outside Diameter Tolerances—Non-Heat-Treatable Heat ExchangerTube

SPECIFIED OUTSIDE DIAMETER, in.	TOLERANCE ① in. plus and minus
Up thru 0.500	.002
0.501–0.749	.0025
0.750–1.000	.003
1.001–1.250	.0035
1.251–2.000	.004

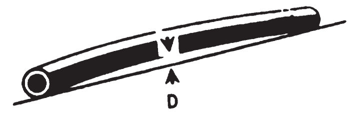
TABLE 12.36 Wall Thickness Tolerances—Heat Exchanger Tube

SPECIFIED WALL THICKNESS, in.	TOLERANCE—in. plus	
	ALLOWABLE DEVIATION OF MEAN ② WALL THICKNESS FROM SPECIFIED WALL THICKNESS	ALLOWABLE DEVIATION OF WALL THICKNESS AT ANY POINT FROM SPECIFIED WALL THICKNESS (Eccentricity)
Up thru 0.035	.004	.006
0.036–0.049	.006	.009
0.050–0.058	.007	.010
0.059–0.065	.008	.012
0.066–0.072	.009	.013
0.073–0.083	.010	.015
0.084–0.095	.011	.017
0.096–0.109	.013	.020
0.110–0.120	.014	.022
0.121–0.134	.016	.024
0.135–0.145	.017	.026
0.146–0.154	.018	.028
0.155–0.179	.021	.032
0.180–0.200	.024	.036

TABLE 12.37 Length Tolerances—Heat Exchanger Tube

SPECIFIED LENGTH	TOLERANCE—in. plus
Up thru 15	3/32
Over 15–20	1/8
Over 20–30	3/16
Over 30–60	1/4

TABLE 12.38 Straightness Tolerances—Heat Exchanger Tube



SPECIFIED OUTSIDE DIAMETER in.	TOLERANCE ③—in. ALLOWABLE DEVIATION FROM STRAIGHT D(max) IN TOTAL LENGTH OR IN ANY MEASURED SEGMENT OF ONE FT. OR MORE OF TOTAL LENGTH
0.375–2.000	.010 · Measured length, ft.

TABLE 12.39 Squareness of Cut Ends—Heat Exchanger Tube

Allowable deviation from square: 1 degree

Footnotes for Tables 12.34 Through 12.39

① As measured by use of “go” or “no go” ring gages.
② Mean wall thickness is the average of two measurements taken opposite each other.
③ Tolerance is applicable when weight of tube on flat surface minimizes deviation.

Formability

The tube ends are capable of being flared by the driving of a conical (1½ in./ft. taper) steel pin into them until the inside diameter has been expanded 20 percent without evidence of metal rupture visible to the unaided eye.

Leak Test

Each tube 1½ in. or less in diameter and 0.083 in. or less in wall thickness is subject to an eddy current test in accordance with ASTM Recommended Practice E 215. Tubes showing a discontinuity or discontinuities equal to or greater than those from 2A holes of the E 215 reference standard are rejected.

OR:

Each tube 1½ in. or less in diameter and 0.200 in. or less in wall thickness is subjected to 250 psi air pressure for a minimum of 5 seconds while immersed in suitable liquid. Tubes showing evidence of leakage are rejected.

Tube Ends

When specified, the tube ends are deburred by use of a suitable tool or device.

Identification Marking

Each tube is marked by use of a suitable marking fluid at intervals along its length with the alloy, temper, manufacturer’s name or trademark, and the letters “HE.”

TABLE 12.40 Mechanical Property Limits—Welded Tube

See Table 7.1 on pages 7-3 through 7-11 for mechanical property limits for aluminum sheet from which welded tube is produced.

TABLE 12.41 Diameter Tolerances—Welded Round Tube

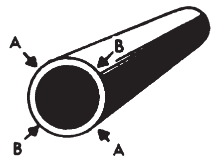
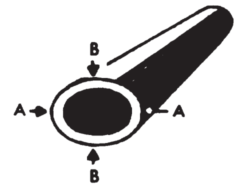
SPECIFIED DIAMETER ① in.	TOLERANCE ①—in. plus and minus	
	ALLOWABLE DEVIATION OF MEAN DIAMETER ② FROM SPECIFIED DIAMETER (Size)  Difference between ½ (AA+BB) and specified diameter	ALLOWABLE DEVIATION OF DIAMETER AT ANY POINT FROM SPECIFIED DIAMETER  Difference between AA or BB and specified diameter
Col. 1	Col. 2	Col. 3
0.500–1.000	.004	.008
1.001–2.000	.005	.010

TABLE 12.42 Width and Depth Tolerances—Welded Square Tube

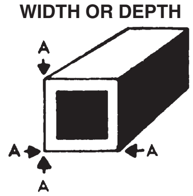
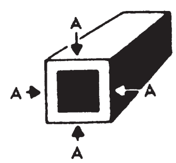
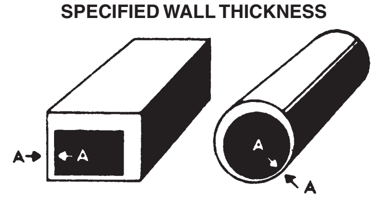
SPECIFIED WIDTH OR DEPTH in.	TOLERANCE ①—in. plus and minus	
	ALLOWABLE DEVIATION OF WIDTH OR DEPTH AT CORNERS FROM SPECIFIED WIDTH OR DEPTH  Difference between AA and specified width or depth	ALLOWABLE DEVIATION OF WIDTH OR DEPTH NOT AT CORNERS FROM SPECIFIED WIDTH OR DEPTH  Difference between AA and specified width or depth
Col. 1	Col. 2	Col. 3
0.501–1.000	.005	.008
1.001–2.000	.006	.010

TABLE 12.43 Wall Thickness Tolerances—Welded Round and Square Tube

SPECIFIED THICKNESS in.	TOLERANCE ③—in. plus
	ALLOWABLE DEVIATION OF WALL THICKNESS AT ANY POINT FROM SPECIFIED WALL THICKNESS 
0.025–0.041	.004
0.042–0.071	.005

Footnotes for Tables 12.41 Through 12.43

① When a dimension tolerance is specified other than as an equal bilateral tolerance, the value of the standard tolerance is that which applies to the mean of the maximum and minimum dimension permissible under the tolerance for the dimension under consideration.

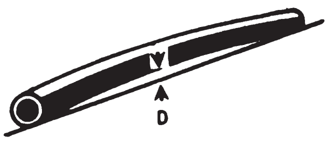
② Mean diameter is the average of two diameter measurements taken at right angle to each other at any point along the length.

③ Not applicable to the weld area or to embossed tube.

TABLE 12.44 Length Tolerances—Welded Tube

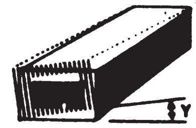
SPECIFIED OUTSIDE DIAMETER OR WIDTH in.	TOLERANCE—in. ALLOWABLE DEVIATION FROM SPECIFIED LENGTH SPECIFIED LENGTH—ft.					
	Up thru 12		Over 12 thru 20		Over 20 thru 40	
	Plus	Minus	Plus	Minus	Plus	Minus
Up thru 2.000	⅛	0	¼	0	⅜	0

TABLE 12.45 Straightness Tolerances—Welded Tube



SPECIFIED OUTSIDE DIAMETER OR WIDTH in.	TOLERANCE ①—in. ALLOWABLE DEVIATION FROM STRAIGHT D(max) IN TOTAL LENGTH OR IN ANY MEASURED SEGMENT OF ONE FT. OR MORE OF TOTAL LENGTH
0.501–1.000	.030 · Measured length, ft.
1.001–2.000	.040 · Measured length, ft.

TABLE 12.46 Twist ②—Tolerances—Welded Tube



SPECIFIED WIDTH in.	TOLERANCE ①—Degrees ALLOWABLE DEVIATION FROM STRAIGHT Y (max) in degrees IN TOTAL LENGTH OR IN ANY MEASURED SEGMENT OF ONE FT. OR MORE OF TOTAL LENGTH
Up thru 1.500	1 · Measured length, ft.
1.501–2.000	½ · Measured length, ft.

TABLE 12.47 Squareness of Cut Ends—Welded Tube

Allowable deviation from square: 1 degree

Footnotes for Tables 12.44 Through 12.47

① Tolerance is applicable when weight of tube on flat surface minimizes deviation.

② Twist is normally measured by placing the welded tube on a flat surface and at any point along its length measuring the maximum distance between the bottom surface of the welded tube and the flat surface. From this measurement, the actual deviation from straightness of the welded tube at that point is subtracted. The remainder is the twist. To convert the standard twist tolerance (degrees) to an equivalent linear value, the sine of the standard tolerance is multiplied by the width of the surface of the section that is on the flat surface. The following values are used to convert angular tolerances to linear deviation:

Tolerance, degrees	Maximum allowable linear deviation inch per inch of width
¼	0.004
½	0.009
1	0.017
1½	0.026
3	0.052
5	0.087
7	0.122
9	0.156
15	0.259
21	0.358

TABLE 12.48 Mechanical Property Limits ①—Pipe, Extruded and Drawn

ALLOY AND TEMPER ③	SPECIFIED PIPE SIZE in.	TENSILE STRENGTH ksi min.		ELONGATION percent min. in 2 in. or 4D ②
		ULTIMATE	YIELD	
3003				
3003-H18	Under 1	27.0	24.0	4
3003-H112	1 and over	14.0	5.0	25
6061				
6061-T6 (Extruded)	Under 1	38.0	35.0	8
	1 and over	38.0	35.0	10 ④
6061-T6 (Drawn)	Under 1	42.0	35.0	8 ⑤
	1 and over	38.0	35.0	10 ⑥
6063				
6063-T6	All	30.0	25.0	8

① The data base and criteria upon which these mechanical property limits are established are outlined on page 6-1 under "Mechanical Properties."

② D represents diameter of cut-out specimen.

③ Pipe in sizes listed in Table 12.55 in alloys and tempers other than those included in this table is produced to the mechanical properties applicable to extruded tube.

④ For wall thicknesses up thru 0.249 inch, the elongation is 8 percent minimum.

⑤ For pipe wall thickness 0.050–0.259 inch, the elongation is 10% min.

⑥ For pipe wall thickness 0.260–0.500 inch, the elongation is 12% min.

TABLE 12.49 Outside Diameter Tolerances—Extruded Pipe and Extruded and Drawn Pipe

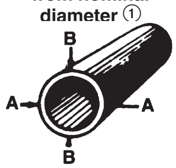
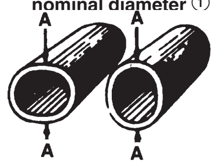
PIPE SIZE in.	TOLERANCE—in.	
	Allowable deviation of mean ② diameter from nominal diameter ①  Difference between ½(AA+BB) and nominal diameter	Allowable deviation of diameter at any point from nominal diameter ①  Difference between AA and nominal diameter
	SCHEDULES 5 AND 10	SCHEDULE 20 AND GREATER
Under 2	+.015–.031	+.015–.031
2–4	+.031–.031	+1%–1%
5–7	+.062–.031	+1%–1%
8–12	+.093–.031	+1%–1%

TABLE 12.50 Wall Thickness Tolerances—Extruded Pipe or Extruded and Drawn Pipe

SCHEDULE NUMBER	TOLERANCE
	ALLOWABLE DEVIATION OF WALL THICKNESS AT ANY POINT FROM NOMINAL ① WALL THICKNESS
5 and 10	±12.5%, ±.012 in. min.
20 and greater	12.5% ③

TABLE 12.51 Weight Tolerances—Extruded Pipe or Extruded and Drawn Pipe

SCHEDULE NUMBER	TOLERANCE
	ALLOWABLE DEVIATION FROM THEORETICAL WEIGHT
5 and 10	⑤
20 and greater	+8% ⑥

TABLE 12.52 Length Tolerances—Extruded Pipe or Extruded and Drawn Pipe

SPECIFIED LENGTH ft.	TOLERANCE in. plus
	ALLOWABLE DEVIATION FROM SPECIFIED LENGTH
Up thru 20	0.25
Over 20 thru 40	0.50

TABLE 12.53 Straightness Tolerances—Extruded Pipe or Extruded and Drawn Pipe

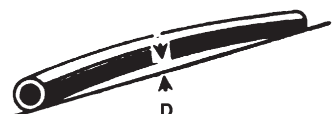
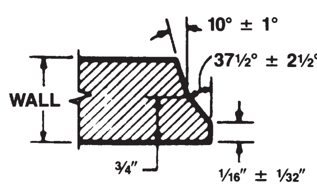
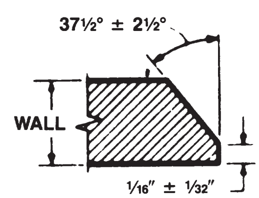
PIPE SIZE in.	TOLERANCE ④—in.
	ALLOWABLE DEVIATION FROM STRAIGHT  D(max)
	IN TOTAL LENGTH OR IN ANY MEASURED SEGMENT OF ONE FT. OR MORE OF TOTAL LENGTH
Under 6	.010 · Measured length, ft.
6–12	.020 · Measured length, ft.

TABLE 12.54 Standard Welding Bevels—Extruded Pipe or Extruded and Drawn Pipe

DOUBLE LEVEL For Wall Thickness Over 0.750 in.	STRAIGHT BEVEL For Wall Thickness 0.750 in. and Less
	

Footnotes for Tables 12.49 Through 12.54

① Nominal diameter and wall thickness are those listed in Table 12.55.
② Mean diameter is the average of any two diameter measurements taken at right angles to each other at any point along the length.
③ Maximum wall thickness is controlled by weight tolerance.
④ When weight of pipe on flat surface minimizes deviation.
⑤ For schedule 5 and 10, only diameter, wall thickness and length tolerances apply.
⑥ Minimum weight is controlled by tolerances for outside diameter and wall thickness.

