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Aluminum standards and data 2003

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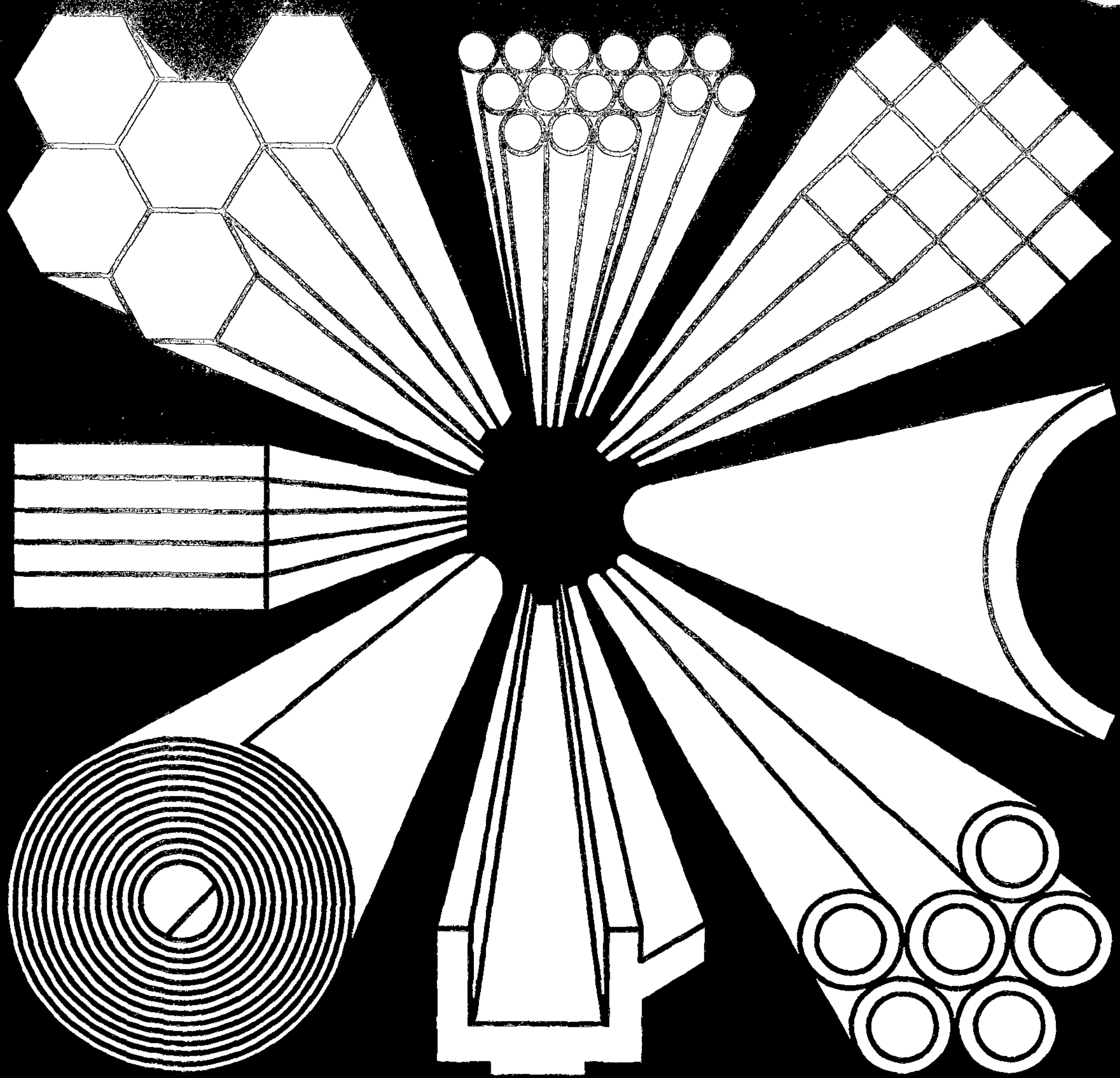

Aluminum standards and data
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About The Aluminum Association

The Aluminum Association, based in Washington, DC, with offices in Detroit, MI, represents U.S. and foreign-based primary producers of aluminum, aluminum recyclers and producers of fabricated products as well as suppliers to the industry. Member companies operate more than 200 plants in North America and many conduct business worldwide.

