ASM Handbook, Volume 2A, *Aluminum Science and Technology*
Kevin Anderson, John Weritz, and J. Gilbert Kaufman, editors
DOI 10.31399/asm.hb.v02a.a0006482

Aluminum Alloy Nomenclature and Temper Designations*

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THE MOST WIDELY ACCEPTED alloy and temper designation system for aluminum and its alloys is the one maintained by the Aluminum Association and recognized by the American National Standards Institute (ANSI) as the *American National Standard Alloy and Temper Designation Systems for Aluminum* (ANSI H35.1) (Ref 1). The alloy-temper system of the Aluminum Association is based on alloy designations (which are grouped as wrought, cast, or foundry ingot product forms) followed by a hyphen with a temper code that defines the condition of the alloy. This designation system provides a standard form for alloy identification that enables the user to understand a great deal about the chemical composition and characteristics of the alloy.

The Aluminum Association alloy designations are categorized as wrought and cast alloys, where wrought and cast alloys are further divided into various alloy groups, as described in this article. Similarly, the temper designation system permits an understanding of the manner in which the product has been fabricated. The temper designation for a given alloy (with the exception of foundry ingots, which have no temper classification) differentiates the alloy based on the primary mechanism of property development. Many alloys respond to thermal treatment that includes solution heat treatment, quenching, and precipitation (age) hardening in either cast or wrought form. These alloys are commonly referred to as heat treatable. A large number of other wrought compositions (referred to as work-hardening alloys) rely only on work hardening through mechanical reduction, usually in combination with various annealing procedures for property development. Casting alloys that are not hardenable by heat treating are used only in as-cast or in a thermally modified condition unrelated to solution or precipitation effects.

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. Another rather widely known alloy classification system is the Unified Numbering System (UNS), which is a system that covers all metallic alloy systems (Ref 2). For aluminum alloys, the UNS system is essentially an adaptation of the Aluminum Association alloy designation system, whereby the UNS format involves the addition of the prefix "A9" (meaning aluminum alloys). The Aluminum Association also is the maintainer of the UNS designation system for wrought and cast aluminum alloys. The UNS alloy designation system, while not used in most domestic or international commerce, is sometimes cited for information purposes in domestic or international standards, including ASTM International material specifications.

The Aluminum Association Technical Committee on Product Standards, and its Subcommittee on Alloy Temper Registration, is the authority, on behalf of the Aluminum Association, that maintains the alloy and temper designation systems and registers new aluminum alloys and tempers. Sometimes, however, producers or fabricators may create their own designations in a style that misleadingly suggests that the designation is registered and recognized by the industry as a whole. This practice can be very misleading, and independent creation of either alloy or temper designations without the complete registration process defined by the Aluminum Association and ANSI H35.1 is to be avoided. The procedures for registering alloys and tempers, and a record of the alloys and tempers registered, are maintained in *International Designation System for Wrought Aluminum and Wrought Aluminum Alloys*, while standard aluminum tempers in widest use are described in *Aluminum Standards and Data*. Other registered tempers are listed in *Tempers for Aluminum and Aluminum Alloy Products* (*Yellow Sheets*) and *Tempers for Aluminum and Aluminum Alloy Products Metric Edition* (*Tan Sheets*), also published by the Aluminum Association.

An additional complication is the fact that, historically, each country around the world has its own designation system for aluminum alloys and tempers. Fortunately, great progress has been made in improving that situation, and the alloy designation system of the Aluminum Association is now recognized by over 90% of the world's aluminum industry. The publication *Recommendation: International Designation System for Wrought Aluminum and Wrought Aluminum Alloys* (*Teal Sheets*) has been accepted almost universally and is the basis for the nearly worldwide *International Accord on Alloy Designations*. Progress also is being made to broaden the agreement to cast alloys and certain basic temper designations as well. Nonetheless, full acceptance of universal equivalents has not yet been completed, and clarification between producers and buyers should still occur.

Aluminum Alloy Designations

Aluminum Association Designations for Wrought Aluminum and Its Alloys. The alloy and temper designation systems for wrought aluminum that are in use today (2018) were adopted by the aluminum industry in approximately 1955, and the current system for the cast aluminum system was developed somewhat later. For wrought alloys, a four-digit system is used to produce a list of wrought composition groups:

- 1*xxx:* Commercially pure compositions of 99.0% or more aluminum
- 2*xxx:* Alloys in which copper is the principal alloying element, although other

*Revised from *Heat Treating of Nonferrous Alloys*, Volume 4E, *ASM Handbook*, ASM International, 2016, p 114–136.

elements, notably magnesium, may be specified

- 3*xxx:* Alloys in which manganese is the principal alloying element
- 4*xxx:* Alloys in which silicon is the principal alloying element
- 5*xxx:* Alloys in which magnesium is the principal alloying element
- 6*xxx:* Alloys in which magnesium and silicon are the principal alloying elements
- 7*xxx:* Alloys in which zinc is the principal alloying element, but other elements such as copper, magnesium, chromium, and zirconium may be specified
- 8*xxx:* Alloys in which other principal alloying elements are used. Active alloys currently include iron, lithium, and cerium as their primary alloying element.
- 9*xxx:* Unused

This section describes the general protocol for this designation system and the representative group of widely used wrought aluminum alloys in Table 1. More details on wrought alloy and temper designations also are discussed in the section "Wrought Aluminum Alloys and Tempers" in this article. For reference, Table 1 also includes UNS designations, which are based directly on the Aluminum Association alloy designation with the prefix "A9."

The first digit of the alloy designation defines the major alloy class of the series, as noted in the preceding list. Assignment of the first digit of the designation of a new alloy is fairly straightforward; few judgment decisions are needed unless there are equal amounts of two or more alloys. In the latter case, specific guidance has been provided by the developers of the alloy designation system that the choice of alloy series assigned shall be in the order of copper (Cu), manganese (Mn), silicon (Si), magnesium (Mg), magnesium silicide (Mg_2Si), and zinc (Zn). Thus, if a new alloy has equal amounts of manganese and zinc, it will be assigned to the 3*xxx* series. In such cases, the 6*xxx* series requires the most judgment because alloys that have more silicon than magnesium, but significant quantities of both, are likely to be placed in the 6*xxx* series rather than the 4*xxx* series in establishing properties and characteristics, due to the predominance of the magnesium and silicon combination added proportionally to form Mg_2Si. Thus, for example, alloys such as 6005, 6066, and 6351 all have significantly more silicon than magnesium or other elements but find themselves in the Mg_2Si series.

The second digit defines modifications in the original alloy as follows: the second digit is always a zero (0) for the original composition, a one (1) for the first modification, a two (2) for the second modification, and so forth. Modifications are typically defined by differences in one or more alloying elements of 0.15 to 0.50% or more, depending on the level of the added element. Assignment of the second digit of the alloy designation is related to the modifications in a specific alloy—in many cases, tightening of controls on one or more impurities to achieve specific properties. If the second digit is 0, it generally indicates that the aluminum making up the bulk of the alloy is commercially pure aluminum having naturally occurring impurity levels. When the second digit is an integer 1 to 9, it indicates that some special control has been placed on the impurity levels of that modification, or that the range for one of the major alloy elements has been shaded one way or the other to achieve certain performance. However, the sequence has no significance in the composition modification; the digits are assigned sequentially as the situations occur, and the sequence indicates chronology more than level of control.

As an example of the designation protocol, consider the following set of alloys: 7075, 7175, 7275, 7375, and 7475. The original alloy was 7075 with commercial-quality aluminum; when added fracture toughness was needed, controls on various impurities, notably iron and silicon, led to the other modification, of which 7175 and 7475 remain active alloys known for their superior toughness.

The third and fourth digits designate the specific alloy within the series. Within the 1*xxx* series (which, by definition, are compositions of 99.0% or more aluminum), the last two of the four digits in the designation indicate the minimum aluminum percentage. These two digits are the same as the two digits to the right of the decimal point in the minimum aluminum percentage specified for the designation when expressed to the nearest 0.01%. For example, the designation 1060 indicates 99.60% minimum aluminum in that composition. The second digit (0) then would indicate no modification in impurity limits or intentionally added elements, in accordance with the designation protocol given in the preceding paragraph.