TABLE 12.55 Diameters, Wall Thicknesses, Weights—Pipe

NOMINAL PIPE SIZE ① IN.	SCHEDULE NUMBER	OUTSIDE DIAMETER in.			INSIDE DIAMETER in.	WALL THICKNESS in.			WEIGHT PER FOOT lb.	
		Nom. ①	Min ② ④	Max. ② ④	Nom.	Nom. ①	Min ②	Max. ②	Nom. ③	Max. ② ③
⅛	40	0.405	0.374	0.420	0.269	0.068	0.060	. .	0.085	0.091
	80	0.405	0.374	0.420	0.215	0.095	0.083	. .	0.109	0.118
¼	40	0.540	0.509	0.555	0.364	0.088	0.077	. .	0.147	0.159
	80	0.540	0.509	0.555	0.302	0.119	0.104	. .	0.185	0.200
⅜	40	0.675	0.644	0.690	0.493	0.091	0.080	. .	0.196	0.212
	80	0.675	0.644	0.690	0.423	0.126	0.110	. .	0.256	0.276
½	5	0.840	0.809	0.855	0.710	0.065	0.053	0.077	0.186	. .
	10	0.840	0.809	0.855	0.674	0.083	0.071	0.095	0.232	. .
	40	0.840	0.809	0.855	0.622	0.109	0.095	. .	0.294	0.318
	80	0.840	0.809	0.855	0.546	0.147	0.129	. .	0.376	0.406
	160	0.840	0.809	0.855	0.464	0.188	0.164	. .	0.453	0.489
¾	5	1.050	1.019	1.065	0.920	0.065	0.053	0.077	0.237	. .
	10	1.050	1.019	1.065	0.884	0.083	0.071	0.095	0.297	. .
	40	1.050	1.019	1.065	0.824	0.113	0.099	. .	0.391	0.422
	80	1.050	1.019	1.065	0.742	0.154	0.135	. .	0.510	0.551
	160	1.050	1.019	1.065	0.612	0.219	0.192	. .	0.672	0.726
1	5	1.315	1.284	1.330	1.185	0.065	0.053	0.077	0.300	. .
	10	1.315	1.284	1.330	1.097	0.109	0.095	0.123	0.486	. .
	40	1.315	1.284	1.330	1.049	0.133	0.116	. .	0.581	0.627
	80	1.315	1.284	1.330	0.957	0.179	0.157	. .	0.751	0.811
	160	1.315	1.284	1.330	0.815	0.250	0.219	. .	0.984	1.062
1¼	5	1.660	1.629	1.675	1.530	0.065	0.053	0.077	0.383	. .
	10	1.660	1.629	1.675	1.442	0.109	0.095	0.123	0.625	. .
	40	1.660	1.629	1.675	1.380	0.140	0.122	. .	0.786	0.849
	80	1.660	1.629	1.675	1.278	0.191	0.167	. .	1.037	1.120
	160	1.660	1.629	1.675	1.160	0.250	0.219	. .	1.302	1.407
1½	5	1.900	1.869	1.915	1.770	0.065	0.053	0.077	0.441	. .
	10	1.900	1.869	1.915	1.682	0.109	0.095	0.123	0.721	. .
	40	1.900	1.869	1.915	1.610	0.145	0.127	. .	0.940	1.015
	80	1.900	1.869	1.915	1.500	0.200	0.175	. .	1.256	1.357
	160	1.900	1.869	1.915	1.338	0.281	0.246	. .	1.681	1.815
2	5	2.375	2.344	2.406	2.245	0.065	0.053	0.077	0.555	. .
	10	2.375	2.344	2.406	2.157	0.109	0.095	0.123	0.913	. .
	40	2.375	2.351	2.399	2.067	0.154	0.135	. .	1.264	1.365
	80	2.375	2.351	2.399	1.939	0.218	0.191	. .	1.737	1.876
	160	2.375	2.351	2.399	1.687	0.344	0.301	. .	2.581	2.788
2½	5	2.875	2.844	2.906	2.709	0.083	0.071	0.095	0.856	. .
	10	2.875	2.844	2.906	2.635	0.120	0.105	0.135	1.221	. .
	40	2.875	2.846	2.904	2.469	0.203	0.178	. .	2.004	2.164
	80	2.875	2.846	2.904	2.323	0.276	0.242	. .	2.650	2.862
	160	2.875	2.846	2.904	2.125	0.375	0.328	. .	3.464	3.741
3	5	3.500	3.469	3.531	3.334	0.083	0.071	0.095	1.048	. .
	10	3.500	3.469	3.531	3.260	0.120	0.105	0.135	1.498	. .
	40	3.500	3.465	3.535	3.068	0.216	0.189	. .	2.621	2.830
	80	3.500	3.465	3.535	2.900	0.300	0.262	. .	3.547	3.830
	160	3.500	3.465	3.535	2.624	0.438	0.383	. .	4.955	5.351
3½	5	4.000	3.969	4.031	3.834	0.083	0.071	0.095	1.201	. .
	10	4.000	3.969	4.031	3.760	0.120	0.105	0.135	1.720	. .
	40	4.000	3.960	4.040	3.548	0.226	0.198	. .	3.151	3.403
	80	4.000	3.960	4.040	3.364	0.318	0.278	. .	4.326	4.672

For all number footnotes, see page 12-24.

TABLE 12.55 Diameters, Wall Thicknesses, Weights—Pipe (concluded)

NOMINAL PIPE SIZE ① IN.	SCHEDULE NUMBER	OUTSIDE DIAMETER in.			INSIDE DIAMETER in.	WALL THICKNESS in.			WEIGHT PER FOOT lb.	
		Nom. ①	Min ② ④	Max. ② ④	Nom.	Nom. ①	Min ②	Max. ②	Nom. ③	Max. ② ③
4	5	4.500	4.469	4.531	4.334	0.083	0.071	0.095	1.354	. .
	10	4.500	4.469	4.531	4.260	0.120	0.105	0.135	1.942	. .
	40	4.500	4.455	4.545	4.026	0.237	0.207	. .	3.733	4.031
	80	4.500	4.455	4.545	3.826	0.337	0.295	. .	5.183	5.598
	120	4.500	4.455	4.545	3.624	0.438	0.383	. .	6.573	7.099
	160	4.500	4.455	4.545	3.438	0.531	0.465	. .	7.786	8.409
5	5	5.563	5.532	5.625	5.345	0.109	0.095	0.123	2.196	. .
	10	5.563	5.532	5.625	5.295	0.134	0.117	0.151	2.688	. .
	40	5.563	5.507	5.619	5.047	0.258	0.226	. .	5.057	5.461
	80	5.563	5.507	5.619	4.813	0.375	0.328	. .	7.188	7.763
	120	5.563	5.507	5.619	4.563	0.500	0.438	. .	9.353	10.10
	160	5.563	5.507	5.619	4.313	0.625	0.547	. .	11.40	12.31
6	5	6.625	6.594	6.687	6.407	0.109	0.095	0.123	2.624	. .
	10	6.625	6.594	6.687	6.357	0.134	0.117	0.151	3.213	. .
	40	6.625	6.559	6.691	6.065	0.280	0.245	. .	6.564	7.089
	80	6.625	6.559	6.691	5.761	0.432	0.378	. .	9.884	10.67
	120	6.625	6.559	6.691	5.501	0.562	0.492	. .	12.59	13.60
	160	6.625	6.559	6.691	5.187	0.719	0.629	. .	15.69	16.94
8	5	8.625	8.594	8.718	8.407	0.109	0.095	0.123	3.429	. .
	10	8.625	8.594	8.718	8.329	0.148	0.130	0.166	4.635	. .
	20	8.625	8.539	8.711	8.125	0.250	0.219	. .	7.735	8.354
	30	8.625	8.539	8.711	8.071	0.277	0.242	. .	8.543	9.227
	40	8.625	8.539	8.711	7.981	0.322	0.282	. .	9.878	10.67
	60	8.625	8.539	8.711	7.813	0.406	0.355	. .	12.33	13.31
	80	8.625	8.539	8.711	7.625	0.500	0.438	. .	15.01	16.21
	100	8.625	8.539	8.711	7.437	0.594	0.520	. .	17.62	19.03
	120	8.625	8.539	8.711	7.187	0.719	0.629	. .	21.00	22.68
	140	8.625	8.539	8.711	7.001	0.812	0.710	. .	23.44	25.31
	160	8.625	8.539	8.711	6.813	0.906	0.793	. .	25.84	27.90
10	5	10.750	10.719	10.843	10.482	0.134	0.117	0.151	5.256	. .
	10	10.750	10.719	10.843	10.420	0.165	0.144	0.186	6.453	. .
	20	10.750	10.642	10.858	10.250	0.250	0.219	. .	9.698	10.47
	30	10.750	10.642	10.858	10.136	0.307	0.269	. .	11.84	12.79
	40	10.750	10.642	10.858	10.020	0.365	0.319	. .	14.00	15.12
	60	10.750	10.642	10.858	9.750	0.500	0.438	. .	18.93	20.45
	80	10.750	10.642	10.858	9.562	0.594	0.520	. .	22.29	24.07
	100	10.750	10.642	10.858	9.312	0.719	0.629	. .	26.65	28.78
12	5	12.750	12.719	12.843	12.438	0.156	0.136	0.176	7.258	. .
	10	12.750	12.719	12.843	12.390	0.180	0.158	0.202	8.359	. .
	20	12.750	12.622	12.878	12.250	0.250	0.219	. .	11.55	12.47
	30	12.750	12.622	12.878	12.090	0.330	0.289	. .	15.14	16.35
	40	12.750	12.622	12.878	11.938	0.406	0.355	. .	18.52	20.00
	60	12.750	12.622	12.878	11.626	0.562	0.492	. .	25.31	27.33
	80	12.750	12.622	12.878	11.374	0.688	0.602	. .	30.66	33.11

Footnotes for Table 12.55

① In accordance with ANSI/ASME Standards B36.10M and B36.19M

② Based on standard tolerances for outside diameter, wall thickness and weight shown earlier in this section.

③ Based on nominal dimensions, plain ends, and a density of 0.098 lb per cu in., the density of 6061 alloy. For alloy 6063 multiply by 0.99 and for alloy 3003 multiply by 1.011.

④ For schedules 5 and 10 these values apply to mean outside diameters.

TABLE 12.56 Designed Dimensions and Weights—Rigid Electrical Conduit

NOMINAL OR TRADE SIZE OF CONDUIT in.	NOMINAL INSIDE DIAMETER in.	OUTSIDE DIAMETER in.	NOMINAL WALL THICKNESS in.	LENGTH ① WITHOUT COUPLING ft. and in.	MINIMUM WEIGHT OF 10 UNIT LENGTHS WITH COUPLINGS ATTACHED lb.
¼	0.364	0.540	0.088	9–11½	13.3
⅜	0.493	0.675	0.091	9–11½	17.8
½	0.622	0.840	0.109	9–11¼	27.4
¾	0.824	1.050	0.113	9–11¼	36.4
1	1.049	1.315	0.133	9–11	53.0
1¼	1.380	1.660	0.140	9–11	69.6
1½	1.610	1.900	0.145	9–11	86.2
2	2.067	2.375	0.154	9–11	115.7
2½	2.469	2.875	0.203	9–10½	182.5
3	3.068	3.500	0.216	9–10½	238.9
3½	3.548	4.000	0.226	9–10¼	287.7
4	4.026	4.500	0.237	9–10¼	340.0
5	5.047	5.563	0.258	9–10	465.4
6	6.065	6.625	0.280	9–10	612.5

TABLE 12.57 Dimensions of Threads—Rigid Electrical Conduit

NOMINAL OR TRADE SIZE OF CONDUIT in.	THREADS PER INCH	PITCH DIAMETER AT END OF THREAD E° in. (taper ¾ in. per ft.)	LENGTH OF THREAD in.	
			EFFECTIVE L_2	OVERALL L_4
¼	18	0.4774	0.40	0.59
⅜	18	0.6120	0.41	0.60
½	14	0.7584	0.53	0.78
¾	14	0.9677	0.55	0.79
1	11½	1.2136	0.68	0.98
1¼	11½	1.5571	0.71	1.01
1½	11½	1.7961	0.72	1.03
2	11½	2.2690	0.76	1.06
2½	8	2.7195	1.14	1.57
3	8	3.3406	1.20	1.63
3½	8	3.8375	1.24	1.68
4	8	4.3344	1.30	1.73
5	8	5.3907	1.41	1.84
6	8	6.4461	1.51	1.95

TABLE 12.58 Designed Dimensions and Weights of Couplings For Conduit

NOMINAL OR TRADE SIZE OF CONDUIT in.	OUTSIDE DIAMETER in.	MINIMUM LENGTH in.	NOMINAL WEIGHT lb.
¼	51/64	1 3/16	0.034
⅜	59/64	1 3/16	0.039
½	1 5/64	1 9/16	0.061
¾	1 21/64	1⅝	0.091
1	1 9/16	2	0.125
1¼	1 61/64	2 1/16	0.189
1½	2 7/32	2 1/16	0.233
2	2¾	2⅛	0.346
2½	3 9/32	3⅛	0.683
3	3 13/16	3¼	0.914
3½	4 7/16	3⅜	1.08
4	5	3½	1.42
5	6 7/32	3¾	2.42
6	7 5/16	4	3.21

TABLE 12.59 Dimensions of 90-Degree Elbows and Weights of Nipples Per Hundred For Conduit

NOMINAL OR TRADE SIZE OF CONDUIT in.	ELBOWS		NIPPLES ②	
	MINIMUM RADIUS TO CENTER OF CONDUIT in.	MINIMUM STRAIGHT LENGTH L_0 AT EACH END in.	A = WEIGHT OF NIPPLE PER INCH lb.	B = WEIGHT LOST IN THREADING 100 NIPPLES lb.
¼	..	..	..	..
⅜	..	..	..	..
½	4	1½	0.022	0.7
¾	4½	1½	0.031	1.4
1	5¾	1⅞	0.043	3.1
1¼	7¼	2	0.057	3.5
1½	8¼	2	0.070	3.8
2	9½	2	0.093	4.9
2½	10½	3	0.149	20.8
3	13	3⅛	0.194	24.2
3½	15	3¼	0.229	31.1
4	16	3⅜	0.272	39.8
5	24	3⅝	0.367	58.8
6	30	3¾	0.488	69.2

TABLE 12.60 Standard Tolerances—Rigid Electrical Conduit

Length: ±¼ in. (without coupling)
Outside Diameter: +1/64 in. or 1/32 in. for 1½ in. and smaller sizes, ±1 percent for 2-in. and larger sizes.
Thread Length, Overall: plus or minus one thread.
Pitch Diameter: plus or minus one turn is the maximum variation permitted from the gauging face of the working thread gauges. This is equivalent to plus or minus 1½ turns from basic dimensions, since a variation of plus or minus ½ turn from basic dimensions is permitted in working gauges.
Outside Diameter—Couplings: 1 percent of diameter shown in Table 12.58 for sizes 1¼ inch and larger, 1/64 inch for smaller sizes.

TABLE 12.61 Identification—Rigid Electrical Conduit

Each length of conduit, elbow, and nipple (except close-threaded nipples) is identified with the manufacturer's name or trademark.

Footnotes for Tables 12.56 Through 12.61

① Conduit is furnished in nominally 10-ft lengths, threaded on each end, with one coupling attached.

② Each lot of 100 nipples shall weigh not less than the number of pounds determined by the formula W = 100 LA B, where W = weight of 100 nipples in pounds; L = length of one nipple in inches; A = weight of nipple per inch in pounds; B = weight, in pounds, lost in threading 100 nipples.

13. Structural Profiles

Introduction

Section 13. of Aluminum Standards and Data covers the mechanical property limits and product dimensional tolerance limits for aluminum alloy structural profiles. These limits are statistically based guaranteed limits, and may be used as the basis of design. Note that the limits applicable in any specific situation are those for the specific size of product ordered.

Mechanical Property Limits for Aluminum Alloy Structural Profiles

The specified aluminum industry mechanical property limits for aluminum alloy structural profiles are provided in Table 13.1. Note that the limits shown are statistically-based guaranteed limits, and are thus suitable for design.

Special Note: The applicable limits for any individual product are those that apply to the specified (ordered) dimension.