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All Aluminum Association published standards, data, specifications and other technical materials are reviewed and revised, reaffirmed or withdrawn. Users are advised to contact The Aluminum Association to ascertain whether the information in this publication has been superseded in the interim between publication and proposed use.

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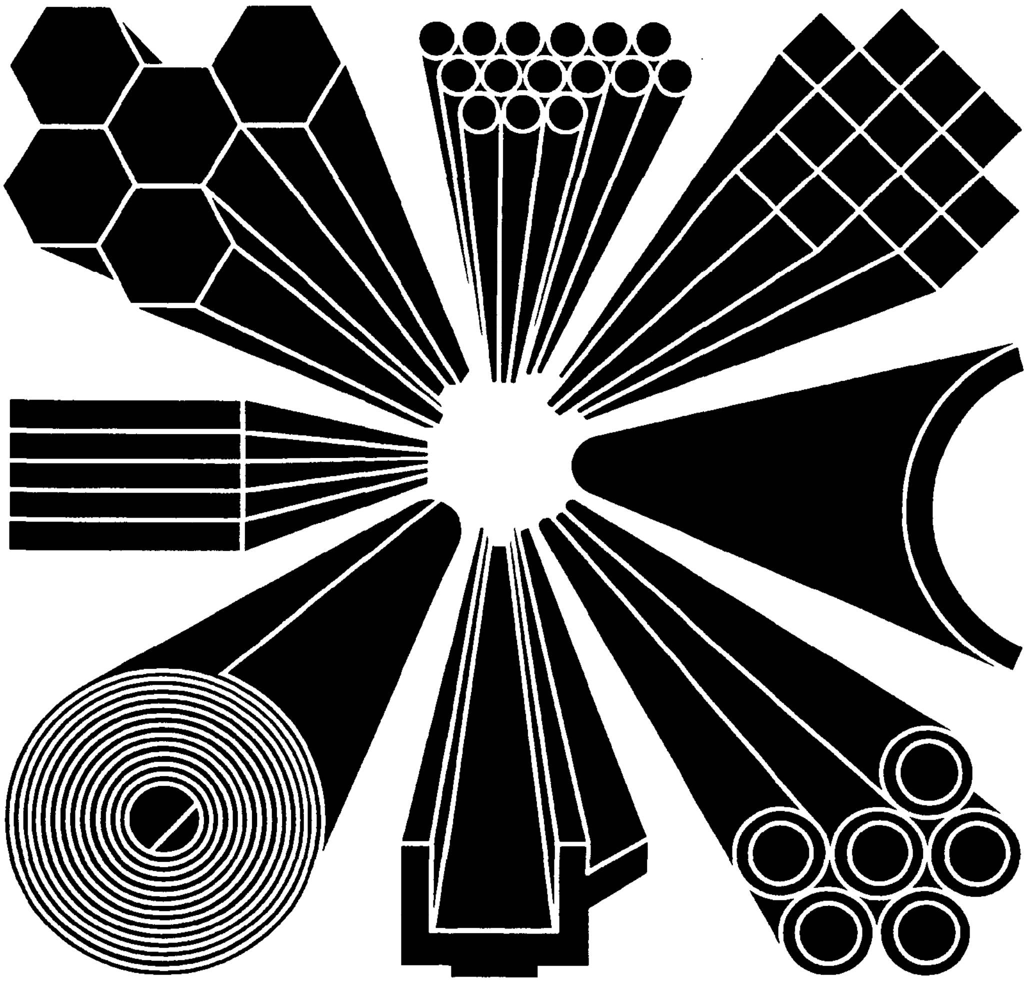

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Abbreviations Used in This Manual

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 below:

Chronological Summary of Changes to the 2000 Edition of Aluminum Standards and Data