In the remaining 2*xxx* to 8*xxx* series, the last two digits have no quantitative significance or numerical meaning. They serve only to identify the specific individual alloys, and they mean nothing in terms of the sequence in which the alloys were developed or registered. Historically, for the older alloys, those digits came from the earlier designations (e.g., 2024 was 24S before 1950). More recently, it has been the tradition that developers of new alloys ask for specific designations, sometimes based on proximity of application to other alloys of the same series or for other reasons. If the developer asks for a specific number when filing for registration, the Aluminum Association Subcommittee on Alloy Temper Registration, which oversees the system, is likely to agree to the request if no confusion would result. However, if no designation is requested, the committee would likely take the lowest used number in the sequence 1 to 99.

Alphabetic Prefix or Suffix. The four-digit designations sometimes include an alphabetic prefix or suffix, but normally it is just four numbers. Under certain situations when minor variations in alloy compositions are introduced, such variation sometimes is noted with the addition of a capital letter behind the original four-number designation, rather than a change in the second digit. An example of the application of this procedure in commercial practice is 6005A—a variation of alloy 6005. In general, the practice is to reflect modifications with the second digit, as noted earlier in this article.

Historically, the prefix "X" was added for experimental alloys. Experimental alloys of either the wrought or cast aluminum series were indicated with the addition of the prefix "X." Use of this prefix was discontinued in July 2015. During development, producers use their own proprietary designation until the new alloy is deemed commercial and the composition limits have been established. Use of the proprietary designation is discontinued when the composition is registered with the Aluminum Association and the ANSI H35.1-compliant designation is assigned.

Earlier Designation Systems for Wrought Aluminum Alloys. For reference purposes, it also is useful to note that prior to the development of the current Aluminum Association Alloy Designation System, another alloy designation system had been in place. Occasionally, a specification or a component turns up where the older designation still is evident, and it is useful to be able to bridge the gap.

The old system for wrought alloy designations consisted of a one- or two-digit number followed by a capital "S." A capital letter in front of the alloy number was used to illustrate a variation of a basic composition. Because it lacked sufficient rigor, flexibility, and consistency, this system was abandoned in the 1950s and replaced by the current system.

When the four-digit system was installed, the letters were dropped, and the two surviving numbers became a part of the new system. For example, alloy 17S became alloy 2017, and similarly, alloy 24S became alloy 2024, as illustrated in Table 2, which provides a reference conversion showing both the current and original designations.

Aluminum Association Designations for Cast Aluminum and Its Alloys. The most widely used designation system for cast aluminum and aluminum alloys in the United States is the Aluminum Association system with four-digit designations:

- *First digit:* Principal alloying constituent(s)
- *Second and third digits:* Purity level for cast aluminum or a unique designation for alloys
- *Fourth digit:* Designation for cast product types as a casting (0) or ingot (1, 2)

Table 1 Alloying elements in wrought aluminum and aluminum alloys

Representative list of common wrought aluminum alloys

Aluminum Association designation	Unified Numbering System (UNS) designation	Composition, maximum unless a range or minimum is specified(a), wt%							
		Si	Fe	Cu	Mn	Mg	Zn	Other specified alloying elements	Al, min or bal
1050	A91050	0.25	0.40	0.05	0.05	0.05	0.05	···	99.50
1060	A91060	0.25	0.35	0.05	0.03	0.03	0.05	···	99.60
1145	A91145	0.55 Si + Fe		0.05	0.05	0.05	0.05	···	99.45
1175	A91175	0.15 Si + Fe		0.10	0.02	0.02	0.04	···	99.75
1200	A91200	1.00 (Si + Fe)		0.05	0.05	···	0.10	···	99.0
1230	A91230	0.70 Si + Fe		0.10	0.05	0.05	0.10	···	99.30
1235	A91235	0.65 Si + Fe		0.05	0.05	0.05	0.10	···	99.35
1345	A91345	0.30	0.40	0.10	0.05	0.05	0.05	···	99.45
1350	A91350	0.10	0.40	0.05	0.01	···	···	···	99.50
2011	A92011	0.40	0.7	5.0–6.0	···	···	0.30	0.20–0.6% Bi; 0.20–0.6% Pb	bal
2014	A92014	0.50–1.2	0.7	3.9–5.0	0.40–1.2	0.20–0.8	0.25	···	bal
2017	A92017	0.20–0.8	0.7	3.5–4.5	0.40–1.0	0.40–0.8	0.25	···	bal
2018	A92018	0.9	1.0	3.5–4.5	0.20	0.45–0.9	0.25	1.7–2.3Ni	bal
2024	A92024	0.50	0.50	3.8–4.9	0.30–0.9	1.2–1.8	0.25	···	bal
2025	A92025	0.50–1.2	1.0	3.9–5.0	0.40–1.2	0.05	0.25	···	bal
2036	A92036	0.50	0.50	2.2–3.0	0.10–0.40	0.30–0.6	0.25	···	bal
2117	A92117	0.8	0.7	2.2–3.0	0.20	0.20–0.50	0.25	···	bal
2124	A92124	0.20	0.30	3.8–4.9	0.30–0.9	1.2–1.8	0.25	···	bal
2218	A92218	0.9	1.0	3.5–4.5	0.20	1.2–1.8	0.25	1.7–2.3Ni	bal
2219	A92219	0.20	0.30	5.8–6.8	0.20–0.40	0.02	0.10	0.02–0.10Ti; 0.05–0.15V; 0.10–0.25Zr	bal
2319	A92319	0.20	0.30	5.8–6.8	0.20–0.40	0.02	0.10	0.10–0.20Ti; 0.05–0.15V; 0.10–0.25Zr	bal
2195	A92195	0.12	0.15	3.7–4.3	0.25	0.25–0.8	0.25	0.10-0.6 Ag 0.8-1.2 Li	bal
2297	A2297	0.10	0.10	2.5–3.1	0.10–0.50	0.25	0.05	1.1-1.7 Li	bal
2618	A92618	0.10–0.25	0.9–1.3	1.9–2.7	···	1.3–1.8	0.10	0.9–1.2Ni; 0.04–0.10Ti	bal
3002	A93002	0.08	0.10	0.15	0.05–0.25	0.05–0.20	0.05	···	bal
3003	A93003	0.6	0.7	0.05–0.20	1.0–1.5	···	0.10	···	bal
3004	A93004	0.30	0.7	0.25	1.0–1.5	0.8–1.3	0.25	···	bal
3005	A93005	0.6	0.7	0.30	1.0–1.5	0.20–0.6	0.25	···	bal
3105	A93105	0.6	0.7	0.30	0.30–0.8	0.20–0.8	0.40	···	bal
4032	A94032	11.0–13.5	1.0	0.50–1.3	···	0.8–1.3	0.25	0.50–1.3Ni	bal
4043	A94043	4.5–6.0	0.8	0.30	0.05	0.05	0.10	···	bal
4045	A94045	9.0–11.0	0.8	0.30	0.05	0.05	0.10	···	bal
4047	A94047	11.0–13.0	0.8	0.30	0.15	0.10	0.20	···	bal
4145	A94145	9.3–10.7	0.8	3.3–4.7	0.15	0.15	0.20	···	bal
4343	A94343	6.8–8.2	0.8	0.25	0.10	···	0.20	···	bal
4543	A94543	5.0–7.0	0.50	0.10	0.05	0.10–0.40	0.10	···	bal
4643	A94643	3.6–4.6	0.8	0.10	0.05	0.10–0.30	0.10	···	bal
4943	A94943	5.0–6.0	0.40	0.10	0.05	0.10–0.50	0.10	···	bal
5005	A95005	0.30	0.7	0.20	0.20	0.50–1.1	0.25	···	bal
5006	A95006	0.40	0.8	0.10	0.40–0.8	0.8–1.3	0.25	···	bal
5010	A95010	0.40	0.7	0.25	0.10–0.30	0.20–0.6	0.30	···	bal
5050	A95050	0.40	0.7	0.20	0.10	1.1–1.8	0.25	···	bal
5052	A95052	0.25	0.40	0.10	0.10	2.2–2.8	0.10	0.15–0.35Cr	bal
5056	A95056	0.30	0.40	0.10	0.05–0.20	4.5–5.6	0.10	0.05–0.20Cr	bal
5082	A95082	0.20	0.35	0.15	0.15	4.0–5.0	0.25	···	bal
5083	A95083	0.40	0.40	0.10	0.40–1.0	4.0–4.9	0.25	0.05–0.25Cr	bal
5086	A95086	0.40	0.50	0.10	0.20–0.7	3.5–4.5	0.25	0.05–0.25Cr	bal
5154	A95154	0.25	0.40	0.10	0.10	3.1–3.9	0.20	0.15–0.35Cr	bal
5183	A95183	0.40	0.40	0.10	0.50–1.0	4.3–5.2	0.25	0.05–0.25Cr	bal
5252	A95252	0.08	0.10	0.10	0.10	2.2–2.8	0.05	···	bal
5254	A95254	0.45 Si + Fe		0.05	0.01	3.1–3.9	0.20	0.15–0.35Cr	bal
5356	A95356	0.25	0.40	0.10	0.05–0.20	4.5–5.5	0.10	0.05–0.20Cr; 0.06–0.20Ti	bal
5454	A95454	0.25	0.40	0.10	0.50–1.0	2.4–3.0	0.25	0.05–0.20Cr	bal
5456	A95456	0.25	0.40	0.10	0.50–1.0	4.7–5.5	0.25	0.05–0.20Cr	bal
5457	A95457	0.08	0.10	0.20	0.15–0.45	0.8–1.2	0.05	···	bal
5552	A95552	0.04	0.05	0.10	0.10	2.2–2.8	0.05	···	bal
5554	A95554	0.25	0.40	0.10	0.50–1.0	2.4–3.0	0.25	0.05–0.20Cr; 0.05–0.20Ti	bal
5556	A95556	0.25	0.40	0.10	0.50–1.0	4.7–5.5	0.25	0.05–0.20Cr; 0.05–0.20Ti	bal
5557	A95557	0.10	0.12	0.15	0.10–0.40	0.40–0.8	···	···	bal
5652	A95652	0.40 Si + Fe		0.04	0.01	2.2–2.8	0.10	0.15–0.35Cr	bal
5654	A95654	0.45 Si + Fe		0.05	0.01	3.1–3.9	0.20	0.15–0.35Cr; 0.05–0.15Ti	bal
5657	A95657	0.08	0.10	0.10	0.03	0.6–1.0	0.05	···	bal
6003	A96003	0.35–1.0	0.6	0.10	0.8	0.8–1.5	0.20	···	bal
6005	A96005	0.6–0.9	0.35	0.10	0.10	0.40–0.6	0.10	···	bal
6013	A96013	0.6-1.0	0.5	0.6-1.1	0.2-0.8	0.8-1.2			bal
6053	A96053	(b)	0.35	0.10	···	1.1–1.4	0.10	0.15–0.35Cr	bal
6060	A96060	0.30–0.6	0.10–0.30	0.10	0.10	0.35–0.6	0.15	···	bal
6061	A96061	0.40–0.8	0.7	0.15–0.40	0.15	0.8–1.2	0.25	0.04–0.35Cr	bal
6063	A96063	0.20–0.6	0.35	0.10	0.10	0.45–0.9	0.10	···	bal
6066	A96066	0.9–1.8	0.50	0.7–1.2	0.6–1.1	0.8–1.4	0.25	···	bal
6070	A96070	1.0–1.7	0.50	0.15–0.40	0.40–1.0	0.50–1.2	0.25	···	bal
6101	A96101	0.30–0.7	0.50	0.10	0.03	0.35–0.8	0.10	0.06B	bal