Dimensional Tolerance Limits for Aluminum Alloy Structural Profiles

Aluminum industry guaranteed tolerance limits for aluminum alloy structural profiles are identical with those for other extruded profiles, as shown in Section 11.0, and specifically in the following tables:

- Table 11.2, .3 & .4 - Cross-Sectional Dimension Tolerances
- Table 11.5 - Length
- Table 11.6 - Straightness
- Table 11.7 - Twist
- Table 11.8 - Flatness (Flat Surfaces) - Bar, Solid and Semihollow Profiles
- Table 11.9 - Flatness (Flat Surfaces) - Hollow Profiles
- Table 11.10 - Surface Roughness
- Table 11.11 - Contour (Curved Surfaces)
- Table 11.12 - Squareness of Cut Ends
- Table 11.13 - Corner and Fillet Radii
- Table 11.14 - Angularity

Some general comments on the applicability and methods for calculating tolerances from these tables are given on p. 4-16 of Aluminum Standards and Data. For structural profiles, it is appropriate to note that these published tolerance limits represent industry standards that are agreed to and capable of being met by all members of the industry. Thus they represent the maximum tolerances that can be provided by any producer; in no case should tolerance ranges larger than these values be provided.

In some cases, substantially tighter limits (i.e., smaller ranges of thickness, width and/or length) may be obtained from individual producers upon special order. In this regard, for example, it is broadly understood in the industry that it may be possible to order product from many suppliers to dimensional tolerances that are one-half those in the limit tables.

For additional information of specific tolerance ranges available, contact producers directly.

Dimensions of Standard Structural Profiles

The specific dimensions, areas, weights and section properties of standard aluminum alloy structural profiles are provided in the following tables:

- Table 13.3 - Aluminum Association Standard Channels - Dimensions, Areas, Weights and Section Properties
- Table 13.4 - Aluminum Association Standard I-Beams - Dimensions, Areas, Weights and Section Properties
- Table 13.5 - American Standard Equal Angles - Dimensions, Areas and Weights
- Table 13.6 - American Standard Unequal Angles - Dimensions, Areas and Weights
- Table 13.7 - American Standard Channels - Dimensions, Areas and Weights
- Table 13.8 - American Standard Shipbuilding and Carbuilding Channels - Dimensions, Areas and Weights
- Table 13.9 - American Standard H-Beams - Dimensions, Areas and Weights
- Table 13.10 - American Standard I-Beams - Dimensions, Areas and Weights
- Table 13.11 - American Standard Wide Flange Beams - Dimensions, Areas and Weights
- Table 13.12 - American Standard Tees - Dimensions, Areas and Weights
- Table 13.13 - American Standard Zees - Dimensions, Areas and Weights

References to Other Structural Profile Information in Aluminum Standards and Data

TABLE 13.1 Mechanical Property Limits ①—Structural Profiles

ALLOY AND TEMPER	TENSILE STRENGTH ksi min.		ELONGATION percent min. in 2 in. or 4D ②
	ULTIMATE	YIELD	
6061			
6061-T6	38.0	35.0	10 ③

① The data base and criteria upon which these mechanical property limits are established are outlined on page 6-1 under "Mechanical Properties."

② D represents specimen diameter.

③ For thicknesses up through 0.249 inch, elongation is 8 percent.

Aluminum Association Channels and I-Beams

Several series of extruded aluminum channels and I-beams have been developed by an Aluminum Association committee and approved as Aluminum Association Standard Structural Profiles. By making more efficient use of the metal than the older standard channels and I-beams, the new profiles should prove more economical to use.

When structural profiles were first produced in aluminum, they were made by rolling. Cross-sectional dimensions and configurations were patterned after steel structural profiles of the same sizes. With the development of the extrusion process, extruded structural profiles gradually replaced the rolled profiles, and today essentially all aluminum structural profiles are extruded.

It has long been recognized that aluminum structural profiles patterned after steel profiles do not utilize the metal most efficiently. With the extrusion process, however, it is possible to produce profiles of any desired configuration, so that aluminum structural profiles no longer need to be limited to configurations produced in steel. The new profiles make better use of the metal in the cross sections, taking full advantage of the extrusion process.

The Aluminum Association channels consist of 20 profiles, including a new 2-inch size, which are intended to replace 38 old profiles. The new I-beams include 15 sections, which the committee expects will replace between 28 and 31 American Standard I-beams.

All Aluminum Association profiles feature parallel flanges. Flange thicknesses of the lighter channels are the same as those of the lighter I-beams having the same depth. The same is true of the heavier channels and I-beams. These features simplify the making of connections between structural members.

The Aluminum Association channels cover a nominal size range of 2 to 12 inches and include two profiles for each nominal size. With three exceptions, two profiles also are listed for each of the nominal sizes of I-beams, which cover a range of 3 to 12 inches. Only single profiles are included for the 5-, 7-, and 9-inch I-beams.

All of the Aluminum Association profiles are somewhat lighter than the comparable old profiles and offer the same or slightly better section properties. With their wider flanges, compared with the old profiles, all of the new profiles have substantially higher properties in the Y-Y axis, thus giving them greater structural stability.

In summary, the new profiles have the following advantages over the old profiles:

1. They use the metal more efficiently.
2. Fewer profiles do the same job.
3. Joining of structural members is improved.

Tables 13.3 and 13.4 give data on cross-sectional dimensions and areas and weights per foot for the new profiles. These tables include also the section properties needed for design purposes.

Following the tabulations for the Aluminum Association channels and I-beams are tables listing dimensions, areas and weights for angles, tees, zees, H-beams and wide-flange beams, for which Aluminum Association designs have not been developed. Tables also are included for the old channels and I-beams.

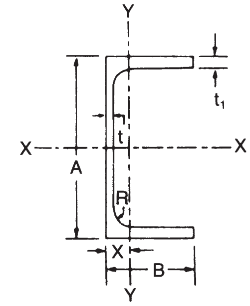


TABLE 13.3 Aluminum Association Standard Channels— Dimensions, Areas, Weights and Section Properties ④

Size		Area ① in.²	Weight ② lb./ft.	Flange Thickness t_1 in.	Web Thickness t in.	Fillet Radius R in.	Section Properties ③						
							Axis X-X			Axis Y-Y			
Depth A in.	Width B in.						I in.⁴	S in.³	r in.	I in.⁴	S in.³	r in.	x in.
2.00	1.00	0.491	0.557	0.13	0.13	0.10	0.288	0.288	0.766	0.045	0.064	0.303	0.298
2.00	1.25	0.911	1.071	0.26	0.17	0.15	0.546	0.546	0.774	0.139	0.178	0.391	0.471
3.00	1.50	0.965	1.135	0.20	0.13	0.25	1.41	0.94	1.21	0.22	0.22	0.47	0.49
3.00	1.75	1.358	1.597	0.26	0.17	0.25	1.97	1.31	1.20	0.42	0.37	0.55	0.62
4.00	2.00	1.478	1.738	0.23	0.15	0.25	3.91	1.95	1.63	0.60	0.45	0.64	0.65
4.00	2.25	1.982	2.331	0.29	0.19	0.25	5.21	2.60	1.62	1.02	0.69	0.72	0.78
5.00	2.25	1.881	2.212	0.26	0.15	0.30	7.88	3.15	2.05	0.98	0.64	0.72	0.73
5.00	2.75	2.627	3.089	0.32	0.19	0.30	11.14	4.45	2.06	2.05	1.14	0.88	0.95
6.00	2.50	2.410	2.834	0.29	0.17	0.30	14.35	4.78	2.44	1.53	0.90	0.80	0.79
6.00	3.25	3.427	4.030	0.35	0.21	0.30	21.04	7.01	2.48	3.76	1.76	1.05	1.12
7.00	2.75	2.725	3.205	0.29	0.17	0.30	22.09	6.31	2.85	2.10	1.10	0.88	0.84
7.00	3.50	4.009	4.715	0.38	0.21	0.30	33.79	9.65	2.90	5.13	2.23	1.13	1.20
8.00	3.00	3.526	4.147	0.35	0.19	0.30	37.40	9.35	3.26	3.25	1.57	0.96	0.93
8.00	3.75	4.923	5.789	0.41	0.25	0.35	52.69	13.17	3.27	7.13	2.82	1.20	1.22
9.00	3.25	4.237	4.983	0.35	0.23	0.35	54.41	12.09	3.58	4.40	1.89	1.02	0.93
9.00	4.00	5.927	6.970	0.44	0.29	0.35	78.31	17.40	3.63	9.61	3.49	1.27	1.25
10.00	3.50	5.218	6.136	0.41	0.25	0.35	83.22	16.64	3.99	6.33	2.56	1.10	1.02
10.00	4.25	7.109	8.360	0.50	0.31	0.40	116.15	23.23	4.04	13.02	4.47	1.35	1.34
12.00	4.00	7.036	8.274	0.47	0.29	0.40	159.76	26.63	4.77	11.03	3.86	1.25	1.14
12.00	5.00	10.053	11.822	0.62	0.35	0.45	239.69	39.95	4.88	25.74	7.60	1.60	1.61

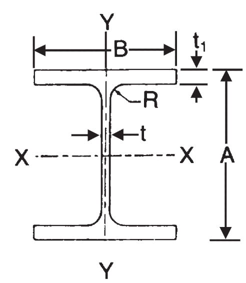


TABLE 13.4 Aluminum Association Standard I-Beams— Dimensions, Areas, Weights and Section Properties ④

Size		Area ① in.²	Weight ② lb./ft.	Flange Thickness t_1 in.	Web Thickness t in.	Fillet Radius R in.	Section Properties ③					
							Axix X-X			Axis Y-Y		
Depth A in.	Width B in.						I in.⁴	S in.³	r in.	I in.⁴	S in.³	r in.
3.00	2.50	1.392	1.637	0.20	0.13	0.25	2.24	1.49	1.27	0.52	0.42	0.61
3.00	2.50	1.726	2.030	0.26	0.15	0.25	2.71	1.81	1.25	0.68	0.54	0.63
4.00	3.00	1.965	2.311	0.23	0.15	0.25	5.62	2.81	1.69	1.04	0.69	0.73
4.00	3.00	2.375	2.793	0.29	0.17	0.25	6.71	3.36	1.68	1.31	0.87	0.74
5.00	3.50	3.146	3.700	0.32	0.19	0.30	13.94	5.58	2.11	2.29	1.31	0.85
6.00	4.00	3.427	4.030	0.29	0.19	0.30	21.99	7.33	2.53	3.10	1.55	0.95
6.00	4.00	3.990	4.692	0.35	0.21	0.30	25.50	8.50	2.53	3.74	1.87	0.97
7.00	4.50	4.932	5.800	0.38	0.23	0.30	42.89	12.25	2.95	5.78	2.57	1.08
8.00	5.00	5.256	6.181	0.35	0.23	0.30	59.69	14.92	3.37	7.30	2.92	1.18
8.00	5.00	5.972	7.023	0.41	0.25	0.30	67.78	16.94	3.37	8.55	3.42	1.20
9.00	5.50	7.110	8.361	0.44	0.27	0.30	102.02	22.67	3.79	12.22	4.44	1.31
10.00	6.00	7.352	8.646	0.41	0.25	0.40	132.09	26.42	4.24	14.78	4.93	1.42
10.00	6.00	8.747	10.286	0.50	0.29	0.40	155.79	31.16	4.22	18.03	6.01	1.44
12.00	7.00	9.925	11.672	0.47	0.29	0.40	255.57	42.60	5.07	26.90	7.69	1.65
12.00	7.00	12.153	14.292	0.62	0.31	0.40	317.33	52.89	5.11	35.48	10.14	1.71

Footnotes for Tables 13.3 and 13.4

① Areas listed are based on nominal dimensions.

② Weights per foot are based on nominal dimensions and a density of 0.098 pound per cubic inch, which is the density of alloy 6061.

③ I = moment of inertia; S = section modulus; r = radius of gyration.

④ Users are encouraged to ascertain current availability of particular structural profiles through inquiries to their suppliers.

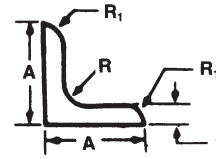


TABLE 13.5 American Standard Structural Profiles—Equal Angles ③

A	t	R	R_1	AREA ① sq. in.	WEIGHT PER FOOT ② lb.
3/4	1/8	1/8	3/32	0.171	0.201
3/4	3/16	1/8	3/32	0.246	0.289
1	3/32	1/8	3/32	0.179	0.211
1	1/8	1/8	3/32	0.234	0.275
1	3/16	1/8	3/32	0.340	0.400
1	1/4	1/8	3/32	0.437	0.514
1 1/4	1/8	3/16	1/8	0.292	0.343
1 1/4	3/16	3/16	1/8	0.434	0.510
1 1/4	1/4	3/16	1/8	0.558	0.656
1 1/2	1/8	3/16	1/8	0.360	0.432
1 1/2	3/16	3/16	1/8	0.529	0.619
1 1/2	1/4	3/16	1/8	0.688	0.809
1 3/4	1/8	3/16	1/8	0.423	0.497
1 3/4	3/16	3/16	1/8	0.622	0.731
1 3/4	1/4	3/16	1/8	0.813	0.956
1 3/4	5/16	3/16	1/8	0.996	1.171
2	1/8	1/4	1/8	0.491	0.577
2	3/16	1/4	1/8	0.723	0.850
2	1/4	1/4	1/8	0.944	1.110
2	5/16	1/4	1/8	1.160	1.364
2	3/8	1/4	1/8	1.366	1.606
2 1/2	1/8	1/4	1/8	0.616	0.724
2 1/2	3/16	1/4	1/8	0.910	1.070
2 1/2	1/4	1/4	1/8	1.194	1.404
2 1/2	5/16	1/4	1/8	1.470	1.729
2 1/2	3/8	1/4	1/8	1.714	2.047
3	3/16	5/16	1/4	1.084	1.275
3	1/4	5/16	1/4	1.432	1.684
3	5/16	5/16	1/4	1.770	2.082
3	3/8	5/16	1/4	2.104	2.474
3	7/16	5/16	1/4	2.428	2.855
3	1/2	5/16	1/4	2.744	3.227
3 1/2	1/4	3/8	1/4	1.691	1.989
3 1/2	5/16	3/8	1/4	2.093	2.461
3 1/2	3/8	3/8	1/4	2.488	2.926
3 1/2	1/2	3/8	1/4	3.253	3.826
4	1/4	3/8	1/4	1.941	2.283
4	5/16	3/8	1/4	2.406	2.829
4	3/8	3/8	1/4	2.862	3.366
4	7/16	3/8	1/4	3.310	3.893
4	1/2	3/8	1/4	3.753	4.414
4	9/16	3/8	1/4	4.187	4.924
4	6/8	3/8	1/4	4.613	5.425
4	11/16	3/8	1/4	5.032	5.918
4	3/4	3/8	1/4	5.441	6.399
5	3/8	1/2	3/8	3.603	4.237
5	7/16	1/2	3/8	4.177	4.912
5	1/2	1/2	3/8	4.743	5.578
5	6/8	1/2	3/8	5.853	6.883
6	3/8	1/2	3/8	4.353	5.119
6	7/16	1/2	3/8	5.052	5.941
6	1/2	1/2	3/8	5.743	6.754
6	5/8	1/2	3/8	7.102	8.352
8	1/2	5/8	3/8	7.773	9.141
8	3/4	5/8	3/8	11.461	13.478
8	1	5/8	3/8	15.023	17.667

For all numbered footnotes, see page 13-7.

