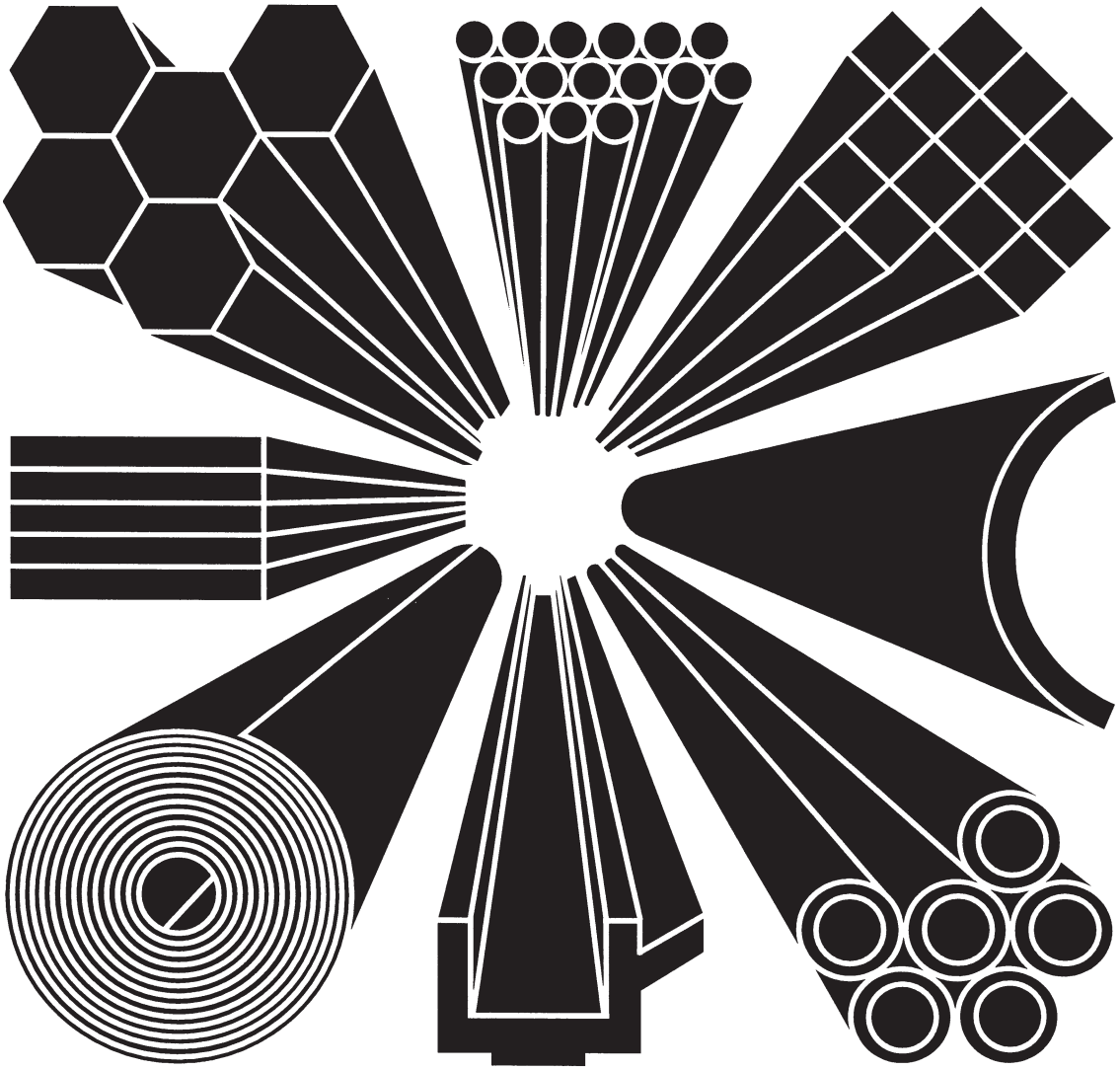
Aluminum standards and data 2013

The Aluminum Association
Incorporated



CONTENTS

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 Aluminum Association Technical Division (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 following pages:

Chronological Summary of Changes to the 2009 Edition of Aluminum Standards and Data		
DATE	**PAGE (TABLE/PARAGRAPH)**	**DESCRIPTION OF CHANGE**
13-11-13	12-10	Deleted test method of Interneral Cleanliness and revised the requirement section.