(continued)

(a) This table only lists elements that have specified ranges for alloying (either as a range or a maximum). This table does not include all elements with specified impurity limits, nor does it necessarily list all registered alloys specified by the Aluminum Association. Reference the *International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys* (*Teal Sheets*) at www.aluminum.org. (b) 45–65% of actual Mg. Source: Aluminum Association Inc.

Table 1 (Continued)

Aluminum Association designation	Unified Numbering System (UNS) designation	Composition, maximum unless a range or minimum is specified(a), wt% Si	Fe	Cu	Mn	Mg	Zn	Other specified alloying elements	Al, min or bal
6105	A96105	0.6–1.0	0.35	0.10	0.10	0.45–0.8	0.10	...	bal
6151	A96151	0.6–1.2	1.0	0.35	0.20	0.45–0.8	0.25	0.15–0.35Cr	bal
6160	A96160	0.30–0.6	0.15	0.20	0.05	0.35–0.6	0.05	...	bal
6162	A96162	0.40–0.8	0.50	0.20	0.10	0.7–1.1	0.25	...	bal
6201	A96201	0.50–0.9	0.50	0.10	0.03	0.6–0.9	0.10	0.06B	bal
6253	A96253	(b)	0.50	0.10	...	1.0–1.5	1.6–2.4	0.04–0.35Cr	bal
6262	A96262	0.40–0.8	0.7	0.15–0.40	0.15	0.8–1.2	0.25	0.04–0.14Cr; 0.40–0.7Bi; 0.40–0.7Pb	bal
6351	A96351	0.7–1.3	0.50	0.10	0.40–0.8	0.40–0.8	0.20	...	bal
6463	A96463	0.20–0.6	0.15	0.20	0.05	0.45–0.9	0.05	...	bal
6951	A96951	0.20–0.50	0.8	0.15–0.40	0.10	0.40–0.8	0.20	...	bal
7005	A97005	0.35	0.40	0.10	0.20–0.7	1.0–1.8	4.0–5.0	0.06–0.20Cr; 0.01–0.06Ti; 0.08–0.20Zr	bal
7008	A97008	0.10	0.10	0.05	0.05	0.7–1.4	4.5–5.5	0.12–0.25Cr	bal
7049	A97049	0.25	0.35	1.2–1.9	0.20	2.0–2.9	7.2–8.2	0.10–0.22Cr	bal
7050	A97050	0.12	0.15	2.0–2.6	0.10	1.9–2.6	5.7–6.7	0.08–0.15Zr	bal
7072	A97072	0.7 Si + Fe		0.10	0.10	0.10	0.8–1.3	...	bal
7075	A97075	0.40	0.50	1.2–2.0	0.30	2.1–2.9	5.1–6.1	0.18–0.28Cr	bal
7108	A97108	0.10	0.10	0.05	0.05	0.7–1.4	4.5–5.5	0.12–0.25Zr	bal
7175	A97175	0.15	0.20	1.2–2.0	0.10	2.1–2.9	5.1–6.1	0.18–0.28Cr	bal
7475	A97475	0.10	0.12	1.2–1.9	0.06	1.9–2.6	5.2–6.2	0.18–0.25Cr	bal
8017	A98017	0.10	0.55–0.8	0.10–0.20	...	0.01–0.05	0.05	0.04B, 0.003Li	bal
8030	A98030	0.10	0.30–0.8	0.15–0.30	...	0.05	0.05	0.001–0.04B	bal
8176	A98176	0.03–0.15	0.40–1.0	...	...	...	0.10	...	bal
8177	A98177	0.10	0.25–0.45	0.04	...	0.04–0.12	0.05	0.04B	bal

(a) This table only lists elements that have specified ranges for alloying (either as a range or a maximum). This table does not include all elements with specified impurity limits, nor does it necessarily list all registered alloys specified by the Aluminum Association. Reference the *International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys* (*Teal Sheets*) at www.aluminum.org. (b) 45–65% of actual Mg. Source: Aluminum Association Inc.