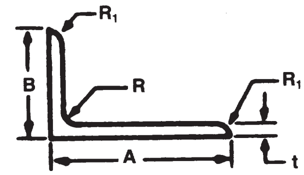


TABLE 13.6 American Standard Structural Profiles—Unequal Angles ③

A	B	t	R	R1	AREA ①	WEIGHT PER FOOT ② lb.
1 1/4	3/4	3/32	3/32	3/64	0.180	0.212
1 1/4	1	1/8	1/8	1/16	0.267	0.314
1 1/2	3/4	1/8	1/8	1/16	0.267	0.314
1 1/2	3/4	3/16	1/8	3/32	0.386	0.454
1 1/2	1	5/32	5/32	5/64	0.368	0.433
1 1/2	1	1/4	3/16	1/8	0.563	0.662
1 1/2	1 1/4	1/8	3/16	1/8	0.329	0.387
1 1/2	1 1/4	3/16	3/16	1/8	0.481	0.566
1 1/2	1 1/4	1/4	3/16	1/8	0.624	0.734
1 3/4	1 1/4	1/8	3/16	1/8	0.358	0.421
1 3/4	1 1/4	3/16	3/16	1/8	0.528	0.621
1 3/4	1 1/4	1/4	3/16	1/8	0.688	0.809
2	1 1/2	1/8	3/16	1/8	0.422	0.496
2	1 1/2	3/16	3/16	1/8	0.622	0.731
2	1 1/2	1/4	3/16	1/8	0.813	0.956
2	1 1/2	3/8	3/16	1/8	1.172	1.378
2 1/2	1 1/2	3/16	1/4	1/8	0.723	0.850
2 1/2	1 1/2	1/4	1/4	1/8	0.944	1.110
2 1/2	1 1/2	5/16	3/16	1/8	1.152	1.355
2 1/2	2	1/8	1/4	1/8	0.554	0.652
2 1/2	2	3/16	1/4	1/8	0.817	0.961
2 1/2	2	1/4	1/4	1/8	1.069	1.257
2 1/2	2	5/16	1/4	1/8	1.314	1.545
2 1/2	2	3/8	1/4	1/8	1.554	1.828
3	2	3/16	5/16	3/16	0.911	1.071
3	2	1/4	5/16	3/16	1.193	1.403
3	2	5/16	5/16	3/16	1.471	1.730
3	2	3/8	5/16	3/16	1.740	2.046
3	2	7/16	5/16	3/16	2.001	2.353
3	2 1/2	1/4	5/16	1/4	1.307	1.537
3	2 1/2	5/16	5/16	1/4	1.614	1.898
3	2 1/2	3/8	5/16	1/4	1.916	2.253
3 1/2	2 1/2	1/4	5/16	1/4	1.432	1.684
3 1/2	2 1/2	5/16	5/16	1/4	1.770	2.082
3 1/2	2 1/2	3/8	5/16	1/4	2.104	2.474
3 1/2	2 1/2	1/2	5/16	1/4	2.744	3.227
3 1/2	3	1/4	3/8	1/4	1.566	1.842
3 1/2	3	5/16	3/8	1/4	1.937	2.278
3 1/2	3	3/8	3/8	1/4	2.300	2.705
3 1/2	3	1/2	3/8	1/4	3.003	3.532
4	3	1/4	3/8	1/4	1.691	1.988
4	3	5/16	3/8	1/4	2.091	2.459
4	3	3/8	3/8	1/4	2.488	2.926
4	3	7/16	3/8	1/4	2.874	3.380
4	3	1/2	3/8	1/4	3.253	3.826
4	3	5/8	3/8	1/4	3.988	4.690
4	3 1/2	3/8	3/8	5/16	2.660	3.128
4	3 1/2	1/2	3/8	5/16	3.488	4.102
5	3	3/8	3/8	5/16	2.848	3.349
5	3	1/2	3/8	5/16	3.738	4.396
5	3 1/2	5/16	7/16	5/16	2.558	3.008
5	3 1/2	3/8	7/16	5/16	3.046	3.582
5	3 1/2	7/16	7/16	5/16	3.527	4.148
5	3 1/2	1/2	7/16	5/16	4.000	4.704
5	3 1/2	5/8	7/16	5/16	4.921	5.787
6	3 1/2	5/16	1/2	5/16	2.878	3.385
6	3 1/2	3/8	1/2	5/16	3.433	4.037
6	3 1/2	1/2	1/2	5/16	4.512	5.306
6	4	3/8	1/2	3/8	3.603	4.237
6	4	7/16	1/2	3/8	4.179	4.915
6	4	1/2	1/2	3/8	4.743	5.578
6	4	9/16	1/2	3/8	5.298	6.230
6	4	5/8	1/2	3/8	5.853	6.883
6	4	3/4	1/2	3/8	6.931	8.151
8	6	5/8	1/2	5/16	8.371	9.844
8	6	11/16	1/2	3/8	9.152	10.763
8	6	3/4	1/2	3/8	9.931	11.679

For all numbered footnotes, see page 13-7.

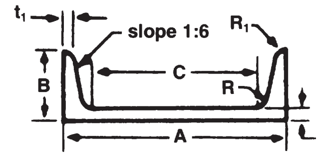


TABLE 13.7 Channels, American Standard ③

A	B	C	t	t_1	R	R_1	AREA ① sq. in.	WEIGHT PER FOOT ② lb.
3	1.410	1¾	0.170	0.170	0.270	0.100	1.205	1.417
3	1.498	1¾	0.258	0.170	0.270	0.100	1.470	1.729
3	1.596	1¾	0.356	0.170	0.270	0.100	1.764	2.074
4	1.580	2¾	0.180	0.180	0.280	0.110	1.570	1.846
4	1.647	2¾	0.247	0.180	0.280	0.110	1.838	2.161
4	1.720	2¾	0.320	0.180	0.280	0.110	2.129	2.504
5	1.750	3¾	0.190	0.190	0.290	0.110	1.969	2.316
5	1.885	3¾	0.325	0.190	0.290	0.110	2.643	3.108
5	2.032	3¾	0.472	0.190	0.290	0.110	3.380	3.975
6	1.920	4½	0.200	0.200	0.300	0.120	2.403	2.826
6	1.945	4½	0.225	0.200	0.300	0.120	2.553	3.002
6	2.034	4½	0.314	0.200	0.300	0.120	3.088	3.631
6	2.157	4½	0.437	0.200	0.300	0.120	3.825	4.498
7	2.110	5½	0.230	0.210	0.310	0.130	3.011	3.541
7	2.194	5½	0.314	0.210	0.310	0.130	3.599	4.232
7	2.299	5½	0.419	0.210	0.310	0.130	4.334	5.097
8	2.290	6¼	0.250	0.220	0.320	0.130	3.616	4.252
8	2.343	6¼	0.303	0.220	0.320	0.130	4.040	4.751
8	2.435	6¼	0.395	0.220	0.320	0.130	4.776	5.617
8	2.527	6¼	0.487	0.220	0.320	0.130	5.514	6.484
9	2.430	7¼	0.230	0.230	0.330	0.140	3.915	4.604
9	2.648	7¼	0.448	0.230	0.330	0.140	5.877	6.911
10	2.600	8¼	0.240	0.240	0.340	0.140	4.488	5.278
10	2.886	8¼	0.526	0.240	0.340	0.140	7.348	8.641
12	2.960	10	0.300	0.280	0.380	0.170	6.302	7.411
12	3.047	10	0.387	0.280	0.380	0.170	7.346	8.639
12	3.170	10	0.510	0.280	0.380	0.170	8.822	10.374
15	3.400	12⅜	0.400	0.400	0.500	0.240	9.956	11.708
15	3.716	12⅜	0.716	0.400	0.500	0.240	14.696	17.282

Footnotes for Tables 13.5 Through 13.13

① Areas listed are based on nominal dimensions.
② Weights are based on nominal dimensions and a density of 0.098 pound per cubic inch, which is the density of alloy 6061.
③ Users are encouraged to ascertain current availability of particular structural profiles through inquiries to their suppliers.

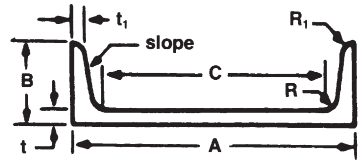


TABLE 13.8 Channels, American Standard Shipbuilding and Carbuilding

A	B	C	t	t_1	R	R_1	SLOPE	AREA [1] sq. in.	WEIGHT PER FOOT [2] lb.
3	2	$1\frac{3}{4}$	0.250	0.250	0.250	0	1:12.1	1.900	2.234
3	2	$1\frac{7}{8}$	0.375	0.375	0.188	0.375	0	2.298	2.702
4	$2\frac{1}{2}$	$2\frac{3}{8}$	0.318	0.313	0.375	0.125	1:34.9	2.825	3.322
5	$2\frac{7}{8}$	3	0.438	0.438	0.250	0.094	1:9.8	4.950	5.821
6	3	$4\frac{1}{2}$	0.500	0.375	0.375	0.250	0	4.909	5.773
6	$3\frac{1}{2}$	4	0.375	0.412	0.480	0.420	1:49.6	5.044	5.932
8	3	$5\frac{3}{4}$	0.380	0.380	0.550	0.220	1:14.43	5.600	6.586
8	$3\frac{1}{2}$	$5\frac{3}{4}$	0.425	0.471	0.525	0.375	1:28.5	6.682	7.858
10	$3\frac{1}{2}$	$7\frac{1}{2}$	0.375	0.375	0.625	0.188	1:9	7.298	8.581
10	$3\frac{9}{16}$	$7\frac{1}{2}$	0.438	0.375	0.625	0.188	1:9	7.928	9.323
10	$3\frac{5}{8}$	$7\frac{1}{2}$	0.500	0.375	0.625	0.188	1:9	8.548	10.052

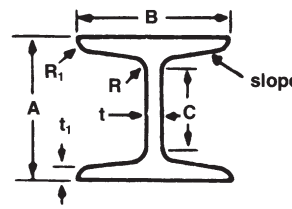


TABLE 13.9 H-Beams, American Standard

A	B	C	t	t_1	R	R_1	SLOPE	AREA [1] sq. in.	WEIGHT PER FOOT [2] lb
4	4	$2\frac{3}{8}$	0.313	0.290	0.313	0.145	1:11.3	4.046	4.758
5	5	$3\frac{3}{8}$	0.313	0.330	0.313	0.165	1:13.6	5.522	6.494
6	5.938	$4\frac{3}{8}$	0.250	0.360	0.313	0.180	1:15.6	6.678	7.853
8	7.938	$6\frac{1}{4}$	0.313	0.358	0.313	0.179	1:18.9	9.554	11.236
8	8.125	$6\frac{1}{4}$	0.500	0.358	0.313	0.179	1:18.9	11.050	12.995

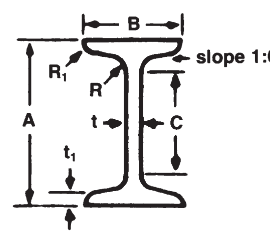


TABLE 13.10 I-Beams,[3] American Standard

A	B	C	t	t_1	R	R_1	AREA [1] sq. in.	WEIGHT PER FOOT [2] lb.
3	2.330	$1\frac{3}{4}$	0.170	0.170	0.270	0.100	1.669	1.963
3	2.509	$1\frac{3}{4}$	0.349	0.170	0.270	0.100	2.203	2.591
4	2.660	$2\frac{3}{4}$	0.190	0.190	0.290	0.110	2.249	2.644
4	2.796	$2\frac{3}{4}$	0.326	0.190	0.290	0.110	2.792	3.283
5	3	$3\frac{1}{2}$	0.210	0.210	0.310	0.130	2.917	3.430
5	3.284	$3\frac{1}{2}$	0.494	0.210	0.310	0.130	4.337	5.100
6	3.330	$4\frac{1}{2}$	0.230	0.230	0.330	0.140	3.658	4.302
6	3.443	$4\frac{1}{2}$	0.343	0.230	0.330	0.140	4.336	5.099
7	3.755	$5\frac{1}{4}$	0.345	0.250	0.350	0.150	5.147	6.053
8	4	$6\frac{1}{4}$	0.270	0.260	0.370	0.160	5.398	6.348
8	4.262	$6\frac{1}{4}$	0.532	0.270	0.370	0.160	7.494	8.813
10	4.660	8	0.310	0.310	0.410	0.190	7.452	8.764
12	5	$9\frac{3}{4}$	0.350	0.350	0.410	0.210	9.349	10.994

For all numbered footnotes, see page 13-7.

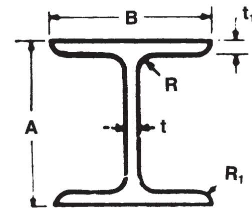


TABLE 13.11 Wide Flange Beams,[3] American Standard

A	B	t	t_1	R	R_1	AREA [1] sq. in.	WEIGHT PER FOOT [2] lb.
6.000	4.000	0.230	0.279	0.250	. .	3.538	4.161
6.000	6.000	0.240	0.269	0.250	. .	4.593	5.401
8.000	5.250	0.230	0.308	0.320	. .	5.020	5.904
8.000	6.500	0.245	0.398	0.400	. .	7.076	8.321
8.000	8.000	0.288	0.433	0.400	. .	9.120	10.725
9.750	7.964	0.292	0.433	0.500	. .	9.706	11.414
9.900	5.750	0.240	0.340	0.312	0.031	6.205	7.297
11.940	8.000	0.294	0.516	0.600	. .	11.772	13.844
12.060	10.000	0.345	0.576	0.600	. .	15.593	18.337

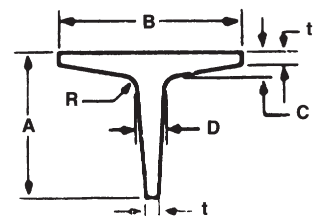


TABLE 13.12 Tees,[3] American Standard

A	B	C	D	t	R	AREA [1] sq. in.	WEIGHT PER FOOT [2] lb.
2	2	0.312	0.312	0.250	0.240	1.071	1.259
2 1/4	2 1/4	0.312	0.312	0.250	0.250	1.208	1.421
2 1/2	2 1/2	0.375	0.375	0.312	0.250	1.626	1.912
3	3	0.438	0.438	0.375	0.312	2.310	2.717
4	4	0.438	0.438	0.375	0.500	3.183	3.743

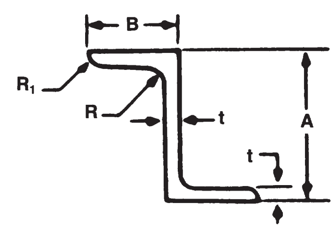


TABLE 13.13 Zees,[3] American Standard

A	B	t	R	R_1	AREA [1] sq. in.	WEIGHT PER FOOT lb.
3	2 11/16	0.250	0.312	0.250	1.984	2.333
3	2 11/16	0.375	0.312	0.250	2.875	3.381
4	3 1/16	0.250	0.312	0.250	2.422	2.848
4 1/16	3 1/8	0.312	0.312	0.250	3.040	3.575
4 1/4	3 3/16	0.375	0.312	0.250	3.672	4.318
5	3 1/4	0.500	0.312	0.250	5.265	6.192
5 1/16	3 5/16	0.375	0.312	0.250	4.093	4.813

For all numbered footnotes, see page 13-7.