13-10-23	4-13	Added Color Code for Alloy 7185
13-10-18	1-3 (Section 2)	Revised the placement of footnote references (2, 3 and 4) and added footnote reference “13” to the heading
13-10-18	1-3 (Section 2, Paragraph 2)	Deleted word “national” and changed “will” to “shall”
13-10-18	1-3	Added footnote “13”
13-10-18	1-4 (Section 2.2, Paragraph 1)	Added wording “original alloy and”
13-10-18	1-4 (Section 2.2)	Deleted word “national” from the last paragraph
13-10-18	1-4 (Section 2.4)	Deleted word “national” from section heading
13-10-18	1-4 (Section 2.4, Paragraph 1)	Deleted “national”, “by another country” and “internationally”; and changed “following” to “after”
13-10-18	1-4 (Section 2.4, Paragraph 2)	Deleted “national” and “registered by another country”
13-10-18	1-4	Modified the placement of comma in footnote 5
13-10-18	1-5 (Section 2.4)	Changed “Different” to “change in” in parts “c” and “d”
13-10-18	1-5 (Section 2.4)	Changed “on” to “of” and added wording “expressed singly or as a combination” to part “c”
13-10-18	1-5 (Section 2.4)	Modified the last paragraph
13-10-18	1-5 (Section 3)	Revised the placement of footnote references (2, 3 and 4)
13-10-18	1-8 (Section 4.3)	Modified first paragraph
13-10-18	1-10	Modified appendix “A3” to add sections A3.1 and A3.2; and added temper designation “O2”
13-03-08	12-7 (12.4)	Revised Column 6, Eccentricity
13-03-08	12-7 (12.5)	Revised Column 5, Eccentricity
13-03-05	1-8	Addition of a definition for H1_8
12-10-25	5-5	Changed “Hard Conversion” to “Substitution” and modified definition
12-10-25	5-5	Changed “Soft Conversion” to “Conversion” and modified definition
12-09-11	4-13	Added Color Code for Alloy 7136
12-09-10	7-12 (7.2)	Deactivated Mechanical Property Limits for Alclad 2014-O Sheet and Plate over 0.500 inch
12-09-10	7-12 (7.2)	Deactivated Mechanical Property Limits to Alclad 2014-T451 Plate over 0.500 inch
12-09-10	7-12 (7.2)	Deactivated Mechanical Property Limits to Alclad 2014-T42 Sheet and Plate over 0.500 inch
12-09-10	7-12 (7.2)	Deactivated Mechanical Property Limits to Alclad 2014-T62 and T651 Plate over 0.500 inch
12-09-10	7-16 (7.2)	Deactivated Mechanical Property Limits to Alclad 2219-O Sheet and Plate over 0.500 inch
12-09-10	7-16 (7.2)	Deactivated Mechanical Property Limits to Alclad 2219-T62 Sheet and Plate over 0.500 inch
12-09-10	7-17 (7.2)	Deactivated Mechanical Property Limits to Alclad 6061-O Sheet and Plate over 0.500 inch
12-09-10	7-17 (7.2)	Deactivated Mechanical Property Limits to Alclad 6061-T451 Plate over 0.500 inch
12-09-10	7-17 (7.2)	Deactivated Mechanical Property Limits to Alclad 6061-T42 Sheet and Plate over 0.500 inch
12-09-10	7-17 (7.2)	Deactivated Mechanical Property Limits to Alclad 6061-T62 and T651 Plate over 0.500 inch
12-09-10	7-18 (7.2)	Deactivated Mechanical Property Limits to Alclad 7075-O Sheet and Plate over 0.500 inch