Table 2 Comparison of previous and current aluminum alloy designation systems

Old designation	Current designation
1S	1100
3S	3003
4S	3004
14S	2014
17S	2017
A17S	2117
24S	2024
25S	2025
26S	2026
32S	4032
50S	5050
B51S	6151
52S	5052
56S	5056
61S	6061
63S	6063
75S	7075
76S	7076

Like the wrought system, the first digit defines the major alloying constituent or constituents, the categories are defined:

- 1*xx.x:* Controlled unalloyed (pure) compositions (99.00% or greater aluminum)
- 2*xx.x:* Alloys in which copper is the principal alloying element
- 3*xx.x:* Alloys in which silicon is the principal alloying element, but other alloying elements such as copper and magnesium are specified
- 4*xx.x:* Alloys in which silicon is the principal alloying element
- 5*xx.x:* Alloys in which magnesium is the principal alloying element
- 6*xx.x:* Unused
- 7*xx.x:* Alloys in which zinc is the principal alloying element
- 8*xx.x:* Alloys in which tin is the principal alloying element
- 9*xx.x:* Aluminum plus other elements

The alloy group is determined by the alloying element present in the greatest mean percentage, except in cases in which the composition being registered qualifies as a modification of a previously registered alloy. If the greatest mean percentage is common to more than one alloying element, the alloy group is determined by the element that comes first in sequence. Note that the 6*xx.x* series is designated as an unused series.

The significance of the second and third digits also is similar to that of the wrought alloy designations. In designations of cast aluminum (the 1*xx.x* type), the second and third digits indicate minimum aluminum content (99.00% or greater); these digits are the same as the two to the right of the decimal point in the minimum aluminum percentage expressed to the nearest 0.01%. For example, alloy 170.0 contains a minimum of 99.70% Al. In 2*xx.x* through 8*xx.x* designations for aluminum alloys, the second and third digits have no numerical significance but only arbitrarily identify individual alloys in the group, in the same fashion as the second and third digits in the designation protocol for wrought alloys.

In the cast alloy designations, a decimal point is placed between the third and fourth digits, and the fourth digit indicates the cast alloy product form:

- "0" denotes castings
- "1" denotes standard ingot
- "2" denotes ingot having composition ranges narrower than but within those of standard ingot

Designations in the form *xxx*.1 and *xxx*.2 include the composition of specific alloys in remelt ingot form suitable for foundry use. Designations in the form *xxx*.0 in all cases define composition limits applicable to castings. Alloying-element and impurity limits for ingot are usually the same as those for castings of the same alloy. When the ingot is remelted, iron and silicon contents tend to increase and magnesium content decreases. For these reasons, ingot chemistry for some alloys may be somewhat different from those specified for castings.

Table 3 lists the nominal compositions of a representative group of commercial aluminum casting alloys, and more details on alloy and temper designations are discussed in the section "Cast Aluminum Alloys and Tempers" in this article. While many of the alloys can be produced from a wide variety of casting processes, commercial die castings are limited to a relatively small number of compositions, namely, 360.0, A360.0, 380.0, A380.0, 383.0, 384.0, A384.0, B390.0, 413.0, C443.0, and 518.0.

In the cast alloy designations more so than in the wrought series, letter prefixes are used to indicate modifications. Explicit rules have been established for determining whether a

Table 3 Nominal composition of aluminum alloy castings

	Nominal composition with balance aluminum(a), wt%									
Alloy	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Sn
100.1	...	0.7	...	...	...	...	...	...	...	...
150.1	...	...	...	...	...	...	...	...	...	...
170.1	...	...	...	...	...	...	...	...	...	...
201.0(b)	...	...	...	...	...	...	...	...	...	...
203.0	...	...	5.0	0.25	...	...	1.5	...	0.20	...
204.0	...	...	...	...	0.25	...	...	...	0.22	...
A206.0	...	...	4.6	0.35	0.25	...	...	...	0.22	...
208.0(c)	3.0	...	4.0	...	...	...	...	...	...	...
222.0(c)	...	...	10.0	...	0.25	...	...	...	...	...
224.0(c)	...	...	5.0	0.35	...	...	...	...	...	...
240.0	...	...	8.0	0.5	6.0	...	0.5	...	...	...
242.0	...	...	4.0	...	1.5	...	2.0	...	...	...
A242.0	...	...	4.1	...	1.4	0.20	2.0	...	0.14	...
249.0(c)	...	...	4.2	0.38	0.38	...	...	3.0	0.18	...
295.0	1.1	...	4.5	...	...	...	...	...	...	...
308.0	5.5	...	4.5	...	...	...	...	...	...	...
319.0	6.0	...	3.5	...	...	...	...	...	...	...
328.0(c)	8.0	...	1.5	0.40	0.40	...	...	...	...	...
332.0	9.5	...	3.0	...	1.0	...	...	...	...	...
333.0	9.0	...	3.5	...	0.28	...	...	...	...	...
336.0	12.0	...	1.0	...	1.0	...	2.5	...	...	...
354.0	9.0	...	1.8	...	0.5	...	...	...	...	...
355.0	5.0	...	1.25	...	0.5	...	...	...	...	...
C355.0	5.0	...	1.25	...	0.5	...	...	...	...	...
356.0	7.0	...	...	...	0.32	...	...	...	...	...
A356.0	7.0	...	...	...	0.35	...	...	...	...	...
357.0	7.0	...	...	...	0.52	...	...	...	...	...
A357.0(d)	7.0	...	...	...	0.55	...	...	...	0.12	...
D357.0(d)	7.0	...	...	...	0.58	...	...	...	0.15	...
E357.0(e)	7.0	...	...	...	0.58	...	...	...	0.15	...
F357.0(e)	7.0	...	...	...	0.55	...	...	...	0.12	...
359.0	9.0	...	...	...	0.6	...	...	...	...	...
360.0	9.5	...	...	...	0.5	...	...	...	...	...
A360.0	9.5	...	...	...	0.5	...	...	...	...	...
365.0	...	...	...	...	...	...	...	...	...	...
380.0	8.5	...	3.5	...	...	...	...	...	...	...
A380.0	8.5	...	3.5	...	...	...	...	...	...	...
383.0	10.5	...	2.5	...	...	...	...	...	...	...
384.0	11.2	...	3.8	...	...	...	...	...	...	...
B390.0	17.0	...	4.5	...	0.55	...	...	...	...	...
391.0	19.0	...	...	...	0.58	...	...	...	...	...
A391.0	19.0	...	...	...	0.58	...	...	...	...	...
B391.0	19.0	...	...	...	0.58	...	...	...	...	...
413.0	12.0	...	...	...	...	...	...	...	...	...
A413.0	12.0	...	...	...	...	...	...	...	...	...
443.0	5.2	...	...	...	...	...	...	...	...	...
B443.0	5.2	...	...	...	...	...	...	...	...	...
C443.0	5.2	...	...	...	...	...	...	...	...	...
A444.0	7.0	...	...	...	...	...	...	...	...	...
512.0	1.8	...	...	...	4.0	...	...	...	...	...
513.0	...	...	...	...	4.0	...	...	1.8	...	...
514.0	...	...	...	...	4.0	...	...	...	...	...
518.0	...	...	...	...	8.0	...	...	...	...	...
520.0	...	...	...	...	10.0	...	...	...	...	...
535.0(f)	...	...	...	0.18	6.8	...	...	...	0.18	...
705.0	...	...	...	0.5	1.6	0.30	...	3.0	...	...
707.0	...	...	...	0.50	2.1	0.30	...	4.2	...	...
710.0	...	...	0.50	...	0.7	...	...	6.5	...	...
711.0	...	1.0	0.50	...	0.35	...	...	6.5	...	...
712.0	...	...	...	...	0.58	0.50	...	6.0	0.20	...
713.0	...	...	0.7	...	0.35	...	...	7.5	...	...
771.0	...	...	...	...	0.9	0.40	...	7.0	0.15	...
850.0	...	...	1.0	...	...	...	1.0	...	...	6.2
851.0	2.5	...	1.0	...	...	...	0.50	...	...	6.2
852.0	...	...	2.0	...	0.75	...	1.2	...	...	6.2

Based on industry handbooks, notably *Aluminum Association Standards for Sand and Permanent Mold Castings*, and the *Aluminum Association Designations and Chemical Composition Limits for Aluminum Alloys in the Form of Castings and Ingot* (*Pink Sheets*). (a) Nominal compositions are midrange of limits for alloying elements with a specified composition range, with aluminum as balance. (b) Also contains 0.40–1.0% (0.7% nominal) Ag. (c) Alloy has been designated "Inactive" by the Aluminum Association but still occurs in some publications. (d) Also contains 0.04–0.07% (0.055% nominal) Be. (e) Beryllium-free, iron held to very low level (0.10 wt% Fe, max) in ingot and during foundry processes. (f) Also contains 0.0003–0.007% (0.005% nominal) Be and 0.005% max B

proposed composition is a modification of an existing one, and prefix letters are used primarily to define differences in impurity limits. An excellent example is illustrated by A356.0 as a variation of 356.0. Both are readily castable into complex shapes, but 356.0, because of the relatively greater impurity levels tolerated by its specifications (e.g., 0.6% Fe maximum), may be more variable in quality, including reduced ductility and toughness. A356.0 is a variation of 356.0 where iron and other impurities are controlled to lower levels (e.g., 0.20% Fe maximum), with the result that appreciably higher strength, ductility, and toughness are reliably provided. Accordingly, one of the most common gravity-cast alloys, 356.0, has modifications A356.0, B356.0, C356.0, and F356.0; each of these alloys has identical major alloy contents but has decreasing specification limits applicable to impurities, especially iron content. Another example is A357.0 as a low-impurity variation of 357.0, for which the situation is quite parallel. The prefix "X" had been reserved for experimental alloys but is no longer used.