14. Forging Stock

Introduction

Section 14. of Aluminum Standards and Data covers the mechanical property limits and product dimensional tolerance limits for aluminum alloy forging stock. These limits are statistically based guaranteed limits, and may be used as the basis of design. Note that the limits applicable in any specific situation are those for the specific size of product ordered.

Mechanical Property Limits for Aluminum Alloy Forging Stock

Aluminum alloy forging stock is produced and sold in the as-fabricated (F temper) condition, for which mechanical properties are not specified or determined.

Special Note: The applicable limits for any individual product are those that apply to the specified (ordered) dimension.

Dimensional Tolerance Limits for Aluminum Alloy Forging Stock

Aluminum industry guaranteed tolerance limits for aluminum alloy forging stock are shown in the following tables:

Table 14.3 - Thickness and Width
Table 14.4 - Length, Specific and Multiple

References to Other Forging Stock Information in Aluminum Standards and Data

TABLE 14.1 Diameter ①—Round Forging Stock

CLASS 1. FORGING STOCK			CLASS 2. FORGING STOCK	
SPECIFIED DIAMETER in.	TOLERANCE in. plus and minus		SPECIFIED DIAMETER in.	TOLERANCE in. plus and minus
	ALLOWABLE DEVIATION FROM SPECIFIED DIAMETER	CONDITIONING ALLOWANCE ②		ALLOWABLE DEVIATION FROM SPECIFIED DIAMETER
0.375–0.500	.015	–1/32	0.375–0.500	.0015
0.501–1.000	.015	–1/32	0.501–1.000	.002
1.001–1.500	.015	–1/32	1.001–1.500	.0025
1.501–3.000	.015	–1/32	1.501–3.000	.008
3.001–5.000	.031	–1/16	. .	. .
5.001–8.000	.063	–1/16	. .	. .

TABLE 14.2 Distance Across Flats ①—Square Forging Stock

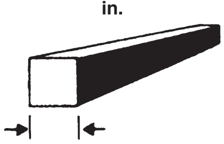
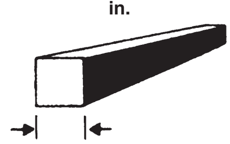
CLASS 1. FORGING STOCK			CLASS 2. FORGING STOCK	
SPECIFIED DISTANCE ACROSS FLATS in. 	TOLERANCE in. plus and minus		SPECIFIED DISTANCE ACROSS FLATS in. 	TOLERANCE in. plus and minus
	ALLOWABLE DEVIATION FROM SPECIFIED DISTANCE ACROSS FLATS	CONDITIONING ALLOWANCE ②		ALLOWABLE DEVIATION FROM SPECIFIED DISTANCE ACROSS FLATS
0.375–0.500	.010	–1/32 on face	0.375–0.500	.002
0.501–1.000	.015	–1/32 on face	0.501–1.000	.0025
1.001–2.000	.018	–1/32 on face	1.001–1.500	.003
2.001–3.000	.020	–1/32 on face	1.501–4.000	.005
3.001–4.000	.032	–1/32 on face	. .	. .

TABLE 14.3 Thickness and Width ①—Rectangular Forging Stock

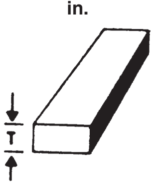
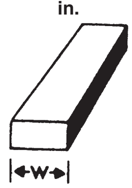
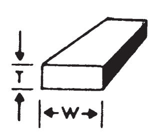
CLASS 1. FORGING STOCK						CLASS 2. FORGING STOCK	
SPECIFIED THICKNESS in. 	TOLERANCE in. plus and minus		SPECIFIED WIDTH in. 	TOLERANCE in. plus and minus		SPECIFIED THICKNESS OR WIDTH in. 	TOLERANCE in. plus and minus
	ALLOWABLE DEVIATION FROM SPECIFIED THICKNESS	CONDITIONING ALLOWANCE ②		ALLOWABLE DEVIATION FROM SPECIFIED WIDTH	CONDITIONING ALLOWANCE ②		ALLOWABLE DEVIATION FROM SPECIFIED THICKNESS OR WIDTH
0.375–0.500	.010	–1/32 on face	Up thru 1.500	.018	–1/16 on face	0.375–0.500	.002
0.501–1.000	.015	–1/32 on face	1.501–4.000	.030	–1/16 on face	0.501–1.000	.0025
1.001–2.000	.018	–1/32 on face	4.001–6.000	.047	–1/16 on face	1.001–1.500	.003
2.001–3.000	.020	–1/32 on face	6.001–10.000	.063	–1/16 on face	1.501–4.000	.005

TABLE 14.4 Length ①—Specific and Multiple—Forging Stock

SPECIFIED DIAMETER, WIDTH OR DISTANCE ACROSS FLATS in.	TOLERANCE—in. plus ALLOWABLE DEVIATION FROM SPECIFIED LENGTH SPECIFIED LENGTH—ft.			
	Up thru 12	Over 12 thru 30	Over 30 thru 50	Over 50
Up thru 2.999	1/8	1/4	3/8	1
3.000–7.999	3/16	5/16	7/16	1
8.000 and over	1/4	3/8	1/2	1

Footnotes for Tables 14.1 and14.4

① These tolerances are applicable for forging stock in rod and bar form. Standard tolerances for forging stock in sheet and plate form are as indicated in the section on Sheet and Plate.

② Conditioning allowance is an additional tolerance at localized areas to permit removal of possible surface defects.

15. Forgings

Introduction

Section 15. of Aluminum Standards and Data covers the mechanical property limits and product dimensional tolerance limits for aluminum alloy forging stock. These limits are statistically based guaranteed limits, and may be used as the basis of design. Note that the limits applicable in any specific situation are those for the specific size of product ordered.

Mechanical Property Limits For Aluminum Alloy Forgings

Specified aluminum industry mechanical property limits for aluminum alloy forgings are shown in the following tables:

- Table 15.1 - Mechanical Property Limits - Die Forgings
- Table 15.2 - Mechanical Property Limits - Hand Forgings
- Table 15.4 - Mechanical Property Limits - Rolled Rings

Note that the limits shown are statistically-based guaranteed limits, and are thus suitable for design.

Special Note: The applicable limits for any individual product are those that apply to the specified (ordered) dimension.

Dimensional Tolerance Limits For Aluminum Alloy Forgings

Specific aluminum industry guaranteed standard tolerance limits for aluminum alloy hand forgings are shown in Table 15.3. Tolerances for other aluminum alloy forgings shall be as agreed upon between purchaser and vendor at the time the contract or order is entered.

Some general comments on the applicability of tolerances from these tables are given on p. 4-16 of Aluminum Standards and Data. For forgings, it is appropriate to note that these published tolerance limits represent industry standards that are agreed to and capable of being met by all members of the industry. Thus they represent the maximum tolerances that can be provided by any producer; in no case should tolerance ranges larger than these values be provided.

In some cases, substantially tighter limits (i.e., smaller ranges of thickness, width and/or length) may be obtained from individual producers upon special order. In this regard, for example, it is broadly understood in the industry that it may be possible to order product from many suppliers to dimensional tolerances that are one-half those in the limit tables.

For additional information of specific tolerance ranges available, contact producers directly.

References to Other Extruded Wire, Rod, Bar and Profile Information in Aluminum Standards and Data

TABLE 15.1 Mechanical Property Limits—Die Forgings ①

ALLOY AND TEMPER	SPECIFIED THICKNESS ② in.	SPECIMEN AXIS PARALLEL TO DIRECTION OF GRAIN FLOW				SPECIMEN AXIS NOT PARALLEL TO DIRECTION OF GRAIN FLOW			BRINELL HARDNESS④
		TENSILE STRENGTH ksi min.		ELONGATION percent min. in 2 in. or 4D ③		TENSILE STRENGTH ksi min.		ELONGATION percent min. in 2 in. or 4D ③	500 Kg Load—10 mm ball min.
		ULTIMATE	YIELD	COUPON	FORGING	ULTIMATE	YIELD	FORGING	
1100-H112 ⑤	Up thru 4.000	11.0	4.0	25	18	. .	. .	. .	20
2014-T4	Up thru 4.000	55.0	30.0	16	11	. .	. .	. .	100
2014-T6	Up thru 1.000	65.0	56.0	8	6	64.0	55.0	3	125
	1.001–2.000	65.0	56.0	⑥	6	64.0	55.0	2	125
	2.001–3.000	65.0	55.0	⑥	6	63.0	54.0	2	125
	3.001–4.000	63.0	55.0	⑥	6	63.0	54.0	2	125
2018-T61	Up thru 4.000	55.0	40.0	10	7	. .	. .	. .	100
2025-T6	Up thru 4.000	52.0	33.0	16	11	. .	. .	. .	100
2218-T61	Up thru 4.000	55.0	40.0	10	7	. .	. .	. .	100
2218-T72	Up thru 4.000	38.0	29.0	8	5	. .	. .	. .	85
2219-T6	Up thru 4.000	58.0	38.0	10	8	56.0	36.0	4	100
2618-T61	Up thru 4.000	58.0	45.0	6	4	55.0	42.0	4	115
3003-H112 ⑤	Up thru 4.000	14.0	5.0	25	18	. .	. .	. .	25
4032-T6	Up thru 4.000	52.0	42.0	5	3	. .	. .	. .	115
5083-H111 ⑤	Up thru 4.000	42.0	22.0	. .	14	39.0	20.0	12	. .
5083-H112 ⑤	Up thru 4.000	40.0	18.0	. .	16	39.0	16.0	14	. .
5456-H112 ⑤	Up thru 4.000	44.0	20.0	. .	16	. .	. .	. .	. .
6053-T6	Up thru 4.000	36.0	30.0	16	11	. .	. .	. .	75
6061-T6	Up thru 4.000	38.0	35.0	10	7	38.0	35.0	5	80
6066-T6	Up thru 4.000	50.0	45.0	12	8	. .	. .	. .	100
6151-T6	Up thru 4.000	44.0	37.0	14	10	44.0	37.0	6	90
7049-T73 ⑧	Up thru 1.000	72.0	62.0	10	7	71.0	61.0	3	135
	1.001–2.000	72.0	62.0	10	7	70.0	60.0	3	135
	2.001–3.000	71.0	61.0	10	7	70.0	60.0	3	135
	3.001–4.000	71.0	61.0	10	7	70.0	60.0	2	135
	4.001–5.000	70.0	60.0	10	7	68.0	58.0	2	135
7050-T74 ⑦ ⑨	Up thru 2.000	72.0	62.0	. .	7	68.0	56.0	5	. .
	2.001–4.000	71.0	61.0	. .	7	67.0	55.0	4	. .
	4.001–5.000	70.0	60.0	. .	7	66.0	54.0	3	. .
	5.001–6.000	70.0	59.0	. .	7	66.0	54.0	3	. .
7075-T6	Up thru 1.000	75.0	64.0	10	7	71.0	61.0	3	135
	1.001–2.000	74.0	63.0	⑥	7	71.0	61.0	3	135
	2.001–3.000	74.0	63.0	⑥	7	70.0	60.0	3	135
	3.001–4.000	73.0	62.0	⑥	7	70.0	60.0	2	135
7075-T73 ⑧	Up thru 3.000	66.0	56.0	. .	7	62.0	53.0	3	125
	3.001–4.000	64.0	55.0	. .	7	61.0	52.0	2	125
7075-T7352 ⑧	Up thru 3.000	66.0	56.0	. .	7	62.0	51.0	3	125
	3.001–4.000	64.0	53.0	. .	7	61.0	49.0	2	125
7175-T74 ⑨ ⑩	Up thru 3.000	76.0	66.0	. .	7	71.0	62.0	4	. .
7175-T7452 ⑨ ⑩	Up thru 3.000	73.0	63.0	. .	7	68.0	55.0	4	. .
7175-T7454 ⑨ ⑩	Up thru 3.000	75.0	65.0	. .	7	70.0	61.0	4	. .

Footnotes for Table 15.1

① The data base and criteria upon which these mechanical property limits are established are outlined on page 6-1 under "Mechanical Properties."

② As-forged thickness. When forgings are machined prior to heat treatment, the properties will also apply to the machined heat treat thickness, provided the machined thickness is not less than one-half the original (as-forged) thickness.

③ D equals specimen diameter.

④ For information only: The Brinell Hardness is usually measured on the surface of a heat-treated forging using a 500 kg load and a 10 mm penetrator ball.

⑤ Properties of H111 and H112 temper forgings are dependent on the equivalent cold work in the forgings. The properties listed should be attainable in any forging within the prescribed thickness range and may be considerably exceeded in some cases.

⑥ When separately forged coupons are used to verify acceptability of forgings in the indicated thicknesses, the properties shown for thicknesses "Up thru 1 inch," including the test coupon elongation, apply.

⑦ Material in this temper when tested at any plane in accordance with ASTM G34 will exhibit exfoliation less than that shown in Photo EB, Figure 2 of ASTM G34. Also, material, 0.750 inch and thicker, when tested in accordance with ASTM G47 in the short transverse direction at a stress level of 35 ksi, will exhibit no evidence of stress corrosion cracking. Capability of individual lots to resist exfoliation corrosion and stress corrosion cracking is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined on pages 6-7 through 6-10.

⑧ Material in this temper, 0.750 inch and thicker, when tested in accordance with ASTM G47 in the short transverse direction at a stress level of 75 percent of the specified minimum yield strength, will exhibit no evidence of stress corrosion cracking. Capability of individual lots to resist stress corrosion is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined on pages 6-7 through 6-10.

⑨ T74 type tempers, although not previously registered, have appeared in the literature and in some specifications as T736 type tempers.

⑩ Material 0.750 inch and thicker when tested in accordance with ASTM G47 short transverse direction at a stress level of 35 Ksi for thicknesses 3.000" and less, or 50% of the registered longitudinal yield strength for thickness greater than 3.000, will exhibit no evidence of stress corrosion cracking. Capability of individual lots to resist stress corrosion cracking is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined on pages 6-7 through 6-10.