DATE	PAGE (TABLE/ PARAGRAPH)	DESCRIPTION OF CHANGE
00-01-04	7-9 (7.1)	Extended the thickness range for 5083-H321 below 0.188 in.
00-05-30	7-34 (7-21, 22 and 23) 7-35 (7-24 and 25)	Revised footnote reference in the "Nominal Coverage Widths" column heading
00-07-13	4-1	Delete ASTM E227 as a reference document for chemical analysis
00-08-15	6-6 (6.2)	Lower the Be limit in footnote 16 to 0.0003 maximum
00-09-13	7-25 (7.6)	Correct values for 5457-O for thicknesses ⅛ in. and greater
00-10-19	3-2 (3.1)	For 3003 delete H14 in the "Rod" column
00-12-28	11-6 (11.2) 11-8 (11.3 and 11.4) 12-6 (12.2 and 12.3) 12-7 (12.4 and 12.5) 12-9	Clarify tolerances applicable to 5xxx alloys with Mg greater than or equal to 4%
01-09-21	1-4 (2.2(a)) 1-5 (2.4(a) and 3(a))	Clarification

DATE	PAGE (TABLE/ PARAGRAPH)	DESCRIPTION OF CHANGE
01-10-29	6-6 (6.2)	Corrected the upper limit for silicon
02-02-05	3-1, 2, 3 and 6 (3.1)	Corrections and deletions
02-03-01	11-10 (11.8)	Corrected decimal error
02-06-18	1-13 (1.1) 2-11 (2.3) 6-4 (6.1) 6-6 (6.2)	6253 deactivated
	1-17 (1.3) 1-21 (1.4) 3-3 (3.1) 6-4 (6.1) 4-11 10-4 (10.1)	Alclad 5056 deactivated
02-07-12	7-29 (7.17)	Footnote 1 added clarification
02-10-23	10-5 (10.2)	Extended the thickness range for 7075-T73 and T7351 above 5.000 in.
03-01-02	1-6 (3.2.2)	Identification of Structural Modifiers in Foundry Ingot
03-01-06	6-10 (6.7) 7-21 (7.2 Footnotes) 11-5 (Footnotes) 15-2 (Footnotes) 15-6 (Footnotes)	ASTM G34 Clarification

The data contained in this manual reflect a consensus of those substantially concerned with its development. The data are intended as a guide to aid the manufacturer, the consumer, and the general public. The existence of the data does not in any respect preclude anyone, whether he has approved the data or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the data. Producers of goods made in conformity with the data contained herein are encouraged on their own responsibility to state in advertising, promotion material, or on tags or labels, that the goods are produced in conformity with the data contained herein, including any ANSI standards incorporated in the manual.

The Aluminum Association has used its best efforts in compiling the information contained in this book. Although the Association believes that its compilation procedures are reliable, it does not warrant, either expressly or impliedly, the accuracy or completeness of this information. The Aluminum Association assumes no responsibility or liability for the use of the information herein.

Some of the registered alloys or tempers may be the subject of a U.S. patent or patent application, and their listing herein is not to be construed in any way as the granting of a license under such patent rights.

All Aluminum Association published standards, data, specifications and other material are reviewed at least every five years and revised, reaffirmed or withdrawn.

Users are advised to contact The Aluminum Association to ascertain whether the information in this publication has been superseded in the interim between publication and proposed use.

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 (shapes) 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)-2003

Information Note: The Aluminum Association is the registrar under ANSI H35.1 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 properties and characteristics of wrought aluminum alloy tempers registered with the Aluminum Association under ANSI H35.1 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, 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 elements②③④	
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.

①Chemical 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.

②For 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.

③Standard 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 (It is customary to express limits of 0.30 percent through 0.55 percent as 0.X0 or 0.X5)	0.XX
Over .55 percent (except that combined Si + Fe limits for 1xxx designations must be expressed as 0.XX or 1.XX)	0.X, X.X, etc.

④Standard 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.

[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 plus 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 plus 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".

(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 those 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 elements in one alloy composition, the arithmetic mean of