In North America, the Aluminum Association designation system is the most commonly used, although it remains relatively common to see the alloys listed with only the first three digits of the alloy designation; for example, for 356.0, one may see simply "356." This is not technically proper usage of the designation system, and the ".0" designation should always be used for cast components. As previously noted, designation systems and alloy nomenclature for aluminum casting alloys also are not internationally standardized to the same extent as wrought aluminum alloys. Many nations have developed and published their own standards, and individual firms have also promoted alloys by proprietary designations. Therefore, earlier variations as well as other rather widely used designation systems are discussed in the section "Cast Aluminum Alloys and Tempers" in this article.

Basic Temper Designations

The alloy-temper designation system used in the United States for aluminum and aluminum alloys is used for all product forms (both wrought and cast), with the exception of ingot. The system is based on the sequences of mechanical or thermal treatments, or both, used to produce the various alloy conditions. The temper designation is always presented immediately following the alloy designation, with a hyphen between the designation and the temper (e.g., 2014-T6).

The first character of the temper designation is a capital letter indicating the general class of treatment. The designations are defined and described:

- *F, as fabricated:* Applies to wrought or cast products made by shaping processes in which there is no special control over thermal conditions or strain-hardening processes employed to achieve specific properties. For wrought alloys, there are no mechanical property limits associated with this temper, although for cast alloys there generally are.
- *O, annealed:* Applies to wrought products that are annealed to obtain the lower-strength temper, usually to increase subsequent workability. The "O" applies to cast products that are annealed to improve ductility and dimensional stability and may be followed by a digit other than zero.
- *H, strain hardened:* Applies to products that have their strength increased by strain hardening. They may or may not have supplementary thermal treatments to produce some reduction in strength. The "H" is always followed by two or more digits.
- *W, solution heat treated:* Applies only to alloys that age spontaneously after solution heat treating. This designation is specific only when digits are used in combination with "W" to indicate the period of natural aging, for example, W ½ h.
- *T, thermally treated to produce stable tempers other than F:* Applies to products that are thermally treated, with or without supplementary strain hardening, to produce stable tempers. The "T" is always followed by one or more digits.

These basic tempers can have major subdivisions that are indicated by one or more digits following the letter. These digits designate specific sequences of treatments that produce specific combinations of characteristics in the product. Variations in treatment conditions within major subdivisions also can be identified by additional digits. The conditions during heat treatment (such as time, temperature, and quenching rate) used to produce a given temper in one alloy may differ from those employed to produce the same temper in another alloy.

The basic temper designation system for wrought and cast aluminum alloys is basically the same, but in practice there are some significant differences in usage. The subsequent sections "Wrought Aluminum Alloys and Tempers" and "Cast Aluminum Alloys and Tempers" in this article focus on those differences while also noting the similarities. The main point is to demonstrate the function and meaning of what may seem like a complex or confusing set of coded numbers. It is important that end users and their heat treaters and fabricators understand these in considerable detail to ensure compliance. As further background, typical mechanical properties and useful reference material in understanding more about aluminum alloy-temper designations are given in the subsequent sections "Wrought Aluminum Alloys and Tempers" and "Cast Aluminum Alloys and Tempers."

Subdivisions of H Tempers

The first number(s) following the H-temper designation indicates the specific combination of basic operations:

- *H1, strain hardened only:* Applies to products that have been strain hardened to obtain a desired level of strength without a supplementary thermal treatment. The number following H1 indicates the degree of strain hardening.
- *H2, strain hardened and partially annealed:* Applies to products that have been strain hardened more than the desired final amount, and their strength is reduced to the desired level by partial annealing. The number added to H2 indicates the degree of strain hardening remaining after partial annealing.
- *H3, strain hardened and stabilized:* Applies to products that have been strain hardened and then stabilized either by a low-temperature thermal treatment or as a result of heat introduced during fabrication of the product. Stabilization usually improves ductility. The H3 temper is used only for those alloys that will gradually age soften at room temperature if they are not stabilized. The number added to H3 indicates the degree of strain hardening remaining after stabilization.
- *H4, strain hardened and lacquered or painted:* Applies to products that are strain hardened and that have been subjected to heat during subsequent painting or lacquering operations. The number added to H4 indicates the amount of strain hardening left after painting or lacquering.

Additional H-Temper Digits. A digit following H1, H2, H3, or H4 indicates the degree of strain hardening as identified or indicated by the minimum value for tensile strength:

- The hardest temper normally produced is indicated by adding the numeral 8 (i.e., H*x*8).
- A degree of cold work equal to approximately one-half that for the H*x*8 temper is indicated by the H*x*4 temper, and so on.
- For a degree of cold work halfway between the O temper and the H*x*4 temper, the H*x*2 temper is used.
- For a degree of cold work halfway between H*x*4 and H*x*8, the H*x*6 temper is used.
- The numbers 1, 3, 5, and 7, similarly, designate tempers intermediate between those just listed.
- The numeral 9 is used to indicate tempers that exceed those of H*x*8 by 14 MPa (2 ksi) or more.

As an example, Table 4 indicates gains in the tensile strength of wrought alloys in the annealed temper when they are treated to the H*x*8 temper.

Several three-digit H tempers also have been standardized. For all strain-hardenable alloys, the three-digit designations are:

- *Hx11:* Applies to products that incur sufficient strain hardening after the final anneal such that they fail to qualify as annealed but not so much or so consistent an amount of strain that they qualify as H*x*1
- *H112:* Applies to products that may acquire some temper from working at an elevated temperature and for which there are mechanical property limits

Other recognized three-digit H tempers apply to types of sheet, as shown in Table 5.

Subdivisions of T Tempers

The first number(s) following the letter "T" designation indicates the specific combination of basic operations:

Table 4 Tensile strengths of H*x*8 tempers

Minimum tensile strength in annealed temper		Increase in tensile strength to H*x*8 temper	
MPa	ksi	MPa	ksi
Up to 40	Up to 6	55	8
45–60	7–9	65	9
65–80	10–12	75	10
85–100	13–15	85	11
105–120	16–18	90	12
125–160	19–24	95	13
165–200	25–30	100	14
205–240	31–36	105	15
245–280	37–42	110	16
285–320	43–46	115	17
325 and over	47 and over	120	18

