# Alloy and Temper Designation Systems for Aluminum - SAE J993b



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**SAE STANDARD**
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# ALLOY AND TEMPER DESIGNATION SYSTEMS FOR ALUMINUM—SAE J993b

**SAE Standard**

Report of Nonferrous Metals Committee approved July 1967 and last revised September 1973. Conforms to American National Standard H35.1–1972.

*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.

*2. Wrought Aluminum and Aluminum Alloy Designation System* (see Note 5.1)—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 shown in Table 1. 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% and greater, the last two of the four digits in the designation indicate the minimum aluminum percentage (Note 5.2). 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%. The second digit in the designation indicates modifications in impurity limits. If the second digit in the designation is zero, it indicates that there is no special control on individual impurities; 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 (Note 5.3). 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.

**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.

**TABLE 1—DESIGNATION SYSTEM FOR WROUGHT ALUMINUM AND ALUMINUM ALLOY**

| Composition | Alloy No. |
|---|---|
| Aluminum, 99.0% min and greater | 1xxx |
| Aluminum alloys grouped by major alloying element[a,b,c] | |
| Copper | 2xxx |
| Manganese | 3xxx |
| Silicon | 4xxx |
| Magnesium | 5xxx |
| Magnesium and silicon | 6xxx |
| Zinc | 7xxx |
| Other element | 8xxx |
| Unused series | 9xxx |

[a]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.

[b]Standard limits for alloying elements and impurities are expressed to the following places:

| | |
|---|---|
| Less than 1/1000% | 0.000X |
| 1/1000 up to 1/100% | 0.00X |
| 1/100 up to 1/10% | |
| Unalloyed aluminum made by a refining process | 0.0XX |
| Alloys and unalloyed aluminum not made by a refining process | 0.0X |
| 1/10 through 1/2% | 0.XX |
| Over 1/2% | 0.X, X.X, etc. |

[c]Standard limits for alloying elements and impurities are expressed in the following sequence: silicon; iron; copper; manganese; magnesium; chromium; nickel; zinc (Note 1); titanium; other elements (each); other elements (Total); aluminum (Note 2).

Note 1—Addit onal 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.

**2.4 National Variations**—National variations (Note 5.4) of wrought aluminum and wrought aluminum alloys registered by another country in accordance with this system are identified by a serial letter (Note 5) before the numerical designation.

*3. Cast Aluminum and Aluminum Alloy Designation System*[1] (see Note 5.1)—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 shown in Table 2. The second two digits identify the aluminum alloy or indicate the aluminum purity. The last digit, which is separated from the others by a decimal point, indicates the product form, that is, castings or ingot. A modification of the original alloy or impurity limits is indicated by a serial letter (Note 5.6) before the numerical designation.

**3.1 Aluminum Castings and Ingot**—In the 1xx.x group for minimum aluminum purities of 99.00% and greater, the second two of the four digits in the designation indicate the minimum aluminum percentage (Note 5.2). 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%. 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. Special control of one or more individual elements other than aluminum is indicated by a serial letter (Note 5.6) before the numerical designation.

**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 paragraph 3.2.1, and xxx.2 indicates ingot which has chemical

**TABLE 2—DESIGNATION SYSTEM FOR CAST ALUMINUM AND ALUMINUM ALLOY**

| Composition | Alloy No. |
|---|---|
| Aluminum, 99.00% min and greater | 1xx.x |
| Aluminum alloy group by major alloying element[a, b, c] | |
| 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 |

[a]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.

[b]Standard limits for alloying elements and impurities are expressed to the following places:

| | |
|---|---|
| Less than 1/1000% | 0.000X |
| 1/1000 up to 1/100% | 0.00X |
| 1/100 up to 1/10% | |
| Unalloyed aluminum made by a refining process | 0.0XX |
| Alloys and unalloyed aluminum not made by a refining process | 0.0X |
| 1/10 through 1/2% | 0.XX |
| Over 1/2% | 0.X, X.X, etc. |

[c]Standard limits for alloying elements and impurities are expressed in the following sequence: silicon; iron; copper; manganese; magnesium; chromium; nickel; zinc (Note 1); titanium; other elements (each); other elements (Total); aluminum (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.

[1]The castings and ingot alloy designation system described herein is not currently in use for some SAE cast aluminum alloys. It is applicable to Aluminum Association (AA) and American National Standard Institute (ANSI), and other, specification systems. Although the chemical composition limits shown in most SAE reports conform to the limits shown for comparable castings and ingots covered in AA and ANSI publications, the designation system described herein is not currently used in SAE Standards and Information Reports.

TABLE 3

| Element, % | For Castings | For Ingot |
|---|---|---|
| Iron, max | Sand and permanent mold: | |
| | 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 |
| | Die | |
| | Up thru 1.3 | 0.3 less than castings |
| | Over 1.3 | 1.1 maximum |
| Magnesium, min | All | |
| | Less than 0.50 | 0.05 more than castings[a] |
| | 0.5 and greater | 0.1 more than castings[a] |
| Zinc, max | Die | |
| | Over 0.25 thru 0.6 | 0.10 less than castings |
| | Over 0.6 | 0.1 less than castings |

[a]Applicable only when the specified magnesium range for castings is greater than 0.15%.

composition limits that differ but fall within the limits for xxx.1 ingot. Alloy modifications (Note 5.3) are indicated by a serial letter (Note 5.9) before the numerical designation.

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 limits noted in Table 3.

**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 (Wrought Products Only)—Applies to wrought products which are fully annealed to obtain the lowest strength condition.

**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 h.

**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 Subdivisions 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 by a low-temperature thermal treatment which results in slightly lowered tensile strength and improved 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 before the stabilization treatment.

