Alloy and Temper Designation Systems for Aluminum (ANSI H35.1-1988)

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 aluminum alloys. Since there is no international accord on designation and registration of tempers for aluminum alloys and aluminum alloy products, reference to ANSI H35.1 properties and characteristics of 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.

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.

2. Wrought Aluminum and Aluminum Alloy Designation System①

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 minimum 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% or higher. The alloy group in the 2xxx through 7xxx alloys 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.

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 lim-

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. 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 For codification purposes an alloying element is any element which 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 purities 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 (see Note 1); Titanium; Other Elements, Each; Other Elements, Total; Aluminum (see Note 2).

Note 1—Additional specified elements having limits are inserted in alphabetical order of their chemical symbols between zinc and titanium, or are specified in footnotes.

Note 2—Aluminum is specified as minimum for unalloyed aluminum, and as a remainder for aluminum alloys.

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 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 metallic elements present in amounts of 0.010 percent or more, each expressed to the second decimal before determining the sum.

its. 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 mean of such a combination should be 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 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 which 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 Difference*
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 mean of such a combination should be 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 8xx.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: i.e., 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 alloying element or combination of elements expressed as an individual 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 mean of such a combination should be 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 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 which has chemical composition limits conforming to 3.2.1, and xxx.2 indicates ingot which has chemical composition limits which differ but fall within the limits of xxx.1 ingot.

3.2.1 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 Sand and Permanent Mold Castings	*for Ingot*
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

for Die Castings — *for Ingot*
Up thru 1.3 . . . . . 0.3 less than castings
Over 1.3 . . . . . 1.1 maximum

Minimum Magnesium Percentage:
for All 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

3.3 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.

4. Temper Designation System®

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 which are annealed to obtain the lowest strength temper, and to cast products which 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 which 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 which 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 which 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

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

H1 **strain-hardened only.** Applies to products which 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 which 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.

H3 **strain-hardened and stabilized.** Applies to products which 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 which, unless stabilized, gradually age-soften at room temperature. The number following this designation indicates the degree of strain-hardening remaining after the stabilization treatment.

4.2.1.2 The digit following the designation H1, H2, and H3 indicates the degree of strain-hardening. Numeral 8 has been assigned to indicate tempers having an ultimate tensile strength equivalent to that achieved by a cold reduction (temperature during reduction not to exceed 120°F) of approximately 75 percent following a full anneal. Tempers between O (annealed) and 8 are designated by numerals 1 through 7. Material having an ultimate tensile strength about midway between that of the O temper and that of the 8 temper is designated by the numeral 4; about midway between O and 4 tempers by the numeral 2; and about midway between the 4 and 8 tempers by the numeral 6. Numeral 9 designates tempers whose minimum ultimate tensile strength

*Applicable only when the specified magnesium range for castings is greater than 0.15 percent.

® 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 which 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.

exceeds that of the 8 temper by 2.0 ksi or more. For two-digit H tempers whose second digit is odd, the standard limits for ultimate tensile strength are exactly midway between those of the adjacent two digit H tempers whose second digits are even.

NOTE: For alloys which cannot be cold reduced an amount sufficient to establish an ultimate tensile strength applicable to the 8 temper (75 percent cold reduction after full anneal), the 6 temper tensile strength may be established by a cold reduction of approximately 55 percent following a full anneal, or the 4 temper tensile strength may be established by a cold reduction of approximately 35 percent after a full anneal.

4.2.1.3 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

4.2.2.1 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 which 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 which 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.

T3 **solution heat-treated,⑨ cold worked, and naturally aged to a substantially stable condition.** Applies to products which 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-treated⑨ and naturally aged to a substantially stable condition.** Applies to products which 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 which 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-treated⑨ and then artificially aged.** Applies to products which 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 characteristic.⑪ 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 which 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 which are cold worked to improve strength.

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

4.2.2.2 Additional digits,⑩ the first of which shall not be zero, may be added to designations T1 through T10 to indicate a variation in treatment which significantly alters the product characteristics that are or would be obtained using the basic treatment. (See Appendix for specific additional digits for T tempers.)

4.3 Variations of O Temper: Annealed

4.3.1 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 which are strain-hardened after annealing and in which the effect of strain-hardening is recognized in the mechanical properties or other characteristics.

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.

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 6000 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 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 which do not alter the characteristics of the product are considered alternate treatments for which additional digits are not assigned.

APPENDIX

A1 Three-Digit H Tempers

A1.1 The following three-digit H temper designations have been assigned for wrought products in all alloys:

H__11 Applies to products which 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 which may acquire some temper from working at an elevated temperature and for which there are mechanical property limits.

A1.2 The following three-digit H temper designations have been assigned for

patterned 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

A2 Additional Digits for T Tempers

A2.1 The following specific additional digits have been assigned for stress-relieved tempers of wrought products:

Stress relieved by stretching.

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, shapes 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, Shapes
and Tube ..... 1 to 3% permanent set.
Drawn Tube..... ½ to 3% permanent set.