- *T1, cooled from elevated-temperature shaping process and naturally aged to a substantially stable condition:* Applies to products that are not cold worked after cooling from an elevated-temperature shaping process or for which the effect of cold work in flattening or straightening may not be recognized in mechanical property limits
- *T2, cooled from an elevated-temperature shaping process, cold worked, and naturally aged to a substantially stable condition:* Applies to products that are cold worked to improve strength after cooling from an elevated-temperature shaping process or for which the effect of cold work in flattening or straightening is recognized in mechanical property limits
- *T3, solution heat treated, cold worked, and naturally aged to a substantially stable condition:* Applies to products that are cold worked to improve strength after solution heat treatment or for 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 that are not cold worked after solution heat treatment or for 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, then artificially aged:* Applies to products that are not cold worked after cooling from an elevated-temperature shaping process or for which the effect of cold work in flattening or straightening may not be recognized in mechanical property limits
- *T6, solution treated, then artificially aged:* Applies to products that are not cold worked after solution treatment or for which the effect of cold work in flattening or straightening may not be recognized in mechanical property limits
- *T7, solution heat treated and overaged/stabilized:* Applies to wrought products that are artificially aged after solution heat treating to increase their strength beyond the maximum value achievable to provide control of some significant property or characteristic, or cast products that are artificially aged after solution treatment to provide stability in dimensions and in strength
- *T8, solution heat treated, cold worked, then artificially aged:* Applies to products that are cold worked to improve strength or for which the effect of cold work in flattening and straightening is recognized in mechanical property limits
- *T9, solution heat treated, artificially aged, then cold worked:* Applies to products that are cold worked to improve strength
- *T10, cooled from an elevated-temperature shaping process, cold worked, then artificially aged:* Applies to products that are cold worked to improve strength or for which the effect of cold work in flattening or straightening is recognized in mechanical property limits

In all of the T-type temper definitions just described, solution heat treatment is achieved by heating the cast or wrought shaped product to a suitable temperature, holding long enough to solution treat, quenching to hold the constituents in solid solution, and then age hardening.

Additional Digits in T-Temper Designations. Additional digits, the first of which shall not be zero, may be added to designations T1 through T10 to indicate a variation in treatment that significantly alters the product characteristics that are or would be obtained using the basic treatment (Table 6). The specific additional digits shown in Table 6 have been assigned for stress-relieved tempers of wrought products. The special T-temper designations listed in Table 7 have been assigned for wrought aluminum products from which test materials are taken and heat treated to demonstrate response to heat treatment of the product as a whole.

Table 5 Tempers for aluminum pattern sheet

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

Table 6 Tempers for stress-relieved products

Temper	Application
Stress relieved by stretching	
T*x*51(a)	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, 1½–3% permanent set
	Rolled or cold-finished rod and bar, 1–3% permanent set
	Die or ring forgings and rolled rings, 1–5% permanent set
T*x*510	Applies to extruded rod, bar, profiles (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, profiles (shapes), and tube, 1–3% permanent set
	Drawn tube, ½–3% permanent set
T*x*511	Applies to extruded rod, bar, profiles (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, profiles (shapes), and tube, 1–3% permanent set
	Drawn tube, ½–3% permanent set
Stress relieved by compressing	
T*x*52(a)	Applies to products that are stress relieved by compressing after solution heat treatment or cooling from an elevated-temperature shaping process to produce a permanent set of 1–5%
Stress relieved by combined stretching and compressing	
T*x*54(a)	Applies to die forgings that are stress relieved by restriking cold in the finish die

(a) Same digits (51, 52, 54) may be added to the designation "W" to indicate unstable solution heat treated and stress-relieved tempers.

Table 7 Tempers for testing response to heat treatment or when heat treatment is performed by user

Temper	Description(a)
T42	Solution heat treated from annealed or F temper and naturally aged to a substantially stable condition
T62	Solution heat treated from annealed or F temper and artificially aged
T7*x*2	Solution heat treated from annealed or F temper and artificially overaged to meet the mechanical properties and corrosion-resistance limits of the T7*x* temper

(a) These temper designations have been assigned for wrought product test materials heat treated from annealed (O, O1, etc.) or F temper to demonstrate response to heat treatment. Temper designations T42 and T62 also may 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.

Cast Aluminum Alloys and Tempers

The nominal compositions and composition limits of aluminum alloys in commercial use today (2018) are presented in Table 1. Because designation systems and alloy nomenclature for aluminum casting alloys are not as standardized as the wrought aluminum alloys, this section includes some additional information on various alloy designations—following a discussion of temper designations of cast aluminum alloys (with the exception of foundry ingots, which have no temper classification). Typical mechanical properties of representative cast aluminum alloys are summarized in Table 8 for customary units and Table 9 for metric units.

As with wrought alloys, several major characteristics of casting alloys are determined by their alloy class. Among the most important such characteristics are those related to castability and to end-product properties and characteristics, as illustrated in Table 10 with ratings from 1 (highest or best) to 5 (lowest or worst). Response to heat treatment is another important characteristic:

- 1*xx*.0: Unalloyed; non-heat-treatable
- 2*xx*.0: Copper; heat treatable
- 3*xx*.0: Silicon plus copper and/or magnesium; heat treatable
- 4*xx*.0: Silicon; heat treatable
- 5*xx*.0: Magnesium; non-heat-treatable
- 6*xx*.0: Unused series
- 7*xx*.0: Zinc; heat treatable
- 8*xx*.0: Tin; heat treatable
- 9*xx*.0: Other elements; limited use

Despite these general categorizations, however, it is appropriate to note that while casting alloys of the 3*xx*.0 and 4*xx*.0 groupings are listed as heat treatable, it is not customary in the die-casting industry to use separate solution heat treatment for these alloys. Some strength advantage is gained by the rapid cooling from the casting process, but even this is not usually a closely controlled procedure. On the other hand, sand and permanent mold casting foundries typically take advantage of solution heat treating capabilities.

The basic temper designation systems for cast aluminum alloys are the same as those for wrought aluminum alloys, but with some differences in usage. Notably, strain hardening is not a strengthening mechanism for cast alloys, because the vast majority of castings are produced to near-finished dimensions in shapes that do not lend themselves to stretching or compression by cold working. From a practical standpoint, the basic temper designations in commercial usage for castings include:

- F: As-cast
- O: Annealed
- T4: Solution treated and aged
- T5: Precipitation hardened
- T6: Solution heat treated, quenched, and precipitation hardened
- T7: Solution heat treated, quenched, and overaged

Like wrought alloys, temper designation immediately follows the alloy designation. The as-cast (F-temper) designation is used for cast products made by any casting process (e.g., sand casting, permanent mold casting, die casting, etc.). It refers to the condition of the casting as it comes from the molds without any further thermal or mechanical treatment. Unlike the case with wrought alloys, the F temper is a very common finish or final temper for castings, especially die castings. In addition, unlike wrought alloys, there are likely to be published typical mechanical properties and, in some cases, even minimum mechanical property limits published for the F temper. For example, 360.0-F designates a 360.0 casting as it has come straight from the mold and cooled to room temperature. In this alloy, this is likely to be the temper supplied to the purchaser.

The annealed (O-temper) designation is used for cast alloys that are annealed (i.e., given a high-temperature stabilization or recrystallization treatment, sufficient to remove the effects of the thermal cycles it experienced during the casting and cooling processes, thermal treatments, and to result in a softening of the material and the minimum practical level of mechanical strength). For castings, the treatment may be used both to improve ductility and increase dimensional stability, but it is not a very common finish temper for castings, as it is for wrought non-heat-treatable aluminum alloys. For example, 222.0-O designates a 222.0 casting whose most recent treatment has been holding at a high temperature (~415 °C, or 775 °F) for 5 h and slow furnace cooling by a carefully defined program, intended for dimensional stability.

The T-temper conditions refer to thermally treated conditions other than the O or F tempers. The T designation applies to any cast alloy that has been given a solution heat treatment followed by a suitable quench and either natural (i.e., in air) or artificial (i.e., in a furnace) aging. The "T" is always followed by one or more digits that define in general terms the subsequent treatments. For example, 356.0-T6 designates a 356.0 casting that has been heat treated, quenched, and artificially aged.

Cast Alloy Temper Subdivisions

For cast alloys, there are no standard variations and therefore no additional digits on the designations for the F and O tempers; the following discussion therefore focuses only the T tempers. Thus, for a 356.0 alloy casting that has been solution heat treated, quenched, and artificially aged, the full alloy and temper designation would be shown as 356.0-T6. Examples of registered temper variations are A357.0-T61, 242.0-T571, and 355.0-T71. Other variations of temper designations are permitted by the Aluminum Association Temper Designation System (Ref 1), the most common being the use of "P" added to a standard temper designation (e.g., T6P) to indicate a producer variation of the standard processing treatment.