4.2.1.2 The digit following the designations 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 (49°C) of approximately 75% following a full anneal. Tempers between 0 (annealed) and 8 are designated by numerals 1 through 7. Material having an ultimate tensile strength about midway between that of the 0 temper and that of the 8 temper is designated by the numeral 4; about midway between the 0 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 exceeds that of the 8 temper by 2.0 ksi (14 MPa) 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% cold reduction after full anneal), the 6 temper tensile strength may be established by a cold reduction of approximately 55% following a full anneal, or the 4 temper tensile strength may be established by a cold reduction of approximately 35% after a full anneal.

4.2.1.3 The third digit (Note 10), when used, indicates a variation of a two-digit temper. It is used when the degree of control of temper or the mechanical properties are different from, but close to, those for the two-digit H temper designation to which it is added, or when some other characteristic is significantly affected. (See Appendix for three-digit H tempers.)

Note: The minimum ultimate tensile strength of a three-digit H temper is at least as close to that of the corresponding two-digit H temper as it is to the adjacent two-digit H tempers.

4.2.2 Subdivisions of T Temper: Thermally Treated

4.2.2.1 Numerals 1 through 10 following the T indicate specific sequences of basic treatments, as follows (Note 5.8):

**T1** Cooled from an Elevated Temperature Shaping Process and Naturally Aged to a Substantially Stable Condition—Applies to products for which the rate of cooling from an elevated temperature shaping process, such as casting or extrusion, is such that their strength is increased by room temperature aging.

**T2** Annealed (Cast Products Only)—Applies to cast products which are annealed to improve ductility and dimensional stability.

**T3** Solution Heat Treated and Then Cold Worked—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.

**T4** Solution Heat Treated 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 cooled from an elevated temperature shaping process, such

as casting or extrusion, and then artificially aged to improve mechanical properties or dimensional stability or both.

**T6** SOLUTION HEAT TREATED 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 TREATED AND THEN STABILIZED—Applies to products which are stabilized to carry them beyond the point of maximum strength to provide control of some special characteristics.

**T8** SOLUTION HEAT TREATED, 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, ARTIFICIALLY AGED, AND THEN COLD WORKED—Applies to products which are cold worked to improve strength.

**T10** COOLED FROM AN ELEVATED TEMPERATURE SHAPING PROCESS, ARTIFICIALLY AGED, AND THEN COLD WORKED—Applies to products which are artificially aged after cooling from an elevated temperature shaping process, such as casting or extrusion, and then cold worked to improve strength further.

4.2.2.2 Additional digits (Note 5.9), 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 characteristics of the product. (See Appendix for specific additional digits for T tempers.)

*5. Notes*

**5.1** Producers of wrought aluminum and wrought aluminum alloys, and aluminum and aluminum alloy castings and foundry ingot, may register chemical composition limits and designations conforming to this standard with the Aluminum Association (AA) provided the aluminum or aluminum alloy is offered for sale, the complete chemical composition limits are registered, and 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 be used only to indicate an aluminum or aluminum alloy having chemical composition limits identical to those registered with AA for that aluminum or aluminum alloy.

**5.2** The aluminum content for unalloyed aluminum made by a refining process is the difference between 100.000% and the sum of all other metallic elements present in amounts of 0.0010% or more each, expressed to the third decimal; for unalloyed aluminum not made by a refining process, it is the difference between 100.00% and the sum of all other metallic elements present in amounts of 0.010% or more each, expressed to the second decimal.

**5.3** 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:

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

To determine compliance when 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%.

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

(d) Change in limits for impurities.

(e) Change in limits for grain refining elements.

(f) Distinctive iron or silicon limits, or both, reflecting high purity base metal.

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

**5.4** A national variation has composition limits which are similar but not identical to those registered by another country, with differences such as:

(a) Differences in the arithmetic mean of limits for alloying elements not exceeding the following amounts:

| Arithmetic Mean of Limits for Alloying Elements in Original Alloy or Modification, % | Maximum Difference, % |
|---|---|
| Up thru 1.0 | 0.15 |
| Over 1.0 thru 2.0 | 0.20 |
| Over 2.0 thru 3.0 | 0.25 |
| Over 3.0 thru 4.0 | 0.30 |
| Over 4.0 thru 5.0 | 0.35 |
| Over 5.0 thru 6.0 | 0.40 |
| Over 6.0 | 0.50 |

To determine compliance when 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. Low iron, reflecting high purity base metal, should be considered an alloy modification. See paragraph 5.3 (f).

(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.

**5.5** The serial letters are assigned internationally in alphabetical sequence with A but omitting I, O, and Q.

**5.6** 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.

**5.7** Numerals 1 through 9 may be arbitrarily assigned as the third digit and registered with AA for an alloy and product to indicate a variation of a two-digit H temper provided the temper is used or is available for use by more than one user, mechanical property limits are registered, 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 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. Zero has been assigned to indicate variations negotiated between the manufacturer and purchaser which are not used widely enough to justify registration.

**5.8** A period of natural aging at room temperature may occur between or after the operations listed for tempers T3 through T10. Control of this period is exercised when it is metallurgically important.

**5.9** Additional digits may be arbitrarily assigned and registered with AA for an alloy and product to indicate a variation of tempers T1 through T10 provided the temper is used or is available for use by more than one user, mechanical property limits are registered, 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 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 provide the temper. 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:

**H111** Applies to products which are strain hardened less than the amount required for a controlled H11 temper.

**H112** Applies to products which acquire some temper from shaping processes not having special control over the amount of strain hardening or thermal treatment, but for which there are mechanical property limits.