TABLE 15.2 Mechanical Property Limits—Hand Forgings ① ② ⑤

ALLOY AND TEMPER	SPECIFIED THICKNESS ③ in.	AXIS OF TEST SPECIMEN	TENSILE STRENGTH ksi min		ELONGATION percent min in 2 in. or 4D ④
			ULTIMATE	YIELD	
2014					
2014-T6	Up thru 2.000	Longitudinal* Long transverse	65.0 65.0	56.0 56.0	8 3
	2.001–3.000	Longitudinal* Long transverse Short transverse	64.0 64.0 62.0	56.0 55.0 55.0	8 3 2
	3.001–4.000	Longitudinal* Long transverse Short transverse	63.0 63.0 61.0	55.0 55.0 54.0	8 3 2
	4.001–5.000	Longitudinal* Long transverse Short transverse	62.0 62.0 60.0	54.0 54.0 53.0	7 2 1
	5.001–6.000	Longitudinal* Long transverse Short transverse	61.0 61.0 59.0	53.0 53.0 53.0	7 2 1
	6.001–7.000	Longitudinal* Long transverse Short transverse	60.0 60.0 58.0	52.0 52.0 52.0	6 2 1
	7.001–8.000	Longitudinal* Long transverse Short transverse	59.0 59.0 57.0	51.0 51.0 51.0	6 2 1
2014-T652	Up thru 2.000	Longitudinal* Long transverse	65.0 65.0	56.0 56.0	8 3
	2.001–3.000	Longitudinal* Long transverse Short transverse	64.0 64.0 62.0	56.0 55.0 52.0	8 3 2
	3.001–4.000	Longitudinal* Long transverse Short transverse	63.0 63.0 61.0	55.0 55.0 51.0	8 3 2
	4.001–5.000	Longitudinal* Long transverse Short transverse	62.0 62.0 60.0	54.0 54.0 50.0	7 2 1
	5.001–6.000	Longitudinal* Long transverse Short transverse	61.0 61.0 59.0	53.0 53.0 50.0	7 2 1
	6.001–7.000	Longitudinal* Long transverse Short transverse	60.0 60.0 58.0	52.0 52.0 49.0	6 2 1
	7.001–8.000	Longitudinal* Long transverse Short transverse	59.0 59.0 57.0	51.0 51.0 48.0	6 2 1
2219					
2219-T6	Up thru 4.000	Longitudinal* Long transverse Short transverse ⑦	58.0 55.0 53.0	40.0 37.0 35.0	6 4 2
2219-T852	Up thru 4.000	Longitudinal* Long transverse Short transverse ⑦	62.0 62.0 60.0	50.0 49.0 46.0	6 4 3
2618					
2618-T61	Up thru 2.000	Longitudinal* Long transverse Short transverse	58.0 55.0 52.0	47.0 42.0 42.0	7 5 4
	2.001–3.000	Longitudinal* Long transverse Short transverse	57.0 55.0 52.0	46.0 42.0 42.0	7 5 4
	3.001–4.000	Longitudinal* Long transverse Short transverse	56.0 53.0 51.0	45.0 40.0 39.0	7 5 4
5083					
5083-H111	Up thru 4.000	Longitudinal* Long transverse	42.0 39.0	22.0 20.0	14 12
5083-H112	Up thru 4.000	Longitudinal* Long transverse	40.0 39.0	18.0 16.0	16 14
5456					
5456-H112	Up thru 3.000	Longitudinal* Long transverse	44.0 42.0	20.0 18.0	16 14

For all numbered footnotes, see page 15-6.

TABLE 15.2 Mechanical Property Limits—Hand Forgings ① ② ⑤ (continued)

ALLOY AND TEMPER	SPECIFIED THICKNESS ③ in.	AXIS OF TEST SPECIMEN	TENSILE STRENGTH ksi min		ELONGATION percent min in 2 in. or 4D ④
			ULTIMATE	YIELD	
6061					
6061-T6	Up thru 4.000	Longitudinal*	38.0	35.0	10
		Long transverse	38.0	35.0	8
		Short transverse ⑦	37.0	33.0	5
	4.001–8.000	Longitudinal*	37.0	34.0	8
		Long transverse	37.0	34.0	6
		Short transverse	35.0	32.0	4
7049					
7049-T73 ⑥	2.001–3.000	Longitudinal*	71.0	61.0	9
		Long transverse	71.0	59.0	4
		Short transverse	69.0	58.0	3
	3.001–4.000	Longitudinal*	69.0	59.0	8
		Long transverse	69.0	57.0	3
		Short transverse	67.0	56.0	2
	4.001–5.000	Longitudinal*	67.0	56.0	7
		Long transverse	67.0	56.0	3
		Short transverse	66.0	55.0	2
7049-T7352 ⑥	Up thru 2.000	Longitudinal*	71.0	59.0	9
		Long transverse	71.0	57.0	4
	2.001–3.000	Longitudinal*	71.0	59.0	9
		Long transverse	71.0	57.0	4
		Short transverse	69.0	56.0	3
	3.001–4.000	Longitudinal*	69.0	57.0	8
		Long transverse	69.0	54.0	3
		Short transverse	67.0	53.0	2
	4.001–5.000	Longitudinal*	67.0	54.0	7
		Long transverse	67.0	53.0	3
		Short transverse	66.0	51.0	2
7050					
7050-T7452 ⑧ ⑨	Up thru 2.000	Longitudinal*	72.0	63.0	9
		Long transverse	71.0	61.0	5
	2.001–3.000	Longitudinal*	72.0	62.0	9
		Long transverse	70.0	60.0	5
		Short transverse	67.0	55.0	4
	3.001–4.000	Longitudinal*	71.0	61.0	9
		Long transverse	70.0	59.0	5
		Short transverse	67.0	55.0	4
	4.001–5.000	Longitudinal*	70.0	60.0	9
		Long transverse	69.0	58.0	4
		Short transverse	66.0	54.0	3
	5.001–6.000	Longitudinal*	69.0	59.0	9
		Long transverse	68.0	56.0	4
		Short transverse	66.0	53.0	3
	6.001–7.000	Longitudinal*	68.0	58.0	9
		Long transverse	67.0	56.0	4
		Short transverse	65.0	52.0	3
	7.001–8.000	Longitudinal*	67.0	57.0	9
		Long transverse	66.0	52.0	4
		Short transverse	64.0	50.0	3
7075					
7075-T6	Up thru 2.000	Longitudinal*	74.0	63.0	9
		Long transverse	73.0	61.0	4
	2.001–3.000	Longitudinal*	73.0	61.0	9
		Long transverse	71.0	59.0	4
		Short transverse	69.0	58.0	3
	3.001–4.000	Longitudinal*	71.0	60.0	8
		Long transverse	70.0	58.0	3
		Short transverse	68.0	57.0	2
	4.001–5.000	Longitudinal*	69.0	58.0	7
		Long transverse	68.0	56.0	3
		Short transverse	66.0	56.0	2
	5.001–6.000	Longitudinal*	68.0	56.0	6
		Long transverse	66.0	55.0	3
		Short transverse	65.0	55.0	2

For all numbered footnotes, see page 15-6.

TABLE 15.2 Mechanical Property Limits—Hand Forgings ① ② ⑤ (concluded)

ALLOY AND TEMPER	SPECIFIED THICKNESS ③ in.	AXIS OF TEST SPECIMEN	TENSILE STRENGTH ksi min		ELONGATION percent min in 2 in. or 4D ④
			ULTIMATE	YIELD	
7075 (Continued)					
7075-T652	Up thru 2.000	Longitudinal*	74.0	63.0	9
		Long transverse	73.0	61.0	4
	2.001–3.000	Longitudinal*	73.0	61.0	9
		Long transverse	71.0	59.0	4
		Short transverse	69.0	57.0	2
	3.001–4.000	Longitudinal*	71.0	60.0	8
		Long transverse	70.0	58.0	3
		Short transverse	68.0	56.0	1
	4.001–5.000	Longitudinal*	69.0	58.0	7
		Long transverse	68.0	56.0	3
		Short transverse	66.0	55.0	1
	5.001–6.000	Longitudinal*	68.0	56.0	6
		Long transverse	68.0	55.0	3
		Short transverse	65.0	54.0	1
7075-T73 ⑥	Up thru 3.000	Longitudinal*	66.0	56.0	7
		Long transverse	64.0	54.0	4
		Short transverse ⑦	61.0	52.0	3
	3.001–4.000	Longitudinal*	64.0	55.0	7
		Long transverse	63.0	53.0	3
		Short transverse	60.0	51.0	2
	4.001–5.000	Longitudinal*	62.0	53.0	7
		Long transverse	61.0	51.0	3
		Short transverse	58.0	50.0	2
	5.001–6.000	Longitudinal*	61.0	51.0	6
		Long transverse	59.0	50.0	3
		Short transverse	57.0	49.0	2
7075-T7352 ⑥	Up thru 3.000	Longitudinal*	66.0	54.0	7
		Long transverse	64.0	52.0	4
		Short transverse ⑦	61.0	50.0	3
	3.001–4.000	Longitudinal*	64.0	53.0	7
		Long transverse	63.0	50.0	3
		Short transverse	60.0	48.0	2
	4.001–5.000	Longitudinal*	62.0	51.0	7
		Long transverse	61.0	48.0	3
		Short transverse	58.0	46.0	2
	5.001–6.000	Longitudinal*	61.0	49.0	6
		Long transverse	59.0	46.0	3
		Short transverse	57.0	44.0	2
7175					
7175-T74 ⑧ ⑩	Up thru 2.000	Longitudinal	73.0	63.0	9
		Long transverse	71.0	60.0	5
	2.001–3.000	Longitudinal	73.0	63.0	9
		Long transverse	71.0	60.0	5
		Short transverse	69.0	60.0	4
	3.001–4.000	Longitudinal	71.0	61.0	9
		Long transverse	70.0	58.0	5
		Short transverse	68.0	57.0	4
	4.001–5.000	Longitudinal	68.0	57.0	8
		Long transverse	67.0	56.0	5
		Short transverse	66.0	55.0	4
	5.001–6.000	Longitudinal	65.0	54.0	8
		Long transverse	64.0	52.0	5
		Short transverse	63.0	52.0	4
7175-T7452 ⑧ ⑩	Up thru 2.000	Longitudinal	71.0	61.0	9
		Long transverse	69.0	58.0	5
	2.001–3.000	Longitudinal	71.0	61.0	9
		Long transverse	69.0	58.0	5
		Short transverse	67.0	54.0	4
	3.001–4.000	Longitudinal	68.0	57.0	9
		Long transverse	67.0	55.0	5
		Short transverse	65.0	51.0	4
	4.001–5.000	Longitudinal	65.0	54.0	8
		Long transverse	64.0	52.0	5
		Short transverse	63.0	49.0	4
	5.001–6.000	Longitudinal	63.0	51.0	8
		Long transverse	61.0	49.0	5
		Short transverse	60.0	46.0	4

For all numbered footnotes, see page 15-6.

Footnotes for Table 15.2

* Tensile tests are performed and properties are guaranteed only when specifically required by purchase order or contract.
① Maximum cross-sectional area 256 square inches, except 2618-T61 is 144 square inches.
② These properties are not applicable to upset biscuit forgings or to rolled forged rings.
③ As-forged thickness. When forgings are machined prior to heat treatment, the properties will also apply to the machined heat treat thickness, provided the original (as-forged) thickness does not exceed the maximum thickness for the alloy as listed.
④ D represents specimen diameter.
⑤ The data base and criteria upon which these mechanical property limits are established are outlined on page 6-1 under "Mechanical Properties."
⑥ Material in this temper, 0.750 inch and thicker, when tested in accordance with ASTM G47 in the short transverse direction at a stress level of 75 percent of the specified minimum yield strength, will exhibit no evidence of stress corrosion cracking. Capability of individual lots to resist stress corrosion is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined on pages 6-7 through 6-10.
⑦ Short transverse properties not applicable to thicknesses 2 in. or less.
⑧ T74 type tempers, although not previously registered, have appeared in the literature and in some specifications as T736 type tempers.
⑨ Material in this temper when tested at any plane in accordance with ASTM G34 will exhibit exfoliation less than that shown in Photo EB, Figure 2 of ASTM G34. Also, material, 0.750 inch and thicker, when tested in accordance with ASTM G47 in the short transverse direction at a stress level of 35 ksi, will exhibit no evidence of stress corrosion cracking. Capability of individual lots to resist exfoliation corrosion and stress corrosion cracking is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined on pages 6-7 through 6-10.
⑩ Material 0.750 inch and thicker, when tested in accordance with ASTM G47 in the short transverse direction at a stress level of 35 Ksi for thicknesses 3.000" and less, or 50% of the registered longitudinal yield strength for thickness greater than 3.000, will exhibit no evidence of stress corrosion cracking. Capability of individual lots to resist stress corrosion is determined by testing the previously selected tensile test sample in accordance with the applicable lot acceptance criteria outlined on pages 6-7 through 6-10.

TABLE 15.3 Standard Tolerances ① For Hand Forgings

ORDERED LENGTH in.	STRAIGHTNESS ② in.	DIMENSIONAL TOLERANCES		
		THICKNESS in., max.	WIDTH ③ in., max.	LENGTH in., max.
up thru 71.99	0.250	0.250	0.375	1.000
72.00–149.99	0.375	0.250	0.500	1.000
150.00 and over	0.500	0.375	0.750	1.000

① Corner radii may vary from 0 to 0.500 inches.
② As measured with the hand forging resting on a flat surface.
③ Measured exclusive of edge bulges typically present on compression cold work forgings.

TABLE 15.4 Mechanical Property Limits—Rolled Rings ① ④

ALLOY AND TEMPER	SPECIFIED WALL THICKNESS in.	AXIS OF TEST SPECIMEN	TENSILE STRENGTH ksi min.		ELONGATION percent min. in 2 in. or 4D ③
			ULTIMATE	YIELD	
2014-T6 and T652	Up thru 2.500	Tangential	65.0	55.0	7
		Axial	62.0	55.0	3
		Radial ②	60.0	52.0	2
	2.501–3.000	Tangential	65.0	55.0	6
		Axial	62.0	52.0	2
		Radial ②	. .	. .	. .
2219-T6	Up thru 2.500	Tangential	56.0	40.0	6
		Axial	55.0	37.0	4
		Radial ②	53.0	35.0	2
2618-T61	Up thru 2.500	Tangential	55.0	41.0	6
		Axial	55.0	41.0	5
		Radial ②	. .	. .	. .
6061-T6 and T652	Up thru 2.500	Tangential	38.0	35.0	10
		Axial	38.0	35.0	8
		Radial ②	37.0	33.0	5
	2.501–3.000	Tangential	38.0	35.0	8
		Axial	38.0	35.0	6
		Radial ②	37.0	33.0	4
6151-T6 and T652	Up thru 2.500	Tangential	44.0	37.0	5
		Axial	44.0	35.0	4
		Radial ②	42.0	35.0	2
7075-T6	Up thru 2.000	Tangential	73.0	62.0	7
		Axial	72.0	61.0	3
		Radial ②	68.0	58.0	2
	2.001–3.500	Tangential	71.0	60.0	6
		Axial	70.0	59.0	3
		Radial ②	. .	. .	. .

① Applicable only to rings having an O.D. to wall thickness ratio of 10/1 or greater. Those having a smaller ratio are subject to special negotiation.
② Radial properties are not guaranteed. For wall thicknesses 2 inches and greater they will be determined when specifically requested for informational purposes only.
③ D represents test specimen diameter.
④ The data base and criteria upon which these mechanical property limits are established are outlined on page 6-1 under "Mechanical Properties."

16. Electrical Conductors

Introduction

Section 16. of Aluminum Standards and Data covers the mechanical property limits and product dimensional tolerance limits for aluminum electrical conductors. These limits are statistically based guaranteed limits, and may be used as the basis of design. Note that the limits applicable in any specific situation are those for the specific size of product ordered.