For the T type of temper for aluminum castings, there are four commercially used subdivisions: T4, T5, T6, and T7. These subdivisions have generally the same meaning as for wrought alloys, but the usage varies slightly:

- T4 indicates the casting has been given a solution heat treatment and, without any cold work, naturally aged (i.e., at room temperature) to a stable condition. For most casting alloys this is an unstable temper, comparable to W for wrought alloys, and so most cast alloys are subsequently aged to T6. Example: 295.0-T4
- T5 indicates the casting has been cooled from the casting process and then artificially aged (i.e., in a furnace). The artificial aging consists of holding at a sufficiently high temperature and sufficiently long time (e.g., 8 h at 175 °C, or 350 °F, or 24 h at 120 °C, or 250 °F) to permit precipitation hardening to take place. This process stabilizes the castings dimensionally, improves machinability, relieves residual stresses, and increases strengths somewhat. Example: 319.0-T5
- T6 indicates the casting has been solution heat treated and artificially aged to achieve maximum precipitation hardening. It results in relatively high strengths with adequate ductility and stabilizes properties and dimensions. Example: 295.0-T6
- T7 indicates the casting has been solution heat treated and artificially aged to an overaged (i.e., past peak strength) condition. This treatment is used to provide a better combination of high strength and high ductility and stabilization of properties and dimensions or resistance to stress-corrosion cracking. Example: A356.0-T7 or A206-T7

Additional digits are used sometimes with these T5, T6, and T7 tempers, but for castings, the variations are not as well defined as for wrought products but do denote variations from the standard practices of either casting or heat treating the part. For different alloys, the same temper designation may not always mean the same variation in casting or heat treating practice:

- *For T5:* The T51, T52, T53, T533, T551, and T571 tempers are recognized variations, intended to either increase dimensional stability or increase strength. For example, for 242.0-T571, the basic temper, T5, indicates that the casting has been

Table 8 Typical mechanical properties (in customary units) of cast aluminum alloys in various temper conditions

Alloy and temper	Tension			Hardness, Brinell No., 500 kg/10 mm	Shear ultimate strength, ksi	Fatigue, endurance limit(b), ksi	Modulus of elasticity(c), 10^6 ksi
	Ultimate strength, ksi	Yield strength(a), ksi	Elongation in 2 in. or *4D*, %				
Sand castings							
201.0-T6	65	55	8	130	...	...	...
201.0-T7	68	60	6	...	...	14	...
201.0-T43	60	37	17	...	...	...	...
204.0-T4	45	28	6	...	...	...	...
A206.0-T4	51	36	7	...	40	...	...
208.0-F	21	14	3	...	17	11	...
213.0-F	24	15	2	70	20	9	...
222.0-O	27	20	1	80	21	9.5	
222.0-T61	41	40	<0.5	115	32	8.5	10.7
224.0-T72	55	40	10	123	35	9	10.5
240.0-F	34	28	1	90	...	...	...
242.0-F	31	20	1	...	...	...	10.3
242.0-O	27	18	1	70	21	8	10.3
242.0-T571	32	30	1	85	26	11	10.3
242.0-T61	32	20	...	90–120	...	...	103
242.0-T77	30	23	2	75	24	10.5	10.3
A242.0-T75	31	...	2	...	...	...	...
295.0-T4	32	16	9	80	26	7	10.0
295.0-T6	36	24	5	75	30	7.5	10.0
295.0-T62	41	32	2	90	33	8	10.0
295.0-T7	29	16	3	55–85	...	...	10.0
319-F	27	18	2	70	22	10	10.7
319.0-T5	30	26	2	80	24	11	10.7
319.0-T6	36	24	2	80	29	11	10.7
328.0-F	25	14	1	45–75	...	...	...
328.0-T6	34	21	1	65–95	...	...	...
355.0-F	23	12	3	...	...	...	10.2
355.0-T51	28	23	2	65	22	8	10.2
355.0-T6	35	25	3	80	28	9	10.2
355.0-T61	35	35	1	90	31	9.5	10.2
355.0-T7	38	26	1	85	28	10	10.2
355.0-T71	35	29	2	75	26	10	10.2
C355.0-T6	39	29	5	85	...	...	...
356.0-F	24	18	6	...	...	...	10.5
356.0-T51	25	20	2	60	20	8	10.5
356.0-T6	33	24	4	70	26	8.5	10.5
356.0-T7	34	30	2	75	24	9	10.5
356.0-T71	28	21	4	60	20	8.5	10.5
A356.0-F	23	12	6	...	...	...	10.5
A356.0-T51	26	18	3	...	...	...	10.5
A356.0-T6	40	30	6	75	...	...	10.5
A356.0-T71	30	20	3	...	...	...	10.5
357.0-F	25	13	5	...	...	...	...
357.0-T51	26	17	3	...	...	...	...
357.0-T6	50	42	2	...	...	...	...
357.0-T7	40	34	3	60	...	...	...
A357.0-T6	46	36	3	85	40	12	...
359.0-T62	50	42	6	16	...	...	...
A390.0-F	26	26	<1.0	100	...	...	...
A390.0-T5	26	26	<1.0	100	...	...	...
A390.0-T6	40	40	<1.0	140	...	13	...
A390.0-T7	36	36	<1.0	115	...	...	...
443.0-F	19	8	8	40	14	8	10.3
B443.0-F	17	6	3	25–55	...	...	...
A444.0-F	21	9	9	30–60	...	...	...
A444.0-T4	23	9	12	43	...	...	...
511.0-F	21	12	3	50	17	8	...
512.0-F	20	13	2	50	17	9	...
514.0-F	25	12	9	50	20	7	...
520.0-T4	48	26	16	75	34	8	...
535.0-F	35	18	9	60–90	...	...	...
535.0-T5	35	18	9	60–90	...	...	...
A535.0-F	36	18	9	65	...	...	...
707.0-T5	33	22	2	70–100	...	...	...
707.0-T7	37	30	1	65–95	...	...	...
710.0-F	32	20	2	60–90	...	...	...
710.0-T5	32	20	2	60–90	...	...	...
712.0-F	34	25	4	60–90	...	...	...
712.0-T5	34	25	4	60–90	...	...	...
713.0-F	32	22	3	60–90	...	...	...
713.0-T5	32	22	3	60–90			
771.0-T5	32	27	3	70–100	...	...	...
771.0-T52	36	30	2	70–100	...	...	...
771.0-T53	36	27	2	...	...	...	...

(continued)

Values are representative of separately cast test bars, not of specimens taken from commercial castings. (a) For tensile yield strengths, offset = 0.2%. (b) Based on 500,000,000 cycles of completely reversed stress using R.R. Moore type of machines and specimens. (c) Average of tension and compression moduli: compressive modulus is nominally approximately 2% greater than the tension modulus. Data taken from various industry handbooks

Table 8 (Continued)