12-09-10	7-18 (7.2)	Deactivated Mechanical Property Limits to Alclad 7075-T62 and T651 Plate over 0.500 inch
12-09-10	7-18 (7.2)	Deactivated Mechanical Property Limits to Alclad 7075-T7351 Plate over 0.500 inch
12-09-10	7-19 (7.2)	Deactivated Mechanical Property Limits to Alclad 7075-T7651 Plate over 0.500 inch

Chronological Summary of Changes to the 2009 Edition of Aluminum Standards and Data		
DATE	**PAGE (TABLE/PARAGRAPH)**	**DESCRIPTION OF CHANGE**
12-09-10	7-19 (7.2)	Deactivated Mechanical Property Limits to 2 1⁄2% Alclad 7075-O Sheet and Plate over 0.500 inch
12-09-10	7-19 (7.2)	Deactivated Mechanical Property Limits to 2 1⁄2% Alclad 7075-T62 and T651 Plate over 0.500 inch
12-09-10	7-19 (7.2)	Deactivated Mechanical Property Limits to 2 1⁄2% Alclad 7075-T7351 Plate over 0.500 inch
12-09-10	7-19 (7.2)	Deactivated Mechanical Property Limits to 2 1⁄2% Alclad 7075-T7651 Plate over 0.500 inch
12-09-10	7-19 (7.2)	Deactivated Mechanical Property Limits to Alclad One Side 7075-O Sheet and Plate over 0.500 inch
12-09-10	7-19 (7.2)	Deactivated Mechanical Property Limits to Alclad One Side 7075-T62 and T651 Plate over 0.500 inch
12-09-10	7-19 (7.2)	Deactivated Mechanical Property Limits to 2 1⁄2% Alclad 7075-O Sheet and Plate over 0.500 inch
12-09-10	7-19 (7.2)	Deactivated Mechanical Property Limits to 2 1⁄2% Alclad One Side 7075-T62 and T651 Plate over 0.500 inch
12-07-18	1-14 (1.1)	Added Nominal Chemical Composition for 6360, and added footnote 12 and definition
12-07-18	1-21 (1.3)	Added 6360 Extrusions Specification Cross Reference
12-07-18	1-23 (1.4)	Added 6360 Extrusions to ASTM B221
12-07-18	2-3 (2.1)	Added 6360-T5 and -T6
12-07-18	2-8 (2.2)	Added 6360-T5 and -T6
12-07-18	2-11 (2.3)	Added 6360-T5 and -T6
12-07-18	2-14 (2.4)	Added 6360
12-07-18	3-5 (3.1)	Added 6360-T5 and -T6 Extrusions
12-07-18	3-10 (3.3)	Added 6360-T5 and -T6 Extrusions
12-07-18	3-14 (3.4)	Added 6360-T5 and -T6 Extrusions
12-07-18	3-17 (3.5)	Added 6360 Alloy
12-07-18	4-13	Added Color Code for Alloy 6360
12-07-18	6-6 (6.2)	Added 6360 Composition Limits
12-07-18	11-3 (11.1)	Added 6360-T5 and -T6 Extrusions
12-07-18	12-5 (12.1)	Added 6360-T5 and -T6 Extrusions
12-06-28	3-16 (3.4)	Revised definition for footnote 2
12-06-20	4-7	Revised Identification Marking section
12-06-20	4-8	Revised Identification Marking section
12-06-20	4-9	Revised Identification Marking section
12-06-20	4-10	Revised Typical Identification Marking Figure 4.1
12-06-20	4-11	Revised Typical Identification Marking Figure 4.1
12-06-12	7-9 (7.1)	Added Max UTS Limits to H116 Tempers
12-06-12	7-10 (7.1)	Added Max UTS Limits to H116 Tempers
12-06-08	4-13	Assignment of Color Codes for 2060 and 2099 in ASD Quality Control Section
12-06-04	11-5	Correction to footnote 14 for table 11.1