T__511 Applies to extruded rod, bar, shapes 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, Shapes
and Tube ..... 1 to 3% permanent set.
Drawn Tube..... ½ to 3% permanent set.

Stress relieved by compressing.

T__52 Applies to products which are stress-relieved by compressing after solution heat treatment or cooling from an elevated temperature shaping process to produce a permanent set of 1 to 5 percent.

Stress relieved by combined stretching and compressing.

T__54 Applies to die forgings which are stress relieved by restriking cold in the finish die.

NOTE: The same digits (51, 52, 54) may be added to the designation W to indicate unstable solution heat-treated and stress-relieved tempers.

A2.2 The following temper designations have been assigned for wrought products test material heat-treated from annealed (O,O1, etc.) or F temper to demonstrate response to heat-treatment.⑫

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.**

Temper designations T42 and T62 may also be applied to wrought products heat-treated from any temper by the user when such heat-treatment results in the mechanical properties applicable to these tempers.

A3 Assigned O Temper Variations

A3.1 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 which are to be machined prior to solution heat treatment by the user. Mechanical property limits are not applicable.**

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⑪ 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.

⑫ When the user requires capability demonstrations from T-temper, the seller shall note "capability compliance" adjacent to the specified and ending tempers. Some examples are: "–T4 to –T6 Capability Compliance as for aging" or "–T351 to –T4 Capability Compliance as for resolution heat treating."

TABLE 6.2 Chemical Composition Limits of Wrought Aluminum Alloys[1][2]

AA DESIGNATION	SILICON	IRON	COPPER	MANGANESE	MAGNESIUM	CHROMIUM	NICKEL	ZINC	TITANIUM	OTHERS[27] Each[20]	OTHERS[27] Total[3]	ALUMINUM Min.[4]
1350	0.25	0.40	0.05	0.05	0.05	..	..	0.05	0.03	0.03[9]	..	99.50
1060	0.25	0.35	0.05	0.03	0.03	..	..	0.05	0.03	0.03[9]	..	99.60
1100	0.95 Si + Fe		0.05–0.20	0.05	..	..	..	0.10	..	0.05[16]	0.15	99.00
1145[3]	0.55 Si + Fe		0.05	0.05	0.05	..	..	0.05	0.03	0.03[9]	..	99.45
1175[7]	0.15 Si + Fe		0.10	0.02	0.02	..	..	0.04	0.02	0.02[19]	..	99.75
1200	1.00 Si + Fe		0.05	0.05	..	..	..	0.10	0.05	0.05	0.15	99.00
1230[7]	0.70 Si + Fe		0.10	0.05	0.05	..	..	0.10	0.03	0.03[9]	..	99.30
1235	0.65 Si + Fe		0.05	0.05	0.05	..	..	0.10	0.06	0.03[9]	..	99.35
1345	0.03	0.40	0.10	0.05	0.05	..	..	0.05	0.03	0.03[9]	..	99.45
1350[6]	0.10	0.40	0.05	0.01	..	0.01	..	0.05	..	0.03[13]	0.10	99.50
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[18]	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[19]	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	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[15]	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 98.

TABLE 6.2 Chemical Composition Limits of Wrought Aluminum Alloys①② (concluded)

AA DESIG-NATION	SILICON	IRON	COPPER	MAN-GANESE	MAG-NESIUM	CHROM-IUM	NICKEL	ZINC	TITAN-IUM	OTHERS㉗		ALUMI-NUM
										Each⑳	Total③	Min.④
6003⑦	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
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
6101⑫	0.30–0.7	0.50	0.10	0.03	0.35–0.8	0.03	..	0.10	..	0.03⑰	0.10	Remainder
6105	0.6–1.0	0.35	0.10	0.10	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	..	0.03⑰	0.10	Remainder
6253⑦	⑮	0.50	0.10	..	1.0–1.5	0.04–0.35	..	1.6–2.4	..	0.05	0.15	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	0.05⑤	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	0.05⑭	0.15	Remainder
7008⑦	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	0.05㉑	0.15	Remainder
7072⑦	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
7108⑦	0.10	0.10	0.05	0.05	0.7–1.4	..	..	4.5–5.5	0.05	0.05㉒	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
8017	0.10	0.55–0.8	0.10–0.20	..	0.01–0.05	..	..	0.05	..	0.03㉓	0.10	Remainder
8030	0.10	0.30–0.8	0.15–0.30	..	0.05	..	..	0.05	..	0.03㉔	0.10	Remainder
8176	0.03–0.15	0.40–1.0	..	..	..	..	..	0.10	..	0.05㉕	0.15	Remainder
8177	0.10	0.25–0.45	0.04	..	0.04–0.12	..	..	0.05	..	0.03㉖	0.10	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 "others" 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 metallic elements present in amounts of 0.010 percent or more each, expressed to the second decimal before determining the sum.

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 0.0008 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; vandium 0.05 percent maximum.

⑳ In addition to those alloys referencing footnote ⑲, 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 Zirconium 0.12–0.25.

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 Includes listed elements for which no specific limit is shown.