Alloy and temper	Tension			Hardness, Brinell No., 500 kg/10 mm	Shear ultimate strength, ksi	Fatigue, endurance limit(b), ksi	Modulus of elasticity(c), 10^6 ksi
	Ultimate strength, ksi	Yield strength(a), ksi	Elongation in 2 in. or 4*D*, %				
771.0-T6	42	35	5	75–105	...	...	...
771.0-T71	48	45	2	105–135	...	...	...
850.0-T5	20	11	8	45	14	...	10.3
851.0-T5	20	11	5	45	14	...	10.3
852.0-T5	27	22	2	65	18	10	10.3
Permanent mold castings							
201.0-T6	65	55	8	130	...	...	...
201.0-T7	68	60	6	...	...	14	...
201.0-T43	60	37	17	...	...	...	...
204.0-T4	48	29	8	...	...	...	...
A206.0-T4	62	38	17	...	42	...	...
A206.0-T7	63	50	12	...	37	...	...
208.0-T6	35	22	2	75–105	...	...	...
208.0-T7	33	16	3	65–95	...	...	...
213.0-F	30	24	2	85	24	9.5	...
222.0-T551	37	35	<0.5	115	30	8.5	10.7
222.0-T52	35	31	1	100	25	...	10.7
238.0-F	30	24	2	100	24	...	...
242.0-T61	47	42	1	110	35	10	10.3
A249.0-T63	69	60	6	...	...	...	...
296.0-T7	39	20	5	80	30	9	10.1
308.0-F	28	16	2	70	22	13	...
319.0-F	34	19	3	85	24	...	10.7
319.0-T6	40	27	3	95	...	...	10.7
324.0-F	30	16	4	70	...	...	...
324.0-T5	36	26	3	90	...	...	...
324.0-T62	45	39	3	105	...	...	...
332.0-T5	36	28	1	105	...	...	...
328.0-T6	34	21	1	65–95	...	...	...
333.0-F	34	19	2	90	27	15	...
242.0-T571	40	34	1	105	30	10.5	10.3
333.0-T5	34	25	1	100	27	12	...
333.0-T6	42	30	2	105	33	15	...
333.0-T7	37	28	2	90	28	12	...
336.0-T551	36	28	1	105	28	14	...
336.0-T65	47	43	1	125	36	...	...
354.0-T61	48	37	3	...	...	...	...
354.0-T62	52	42	2	...	...	...	...
355.0-F	27	15	4	...	...	...	10.2
355.0-T51	30	24	2	75	24	...	10.2
355.0-T6	42	27	4	90	34	10	10.2
355.0-T61	45	40	2	105	36	10	10.2
355.0-T7	40	30	2	85	30	10	10.2
355.0-T71	36	31	3	85	27	10	10.2
C355.0-T6	48	28	8	90	...	...	10.2
C355.0-T61	46	34	6	100	...	...	10.2
C355.0-T62	48	37	5	100	...	...	10.2
356.0-F	26	18	5	...	...	...	10.5
356.0-T51	27	20	2	...	...	...	10.5
356.0-T6	38	27	5	80	30	13	10.5
356.0-T7	32	24	6	70	25	11	10.5
356.0-T71	25	...	3	60–90	...	...	10.5
A356.0-F	27	13	8	...	...	...	10.5
A356.0-T51	29	20	5	...	...	...	10.5
A356.0-T6	41	30	12	80	...	...	10.5
357.0-F	28	15	6	...	...	...	...
357.0-T51	29	21	4	...	...	...	...
357.0-T6	52	43	5	100	35	13	...
357.0-T7	38	30	5	70	...	...	...
A357.0-T6	52	42	5	100	35	15	...
359.0-T61	48	37	6	...	...	...	...
359.0-T62	50	42	6	...	...	16	...
A390.0-F	29	29	<1.0	110	...	...	...
A390.0-T5	29	29	<1.0	110	...	...	...
A390.0-T6	45	45	<1.0	145	...	17	...
A390.0-T7	38	38	<1.0	120	...	15	...
443.0-F	23	9	10	45	16	8	10.3
B443.0-F	21	6	6	30–60	...	...	...
A444.0-F	24	11	13	44	...	...	...
A444.0-T4	23	10	21	45	16	8	...
513.0-F	27	16	7	60	22	10	...
535.0-F	35	18	8	60–90	...	...	...
705.0-T5	37	17	10	55–75	...	...	...
707.0-T7	45	35	3	80–110	...	...	...
711.0-T1	28	18	7	55–85	...	...	...

(continued)

Values are representative of separately cast test bars, not of specimens taken from commercial castings. (a) For tensile yield strengths, offset = 0.2%. (b) Based on 500,000,000 cycles of completely reversed stress using R.R. Moore type of machines and specimens. (c) Average of tension and compression moduli: compressive modulus is nominally approximately 2% greater than the tension modulus. Data taken from various industry handbooks

Table 8 (Continued)

Alloy and temper	Tension			Hardness, Brinell No., 500 kg/10 mm	Shear ultimate strength, ksi	Fatigue, endurance limit(b), ksi	Modulus of elasticity(c), 10^6 ksi
	Ultimate strength, ksi	Yield strength(a), ksi	Elongation in 2 in. or 4*D*, %				
713.0-T5	32	22	4	60–90			
850.0-T5	23	11	12	45	15	9	10.3
851.0-T5	20	11	5	45	14	9	10.3
851.0-T6	18	···	8	···	···	···	10.3
852.0-T5	32	23	5	70	21	11	10.3
Die castings							
360.0-F	44	25	3	75	28	20	10.3
A360.0-F	46	24	4	75	26	18	10.3
380.0-F	46	23	3	80	28	20	10.3
A380.0-F	47	23	4	80	27	20	10.3
383.0-F	45	22	4	75	···	21	10.3
384.0-F	48	24	3	85	29	20	
390.0-F	40.5	35	>1	···	···	···	···
B390.0-F	46	36	>1	120	···	20	11.8
392.0-F	42	39	>1	···	···	···	···
413.0-F	43	21	3	80	25	19	10.3
A413.0-F	42	19	4	80	25	19	···
C443.0-F	33	14	9	65	29	17	10.3
518.0-F	45	28	5	80	29	20	···

Values are representative of separately cast test bars, not of specimens taken from commercial castings. (a) For tensile yield strengths, offset = 0.2%. (b) Based on 500,000,000 cycles of completely reversed stress using R.R. Moore type of machines and specimens. (c) Average of tension and compression moduli: compressive modulus is nominally approximately 2% greater than the tension modulus. Data taken from various industry handbooks

Table 9 Typical mechanical properties (in metric units) of cast aluminum alloys in various temper conditions

Alloy and temper	Tension			Hardness, Brinell No., 500 kg/10 mm	Shear ultimate strength, MPa	Fatigue, endurance limit(b), MPa	Modulus of elasticity(c), 10^6 MPa
	Ultimate strength, MPa	Yield strength(a), MPa	Elongation in 5*D*, %				
Sand castings							
201.0-T6	450	380	8	130	···	···	···
201.0-T7	470	415	6	···	···	95	···
201.0-T43	415	255	17	···	···	···	···
204.0-T4	310	195	6	···	···	···	···
A206.0-T4	350	250	7	···	275	···	···
208.0-F	145	655	3	···	115	75	···
213.0-F	165	105	2	70	140	60	···
222.0-O	185	140	1	80	145	65	
222.0-T61	285	275	<0.5	115	220	60	74
224.0-T72	380	275	10	123	240	60	73
240.0-F	235	195	1	90	···	···	···
242.0-F	145	140	1	···	···	···	71
242.0-O	185	125	1	70	145	55	71
242.0-T571	220	205	1	85	180	75	71
242.0-T61	220	140	···	90–120	···	···	71
242.0-T77	205	160	2	75	165	70	71
A242.0-T75	215	···	2	···	···	···	···
295.0-T4	220	110	9	80	180	50	69
295.0-T6	250	165	5	75	205	50	69
295.0-T62	285	220	2	90	230	55	69
295.0-T7	200	110	3	55–85	···	···	69
319-F	185	125	2	70	150	70	74
319.0-T5	205	180	2	80	165	75	74
319.0-T6	250	165	2	80	200	75	74
328.0-F	170	95	1	45–75	···	···	···
328.0-T6	235	145	1	65–95	···	···	···
355.0-F	160	85	3	···	···	···	70
355.0-T51	195	160	2	65	150	55	70
355.0-T6	240	170	3	80	195	60	70
355.0-T61	240	240	1	90	215	65	70
355.0-T7	260	180	1	85	195	70	70
355.0-T71	240	200	2	75	180	70	70
C355.0-T6	270	200	5	85	···	···	···
356.0-F	165	125	6	···	···	···	73
356.0-T51	170	140	2	60	140	55	73
356.0-T6	230	135	4	70	180	60	73
356.0-T7	235	205	2	75	165	60	73
356.0-T71	195	145	4	60	140	60	73
A356.0-F	160	85	6	···	···	···	73
A356.0-T51	180	125	3	···	···	···	73
A356.0-T6	275	205	6	75	···	···	73
A356.0-T71	205	140	3	···	···	···	73

(continued)

Values are representative of separately cast test bars, not of specimens taken from commercial castings. (a) For tensile yield strengths, offset = 0.2%. (b) Based on 500,000,000 cycles of completely reversed stress using R.R. Moore type of machines and specimens. (c) Average of tension and compression moduli: compressive modulus is nominally approximately 2% greater than the tension modulus. Data taken from various industry handbooks