12-06-04	12-5	Correction to footnote 7 for table 12.1
12-05-30	12-13 (12.19)	Correction to Alloy/Temper number
12-05-08	3-14 (3.4)	Replaced footnote 13 with footnote 15 for 6063-T4 Extruded Rod, Bar, Profiles & Tube
12-04-27	6-8 (6.4)	Modified footnote 7
12-04-16	13-4 (13.3)	Realigned line under Section Properties
12-03-29	7-27 (7.10)	Correction to table heading
12-03-22	12-16 (12.22)	Insertion of minus sign in Tolerance columns
12-03-21	5-2	Modified definition for Combination
12-03-21	5-2	Modified definition for Interference Color
12-01-31	5-3	Modified definition for Billet
12-01-31	5-16	Added definition for Product, Semi-finished

Chronological Summary of Changes to the 2009 Edition of Aluminum Standards and Data		
DATE	**PAGE (TABLE/PARAGRAPH)**	**DESCRIPTION OF CHANGE**
12-01-31	5-16	Added definition for Product, Unwrought
12-01-31	5-16	Added definition for Product, Wrought
12-01-31	5-18	Added definition for Semi-finished Product
12-01-31	5-23	Added definition for Unwrought Product
12-01-31	5-24	Relocated definition for Wrought Product
11-12-30	10-7 (10.9)	Correction to width listed for 1.501-2.000 gauge range
11-12-01	2-12	Modified the first paragraph to add “nominal and weight” in second sentence
11-09-13	12-6 (12.2)	Revised table header
11-07-15	4-13	Deleted alloys 2111 and 5554 in table of color codes
11-06-24	4-13	Assigned color codes to alloys 2040 and 7085 in table of color codes
11-06-14	1-23 (1.4)	Added AMS 2770
11-06-14	3-16 (3.4)	Revised footnote 2, to replace ASTM B597 (cancelled) with ASTM B918
11-06-10	12-21 (12.48)	Modified column header and added footnotes 7 and 8
11-06-10	12-22 (12.49)	Modified column header and added footnotes 7 and 8
11-06-10	12-22 (12.49)	Changed pipe size from 5-7 to 5-6
11-06-10	12-22 (12.53)	Modified column header and added footnote 7 and 8
11-06-10	12-23 (12.55)	Modified column header to add footnote 5
11-06-10	12.24 (12.55)	Modified column header and added footnote 5
11-03-24	7-30 (7.18)	Added T7451 Temper to footnote 2
11-03-05	6-6 (6.2)	Revision to footnote 2
11-02-18	1-14 (1.1)	Deleted Alloy 7178
11-02-18	1-22 (1.3)	Deleted Alloy 7178 & Alclad 7178
11-02-18	1-23 (1.4)	Deleted Alloy 7178 & Alclad 7178
11-02-18	1-25 (1.4)	Deleted referenced spec for Alloy 7178 & Alclad 7178
11-02-18	2-4 (2.1)	Deleted Alloy 7178 & Alclad 7178
11-02-18	2-9 (2.2)	Deleted Alloy 7178
11-02-18	2-11 (2.3)	Deleted Alloy 7178
11-02-18	2-14 (2.4)	Deleted Alloy 7178
11-02-18	3-6 (3.1)	Deleted Alloy 7178 & Alclad 7178
11-02-18	3-10 (3.3)	Deleted Alloy 7178
11-02-18	3-16 (3.4)	Deleted Alloy 7178 and revised footnote 27
11-02-18	3-17 (3.5)	Deleted Alloy 7178
11-02-18	4-13	Deleted Alloy 7178
11-02-18	6-4 (6.1)	Deleted Alclad 7178 S&P
11-02-18	6-6 (6.2)	Deleted Alloy 7178
11-02-18	6-7 (6.3)	Deleted Alloy 7178
11-02-18	6-8 (6.4)	Deleted Alloy 7178