Property Limits for Aluminum Alloy Electrical Conductors

Specified aluminum industry property limits for aluminum alloy electrical conductors are shown in the following tables:

Table 16.1 - Property Limits - Drawing Stock
Table 16.2 - Property Limits - Wire
Table 16.3 - Property Limits - Rod, Bar, Tube, Pipe, Structural Profiles and Sheet
Table 16.4 - Equivalent Resistivity Values
Table 16.5 - Flatwise Bending Radii
Table 16.6 - Edgewise Bending Radii -1350-H12, H111

Note that the limits shown are statistically-based guaranteed limits, and are thus suitable for design.

Special Note: The applicable limits for any individual product are those that apply to the specified (ordered) dimension.

Dimensional Tolerance Limits for Aluminum Alloy Electrical Conductors

Specific aluminum industry guaranteed tolerance limits for aluminum alloy electrical conductor are shown in Tables 16.7 through 16.30, as listed below:

Table 16.7 - Diameter - Cold-Finished Wire
Table 16.8 - Diameter - Drawing Stock
Table 16.9 - Diameter - Magnet Wire

Rolled and Sawed-Plate Bar
Table 16.10 - Thickness - Rolled Bar
Table 16.11 - Width - Rolled Bar
Table 16.12 - Length - Rolled Bar and Sawed-Plate Bar
Table 16.13 - Straightness - Rolled Bar and Sawed-Plate Bar
Table 16.14 - Flatness (Flat Surfaces) - Rolled Bar and Sawed-Plate Bar
Table 16.15 - Angularity - Rolled Bar
Table 16.16 - Squareness of Sawcuts - Rolled Bar
Table 16.17 - Corner and Edge Radii - Rolled Bar
Table 16.18 - Thickness - Sawed-Plate Bar
Table 16.19 - Twist - Rolled Bar and Sawed-Plate Bar
Table 16.20 - Width - Sawed-Plate Bar
Table 16.21 - Corners and Edges - Sawed-Plate Bar

Extruded Electrical Conductor
Table 16.22 - Thickness, Width, Diameter - Extruded Rod and Bar
Table 16.23 - Length - Extruded Rod and Bar
Table 16.24 - Flatness (Flat Surfaces) - Extruded Bar
Table 16.25 - Twist - Extruded Bar
Table 16.26 - Straightness - Extruded Rod and Bar
Table 16.27 - Angularity - Extruded Bar
Table 16.28 - Squareness of Cut Ends - Extruded Rod and Bar
Table 16.29 - Corner and Edge Radii - Extruded Bar

Pipe
Table 16.31 - Outside Diameter - Pipe
Table 16.32 - Wall Thickness - Pipe
Table 16.33 - Straightness - Pipe
Table 16.34 - Length - Pipe
Table 16.35 - Weight - Pipe

Electrical Conductor Structural Profiles - Aluminum industry guaranteed tolerance limits for aluminum alloy electrical conductor structural profiles are identical with those for other extruded profiles, as shown in Section 11.0, and specifically in the following tables:

Table 11.2 - Cross-Sectional Dimension Tolerances
Table 11.3 - Length
Table 11.4 - Straightness
Table 11.5 - Twist
Table 11.6 - Flatness (Flat Surfaces) - Bar, Solid and Semihollow Profiles
Table 11.7 - Flatness (Flat Surfaces) - Hollow Profiles
Table 11.8 - Surface Roughness
Table 11.9 - Contour (Curved Surfaces)
Table 11.10 - Squareness of Cut Ends
Table 11.11 - Corner and Fillet Radii
Table 11.12 - Angularity

Some general comments on the applicability and methods for calculating tolerances from these tables are given on p. 4-16 of Aluminum Standards and Data. For electrical conductors, it is appropriate to note that these published tolerance limits represent industry standards that are agreed to and capable of being met by all members of the industry. Thus they represent the maximum tolerances that can be provided by any producer; in no case should tolerance ranges larger than these values be provided.

In some cases, substantially tighter limits (i.e., smaller ranges of thickness, width and/or length) may be obtained from individual producers upon special order. In this regard, for example, it is broadly understood in the industry that it may be possible to order product from many suppliers to dimensional tolerances that are one-half those in the limit tables.

For additional information of specific tolerance ranges available, contact producers directly.

References to Other Electrical Conductor Information in Aluminum Standards and Data

TABLE 16.1 Property Limits—Drawing Stock ④—Electric Conductors

ALLOY AND TEMPER	SPECIFIED DIAMETER in.	ULTIMATE STRENGTH ksi		ELECTRICAL CON-DUCTIVITY ① min percent IACS at 68F
		min.	max.	
1350				
1350-O	0.375–1.000	8.5	14.0	61.8
1350-H12 and H22	0.375–1.000	12.0	17.0	61.5
1350-H14 and H24	0.375–1.000	15.0	20.0	61.4
1350-H16 and H26	0.375–1.000	17.0	22.0	61.3
5005				
5005-O	0.375	14.0	20.0	54.3
5005-H12 and H22	0.375	17.0	23.0	54.0
5005-H14 and H24	0.375	20.0	26.0	53.9
5005-H16 and H26	0.375	24.0	30.0	53.8
8017				
8017-H12 and H22	0.375	16.0	22.0	58.0
8030				
8030-H12	0.375	16.0	20.5	60.0
8176				
8176-H14	0.375	16.0	20.0	59.0

TABLE 16.2 Property Limits—Wire ④—Electric Conductors (Up thru 0.374 in. Diameter)

ALLOY AND TEMPER	ULTIMATE STRENGTH ksi		ELECTRICAL CON-DUCTIVITY ① min percent IACS at 68F
	min.	max.	
1350			
1350-O	8.5	14.0	61.8
1350-H12 and H22	12.0	17.0	61.0
1350-H14 and H24	15.0	20.0	61.0
1350-H16 and H26	17.0	22.0	61.0
8017			
8017-H212 ⑤	15.0	21.0	61.0
8030			
8030-H221	15.0	22.0	61.0
8176			
8176-H24	15.0	20.0	61.0

See continuation of Table 16.2 for other tempers and alloys of electric conductor wire.

TABLE 16.2 Property Limits—Wire—Electric Conductors (continued) ④

ALLOY AND TEMPER	SPECIFIED DIAMETER in.	ULTIMATE STRENGTH ksi min.		ELONGATION Percent min. in 10 in.		ELECTRICAL CONDUCTIVITY ① min. percent IACS at 68F
		Individual ②	Average ③	Individual ②	Average ③	
1350						
1350-H19	0.0105–0.0500	23.0	25.0	. .	. .	61.0
	0.0501–0.0600	27.0	29.0	1.2	1.4	
	0.0601–0.0700	27.0	28.5	1.3	1.5	
	0.0701–0.0800	26.5	28.0	1.4	1.6	
	0.0801–0.0900	26.0	27.5	1.5	1.6	
	0.0901–0.1000	25.5	27.0	1.5	1.6	
	0.1001–0.1100	24.5	26.0	1.5	1.6	
	0.1101–0.1200	24.0	25.5	1.6	1.7	
	0.1201–0.1400	23.5	25.0	1.7	1.8	
	0.1401–0.1500	23.5	24.5	1.8	1.9	
	0.1501–0.1800	23.0	24.0	1.9	2.0	
	0.1801–0.2100	23.0	24.0	2.0	2.1	
	0.2101–0.2600	22.5	23.5	2.2	2.3	
5005						
5005-H19	0.0601–0.0700	38.0	40.0	1.3	. .	53.5
	0.0701–0.0800	37.5	39.5	1.4	. .	
	0.0801–0.0900	37.0	39.0	1.5	. .	
	0.0901–0.1000	36.5	38.5	1.5	. .	
	0.1001–0.1100	36.0	38.0	1.5	. .	
	0.1101–0.1200	35.5	37.5	1.6	. .	
	0.1201–0.1400	35.0	37.0	1.7	. .	
	0.1401–0.1500	35.0	36.5	1.8	. .	
	0.1501–0.1600	34.5	36.0	1.9	. .	
	0.1601–0.2100	32.5	34.0	2.0	. .	
	0.2101–0.2600	31.5	33.0	2.2	. .	
6201						
6201-T81	0.0612–0.1327	46.0	48.0	3.0	. .	52.5
	0.1328–0.1878	44.0	46.0	3.0	. .	
8176						
8176-H24	0.0500–0.2040	15.0	17.0	10.0	. .	61.0

For all numbered footnotes, see page 16-4.

TABLE 16.3 Property Limits—Rod, Bar, Tube, Pipe, Structural Profiles and Sheet ④—Electric Conductors

PRODUCT	ALLOY AND TEMPER	SPECIFIED THICKNESS in.	TENSILE STRENGTH ksi				ELECTRICAL CONDUCTIVITY ① min. percent IACS at 68F
			ULTIMATE		YIELD		
			min.	max.	min.	max.	
Extruded rod, bar, tube, pipe, and structural profiles	1350-H111	All	8.5	. .	3.5	. .	61.0
	6101-H111	0.250–2.000	12.0	. .	8.0	. .	59.0
	6101-T6	0.125–0.500	29.0	. .	25.0	. .	55.0
	6101-T61	0.125–0.749	20.0	. .	15.0	. .	57.0
		0.750–1.499	18.0	. .	11.0	. .	57.0
		1.500–2.000	15.0	. .	8.0	. .	57.0
	6101-T63	0.125–1.000	27.0	. .	22.0	. .	56.0
	6101-T64	0.125–1.000	15.0	. .	8.0	. .	59.5
	6101-T65	0.125–0.749	25.0	32.0	20.0	27.0	56.5
Rolled bar	1350-H12	0.125–1.000	12.0	. .	8.0	. .	61.0
Sawed-plate bar	1350-H112	0.125–0.499	11.0	. .	6.0	. .	61.0
		0.500–1.000	10.0	. .	4.0	. .	61.0
		1.001–1.500	9.0	. .	3.5	. .	61.0
Sheet	1350-O	0.006–0.125	8.0	14.0	. .	. .	61.8

TABLE 16.4 Equivalent Resistivity Values —Electric Conductors

VOLUME CONDUCTIVITY percent IACS at 68°F	EQUIVALENT RESISTIVITY AT 68°F ⑥ VOLUME	
	ohm—circular mil/ft.	microhm—in.
52.5	19.754	1.2929
53.5	19.385	1.2687
53.8	19.277	1.2617
53.9	19.241	1.2593
54.0	19.206	1.2570
54.3	19.099	1.2501
55.0	18.856	1.2341
56.0	18.520	1.2121
56.5	18.356	1.2014
57.0	18.195	1.1908
59.0	17.578	1.1505
59.5	17.430	1.1408
61.0	17.002	1.1128
61.2	16.946	1.1091
61.3	16.918	1.1073
61.4	16.891	1.1055
61.5	16.863	1.1037
61.8	16.782	1.0983
62.0	16.727	1.0948
62.1	16.700	1.0931
62.2	16.674	1.0913
62.3	16.647	1.0896
62.4	16.620	1.0878

Footnotes for Tables 16.1 Through 16.4

① To convert conductivity to maximum resistivity use Table 16.4.
② Any test in a lot.
③ Average of all tests in a lot.
④ The data base and criteria upon which these mechanical property limits are established are outlined on page 6-1 under "Mechanical Properties."
⑤ Applicable up thru 0.250 in.
⑥ Equivalent weight resistivity in ohm-lb./mile^2 at 68°F equals:

$9844.8 \times \frac{1}{N} \times$, where N is the volume conductivity from the first column
and is the alloy density in lbs./in.^{3} (see Table 2.4)

Bend Properties of Bus Bar

Extruded, rolled, and sawed-plate bus bars are capable of being bent flatwise at room temperature through an angle of 90 degrees to minimum inside radii as shown in Table 16.5, without cracking, and with no evidence of slivers or other imperfections. Extruded 1350-H111 and rolled 1350-H12 bus bars whose width-to-thickness ratios do not exceed 12 and whose widths do not exceed 4 inches, are capable of being bent cold edgewise 90 degrees around mandrels having radii shown in Table 16.6, without cracking or excessive localized thinning.

Extruded 6101-H111 and T64 bars having a maximum thickness of 0.250 in. and a maximum width of 2.000 in. are capable of being bent edgewise at room temperature through an angle of 90 degrees to an inside bend radius equal to one-half the bar width without developing cracks or ruptures visible to the unaided eye.

TABLE 16.5 Flatwise Bending Radii—Bus Bar

TYPE OF BAR	ALLOY AND TEMPER	THICKNESS in.	RADIUS min. ①
Extruded	1350-H111	All	1 · thickness
	6101-H111	0.250–0.750 0.751–1.000	1 · thickness 2 · thickness
	6101-T6	0.125–0.375 0.376–0.500	2 · thickness 2½ · thickness
	6101-T61	0.125–0.500 0.501–0.749 0.750–1.000 1.001–1.625	1 · thickness 2 · thickness 3 · thickness 4 · thickness
	6101-T63	0.125–0.375 0.376–0.500 0.501–1.000	1 · thickness 1½ · thickness 2½ · thickness
	6101-T64	0.125–0.750 0.751–1.000	1 · thickness 2 · thickness
	6101-T65	0.125–0.500 0.501–0.749	1 · thickness 2 · thickness
Rolled	1350-H12	All	1 · thickness
Sawed plate	1350-H112	All	1 · thickness

① Applicable to widths up through 6 inches in the T6, T61, T63 and T65 tempers and to widths up through 12 inches for all other listed tempers. Bend radii for greater widths are subject to inquiry.

TABLE 16.6 Edgewise Bending Radi—Bus Bar 1350-H12, H111

WIDTH OF BAR–in.	MANDREL RADIUS
Up thru 0.500	½
0.501–1.000	1
1.001–1.500	1½
1.501–2.000	2
2.001–2.500	2½
2.501–3.000	3
3.001–3.500	3½
3.501–4.000	4

TABLE 16.7 Diameter—Tolerances—Cold-Finished Wire—Electric Conductors

SPECIFIED DIAMETER in.	TOLERANCE in. plus and minus or percent: ALLOWABLE DEVIATION OF MEAN ① DIAMETER FROM SPECIFIED DIAMETER
0.0100–0.0359	.0005
0.0360–0.0999	.0010
0.1000–0.2600	1%

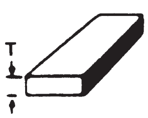
TABLE 16.8 Diameter—Tolerances—Drawing Stock—Electric Conductors

SPECIFIED DIAMETER in.	TOLERANCE—in. plus and minus: ALLOWABLE DEVIATION FROM SPECIFIED DIAMETER
0.375–0.500	.020
0.501–1.000	.025

TABLE 16.9 Diameter—Tolerances—Magnet Wire—Electric Conductors

SPECIFIED DIAMETER in.	TOLERANCE—in. plus and minus: ALLOWABLE DEVIATION OF MEAN ① DIAMETER FROM SPECIFIED DIAMETER
0.010	.0001
0.011–0.020	.0002
0.021–0.030	.0003
0.031–0.040	.0004
0.041–0.050	.0005
0.051–0.060	.0006
0.061–0.080	.0008
0.081–0.150	.0010
0.151–0.260	.0015

TABLE 16.10 Thickness—Tolerances—Rolled Bar—Electric Conductors

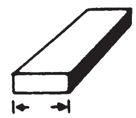


SPECIFIED THICKNESS in.	TOLERANCE in. plus and minus: ALLOWABLE DEVIATION FROM SPECIFIED THICKNESS
0.125–0.500	.006
0.501–0.750	.008
0.751–1.000	.012
1.001–2.000	.020

Footnotes for Tables 16.7 Through 16.14

① Mean diameter is the average of two measurements taken at right angles to each other at any point along the length. At least three such measurements are made, one near each end and one near the middle of the coil.
② Straightness shall be measured by placing the bar on a level table so that the arc or departure from straightness is horizontal. Measure the maximum depth of arc to the nearest 1/32 inch using a steel scale and a straightedge.
③ When weight of piece on flat surface minimizes deviation.