11-02-18	6-9 (6.5)	Deleted Alloy 7178
11-02-18	6-10 (6.7)	Deleted Alloy 7178
11-02-18	7-20 (7.2)	Deleted Alloy 7178 & Alclad 7178
11-02-18	7-24 (7.5)	Deleted Alloy 7178
11-02-18	7-25 (7.6)	Deleted Alloy 7178
11-02-18	7-26 (7.7b)	Deleted Alloy 7178
11-02-18	10-6 (10.3)	Deleted Alloy 7178
11-02-18	10-6 (10.4)	Deleted Alloy 7178
11-02-18	11-4 (11.1)	Deleted Alloy 7178
10-12-14	1-8	Repositioned the Appendix heading
10-12-14	1-8	Correction to definitions listed for H116 and H321

Chronological Summary of Changes to the 2009 Edition of Aluminum Standards and Data		
DATE	**PAGE (TABLE/PARAGRAPH)**	**DESCRIPTION OF CHANGE**
10-11-29	3-6 (3.1)	Revision to Footnote 2
10-11-23	2-3 (2.1)	Deleted Alloy 6101-H111
10-11-23	3-5 (3.1)	Deleted Alloy 6101-H111
10-11-23	16-4 (16.3)	Deleted Alloy 6101-H111
10-11-23	16-5 (16.5)	Deleted Alloy 6101-H111
10-11-03	2-11 (2.3)	Correction to Footnote 1
10-09-24	1-14 (1.1)	Deleted Alloy 7008
10-09-24	2-14 (2.4)	Deleted Alloy 7008
10-09-24	3-6 (3.1)	Deleted Alloy 7008
10-09-24	6-4 (6.1)	Deleted Alloy 7008
10-09-24	6-6 (6.2)	Deleted Alloy 7008
10-09-24	7-19 (7.2)	Deleted Alloy 7008
10-08-19	11-3 (11.1)	Added footnote 15 to 6082-T6, T6511
10-08-19	11-5	Added definition for footnote 15
10-08-09	12-5 (12.1)	Added footnote 8 to 6082-T6
10-08-09	12-5	Added definition for footnote 8
10-07-28	7-5 (7.1)	Correction to min Yield Strength from 9 to 9.0 for Alclad 3003-H112
10-07-28	7-6 (7.1)	Correction to min Yield Strength from 26.0 to 25.5 for 3005-H27
10-07-28	7-14 (7.2)	Correction to min Ultimate Strength from 63 to 63.0 for $1^{1}/_{2}$ Alclad 2024-T3
10-05-18	iii	Revision to Define ”AATD”
10-02-02	1-13 (1.1)	Deleted Alloy 5652
10-02-02	1-23 (1.4)	Deleted Alloy 5652 From SB-209, B209, B241
10-02-02	2-3 (2.1)	Deleted Alloy 5652
10-02-02	2-3 (2.1)	Corrected Alloy/Temper 5456-H25 to 5456-H112
10-02-02	2-8 (2.2)	Deleted Alloy 5652
10-02-02	2-10 (2.3)	Deleted Alloy 5652
10-02-02	2-14 (2.4)	Deleted Alloy 5652
10-02-02	3-4 (3.1)	Deleted Alloy 5652
10-02-02	3-9 (3.3)	Deleted Alloy 5652
10-02-02	3-17 (3.5)	Deleted Alloy 5652
10-02-02	6-5 (6.2)	Deleted Alloy 5652
10-02-02	7-10 (7.1)	Deleted Alloy 5652
10-02-02	7-20 (7.2)	Correction to Alclad 7475-T61 Sheet, Tensile Yield Strength
10-02-02	7-20 (7.2)	Correction to Alclad 7475-T761 Sheet, Specified Thickness and Tensile Yield Strength
10-02-02	7-24 (7.5)	Deleted Alloy 5652
10-02-02	7-25 (7.6)	Deleted Alloy 5652
10-02-02	7-29 (7.17)	Deleted Alloy 5652
09-11-17	2-12 & 2-13	Modifications to the Density Calculation Procedure
09-09-25	5-1	Corrected spelling in Alclad definition section
09-09-08	6-9 (6.6)	Footnote 5, Corrected width to read W=0.25
09-07-29	7-10 (7.1)	Reinstated Missing Alloy/Temper 5254-H32
09-07-10	2-8 (2.2)	Correction to Elongation of 6063-T5 at 75 °F

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