TABLE 16.11 Width—Tolerances—Rolled Bar—Electric Conductors



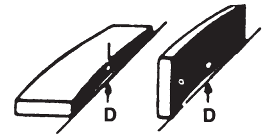
SPECIFIED WIDTH in.	TOLERANCE in. plus and minus: ALLOWABLE DEVIATION FROM SPECIFIED WIDTH
0.500–1.500	.016
1.501–4.000	.032
4.001–6.000	.047
6.001–12.000	.063

TABLE 16.12 Length—Tolerances—Rolled Bar and Sawed-Plate Bar—Electric Conductors

SPECIFIED WIDTH in.	TOLERANCE—in. plus	
	Up thru 18 ft.	Over 18 ft.
Up thru 3.499	1/8	1/4
3.500 and over	1/4	1/4

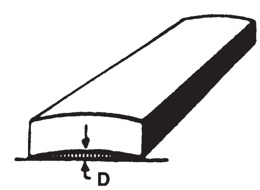
TABLE 16.13 Straightness—Tolerances—Rolled Bar and Sawed-Plate Bar—Electric Conductors

TOLERANCE ② ③—in.



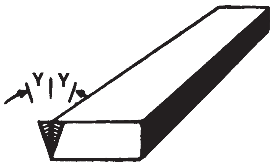
D (max.) = 1/4 inch in any 5 feet of bar length

TABLE 16.14 Flatness—Tolerances—Rolled Bar and Sawed-Plate Bar—Electric Conductors



SPECIFIED WIDTH in.	TOLERANCE—in.: Maximum Allowable Deviation D
Up thru 1	.004
Over 1	.004 · W (inches)
In any 1 in. of width	.004

TABLE 16.15 Angularity—Rolled Bar—Electric Conductors



Allowable deviation from nominal angle: ±1 degree.

TABLE 16.16 Squareness of Saw Cuts—Rolled Bar—Electric Conductors

Allowable deviation from square: 1 degree.

TABLE 16.17 Corner and Edge Radii —Tolerances—Rolled Bar—Electric Conductors

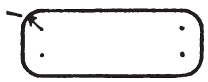
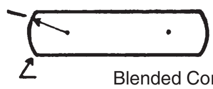
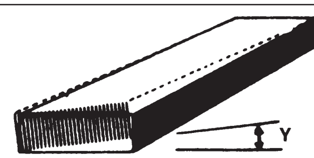
	SPECIFIED EDGE CONTOUR	SPECIFIED BAR THICKNESS in.	NOMINAL RADIUS	RADIUS TOLERANCE
Square Corners		0.125–1.000 1.001 and over	. . . .	+1/32 +1/16
Round Corners	Radius 	0.125–0.188 0.189–1.000 1.001 and over	1/32 1/16 1/8	±1/64 ±1/64 ±1/64
Rounded Edge	Radius  Blended Corners	0.125 and over	1¼ · Bar thickness	±¼ · Bar thickness
Full Rounded Edge	Radius 	All	½ · Bar thickness	+25%

TABLE 16.18 Thickness —Tolerances—Sawed-Plate Bar—Electric Conductors

SPECIFIED THICKNESS in.	TOLERANCE in. plus and minus ALLOWABLE DEVIATION FROM SPECIFIED THICKNESS
0.250–0.320	.013
0.321–0.438	.019
0.439–0.625	.025
0.626–0.875	.030
0.876–1.125	.035
1.126–1.375	.040
1.376–1.625	.045
1.626–1.875	.052
1.876–2.250	.060
2.251–2.750	.075
2.751–3.000	.090

TABLE 16.19 Twist ①—Tolerances—Sawed-Plate Bar—Electric Conductors

SPECIFIED WIDTH in.	TOLERANCE ②-DEGREES Allowable Deviation from Straight  Y (max.) in degrees	
	IN TOTAL LENGTH OR IN ANY MEASURED SEGMENT OF ONE FT. OR MORE OF TOTAL LENGTH	MAXIMUM FOR TOTAL LENGTH
Up thru 1.499	1 · Measured length, ft.	7
1.500–2.999	½ · Measured length, ft.	5
3.000 and over	¼ · Measured length, ft.	3

Footnotes for Tables 16.15 Through 16.19

① Twist is normally measured by placing the bar on a flat surface and at any point along its length measuring the maximum distance between the bottom surface of the bar and the flat surface. From this measurement, the actual deviation from straightness of the bar at that point is subtracted. The remainder is the twist. To convert the standard twist tolerance (degrees) to an equivalent linear value, the sine of the standard tolerance is multiplied by the width of the surface of the section that is on the flat surface. The following values are used to convert angular tolerances to linear deviation:

Tolerance, degrees	Maximum allowable linear deviation inch per inch of width
¼	0.004
½	0.009
1	0.017
1½	0.026
3	0.052
5	0.087
7	0.122
9	0.156
15	0.259
21	0.358

② When weight of piece on flat surface minimizes deviation.

TABLE 16.20 Width—Tolerances—Sawed-Plate Bar—Electric Conductors

SPECIFIED WIDTH in.	TOLERANCE in. plus and minus
	ALLOWABLE DEVIATION FROM SPECIFIED WIDTH
2.000–6.000	.094
6.001–14.000	.125

TABLE 16.21 Corners and Edges—Sawed-Plate Bar—Electric Conductors

Edge surfaces and rough, showing saw marks, and corners are substantially square, with a slight burr.

TABLE 16.22 Thickness, Width, Diameter—Tolerances—Extruded Rod and Bar—Electric Conductors

SPECIFIED THICKNESS WIDTH, OR DIAMETER in.	TOLERANCE ①—in. plus and minus
	ALLOWABLE DEVIATION FROM SPECIFIED DIMENSION
0.125–0.249	.007
0.250–0.499	.008
0.500–0.749	.009
0.750–0.999	.010
1.000–1.499	.012
1.500–1.999	.014
2.000–3.999	.024
4.000–5.999	.034
6.000–7.999	.044
8.000–9.999	.064
10.000–12.000	.074

TABLE 16.23 Length—Tolerances—Extruded Rod and Bar—Electric Conductors

SPECIFIED WIDTH in.	TOLERANCE—in. plus	
	ALLOWABLE DEVIATION FROM SPECIFIED LENGTH	
	SPECIFIED LENGTH—ft.	
	Up thru 12	Over 12 thru 30
Up thru 2.999	1/8	1/4
3.000–7.999	3/16	5/16
8.000 and over	1/4	3/8

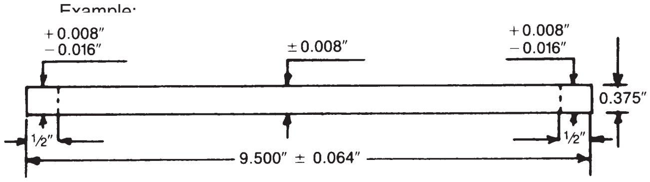
Footnotes for Tables 16.20 Through 16.23

① For some items of relatively thin wide bar greater thickness tolerances are required as follows:

a. Specified bar thickness less than 0.500 in.; corner radii 1/16 in. or less; width to thickness ratio 24 to 1 and greater.

Tolerance per Table 16.22 except for distance ½ in. from each edge where plus tolerance of Table 16.22 applies and minus tolerance of 2 · Table 16.22 tolerance applies.

Example:



b. Specified bar thickness 0.500 in. and greater; corner radii 3/16 in. or less; width to thickness ratio 10 to 1 and greater. Thickness tolerance per Table 16.22 except for distance ½ in. from edge where plus tolerance of Table 16.22 applies and minus tolerance 2 · Table 16.22 applies.

TABLE 16.24 Flatness (Flat Surfaces)—Tolerances—Extruded Bar—Electric Conductors

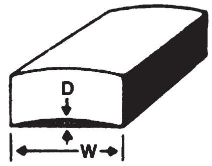
SPECIFIED WIDTH in.	TOLERANCE—in.
	 Maximum Allowable Deviation D
Up thru 1	0.004
Over 1 thru 5.999	.004 · W (inches)
In any 1 in. of width	0.004

TABLE 16.25 Twist ①—Tolerances—Extruded Bar—Electric Conductors

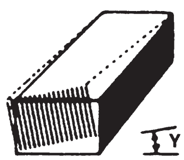
SPECIFIED WIDTH in.	TOLERANCE ②-DEGREES	
	ALLOWABLE DEVIATION FROM STRAIGHT  Y (max.) in degrees	
	IN TOTAL LENGTH OR IN ANY MEASURED SEGMENT OF ONE FT. OR MORE OF TOTAL LENGTH	MAXIMUM FOR TOTAL LENGTH
Up thru 1.499	1 · Measured length, ft.	7
1.500–2.999	½ · Measured length, ft.	5
3.000 and over	¼ · Measured length, ft.	3

TABLE 16.26 Straightness ① ②—Tolerances—Extruded Rod and Bar—Electric Conductors

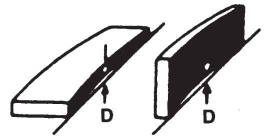
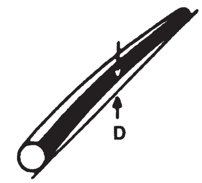
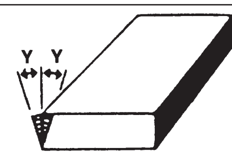
BAR		ROD	
TOLERANCE in. in any 10 ft.		SPECIFIED DIAMETER in.	TOLERANCE in.
			
Flatwise	Edgewise	D (max.)	IN TOTAL LENGTH OR IN ANY MEASURED SEGMENT OF ONE FT. OR MORE OF TOTAL LENGTH
D(max.) = ¼	D (max.) = ⅛	0.375–5.999	.010 · Measured length, ft.
		6.000 and over	.020 · Measured length, ft.

TABLE 16.27 Angularity—Extruded Bar—Electric Conductors

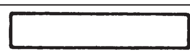
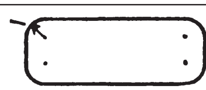
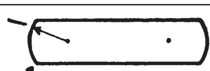


Allowable deviation from nominal angle: ±1 degree.

TABLE 16.28 Squareness of Cut Ends—Extruded Rod and Bar—Electric Conductors

Allowable deviation from square: 1 degree.

TABLE 16.29 Corner and Edge Radii—Tolerances—Extruded Bar—Electric Conductors

	SPECIFIED EDGE CONTOUR	SPECIFIED BAR THICKNESS in.	NOMINAL RADIUS	RADIUS TOLERANCE
Square Corners		0.125–1.000 1.001 and over	. . . .	+1⁄32 in. +1⁄16 in.
Round Corners	Radius 	0.125–0.188 0.189–1.000 1.001 and over	1⁄32 1⁄16 ⅛	±1⁄64 in. ±1⁄64 in. ±1⁄64 in.
Rounded Edge	Radius  Blended Corners	Up thru 0.149 0.150 and over	1¼ · Bar thickness 1¼ · Bar thickness	±1⁄64 in. ±10%
Full Rounded Edge	Radius 	Up thru 0.374 0.375 and over	½ · Bar thickness ½ · Bar thickness	±11⁄64 in. +10%

Footnotes for Tables 16.24 Through 16.29

① Deviation from straightness shall be checked as follows: Place the bar or rod on a level surface so that the departure from straightness is horizontal. Measure the maximum depth of arc to the nearest 1⁄32 inch using a steel scale and a 120-inch-long straightedge.

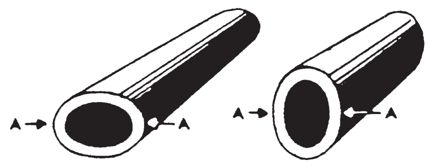
② When weight of piece on flat surface minimizes deviation.

③ Twist is normally measured by placing the bar on a flat surface and at any point along its length measuring the maximum distance between the bottom surface of the bar and the flat surface. From this measurement, the actual deviation from straightness of the bar at that point is subtracted. The remainder is the twist. To convert the standard twist tolerance (degrees) to an equivalent linear value, the sine of the standard tolerance is multiplied by the width of the surface of the section that is on the flat surface. The following values are used to convert angular tolerances to linear deviation:

Tolerance, degrees	Maximum allowable linear deviation inch per inch of width
¼	0.004
½	0.009
1	0.017
1½	0.026
3	0.052
5	0.087
7	0.122
9	0.156
15	0.259
21	0.358

TABLE 16.30 Standard Tolerances for Structural Profile (see Section 11, Extrusions)

TABLE 16.31 Outside Diameter—Tolerances —Pipe—Electric Conductors



PIPE SIZE in.	TOLERANCE—in. or percent	
	ALLOWABLE DEVIATION OF DIAMETER AT ANY POINT FROM NOMINAL DIAMETER ① ② — Difference between AA and nominal diameter	
	SCHEDULE 40 or 80	
Under 2	+.015	–.031
2–4	+1%	–1%
5–7	+1%	–1%
8–12	+1%	–1%

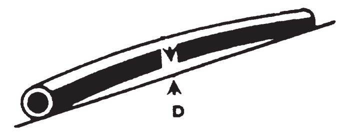
TABLE 16.32 Wall Thickness—Pipe—Electric Conductors

Allowable deviation of wall thickness at any point from nominal wall thickness ①: minus 12½ percent. (Maximum wall thickness is controlled by weight tolerance.

Footnotes for Tables 16.31 Through 16.35

① Nominal diameter and wall thickness are those listed in Table 12.55.
② Not applicable to annealed (O temper) pipe.
③ When weight of piece on flat surface minimizes deviation.

TABLE 16.33 Straightness—Tolerances —Pipe—Electric Conductors



PIPE SIZE in.	TOLERANCE ③—in.
	ALLOWABLE DEVIATION FROM STRAIGHT — D (max.)
	IN TOTAL LENGTH OR IN ANY MEASURED SEGMENT OF ONE FT. OR MORE OF TOTAL LENGTH
Under 6	0.010 · Measured length, ft.
6–12	0.020 · Measured length, ft.

TABLE 16.34 Length—Tolerances —Pipe—Electric Conductors

Allowable deviation from specified length: plus ¼ in. Applies only in lengths 20 ft. and under.

TABLE 16.35 Weight—Pipe—Electric Conductors

Allowable deviation from theoretical weight: plus 8 percent. (Minimum weight is controlled by tolerances for outside diameter and wall thickness.)

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