Introduction to Aluminum Alloys and Tempers
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CHAPTER 2

Aluminum Alloy and Temper Designation Systems of the Aluminum Association

IT IS VERY USEFUL for secondary fabricators and users of aluminum products and components to have a working knowledge of the Aluminum Association alloy and temper designation systems. The alloy 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. Similarly, the temper designation system permits an understanding of the manner in which the product has been fabricated.

The alloy and temper designation systems for wrought aluminum that are in use today were adopted by the aluminum industry around 1955, and the current system for the cast aluminum system was developed somewhat later. The aluminum industry itself manages the creation and continuing maintenance of these systems through its industry organization, the Aluminum Association. This chapter describes the basic systems as defined and maintained by that organization.

The alloy registration process is carefully controlled and its integrity maintained by the Technical Committee on Product Standards of the Aluminum Association. This committee is made up of industry standards experts. Further, as noted earlier, the Aluminum Association designation system is the basis of the ANSI Standards, incorporated in ANSI H35.1 and, for the wrought alloy system at least, forms the basis for the nearly worldwide *International Accord on Alloy Designations*.

The Aluminum Association Alloy and Temper Designation Systems covered in ANSI H35.1 and *Aluminum Standards and Data* are outlined in this chapter. Additional information is provided in subsequent chapters to assist in understanding and using the systems, as well as recognizing the meanings of the designations themselves.

Wrought Aluminum Alloy Designation System

The Aluminum Association Wrought Alloy Designation System consists of four numerical digits, sometimes including alphabetic prefixes or suffixes, but normally just the four numbers:

- The first digit defines the major alloying class of the series starting with that number.
- The second defines variations in the original basic alloy: that digit is always a zero (0) for the original composition, a one (1) for the first variation, a two (2) for the second variation, and so forth. Variations 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.
- The third and fourth digits designate the specific alloy within the series; there is no special significance to the values of those digits, nor are they necessarily used in sequence.

Table 1 shows the meaning of the first of the four digits in the alloy designation system. The alloy family is identified by that number and the associated main alloying ingredient(s), with three exceptions:

- Members of the 1000 series family are commercially pure aluminum or special purity versions and as such do not typically have any alloying elements intentionally added; however, they do contain minor impurities that are not removed unless the intended application requires it.
- The 8000 series family is an "other elements" series comprising alloys with rather unusual major alloying elements such as iron and nickel.
- The 9000 series is unassigned.

Table 1 Main alloying elements in the wrought alloy designation system

Alloy	Main alloying element
1*xxx*	Mostly pure aluminum; no major alloying additions
2*xxx*	Copper
3*xxx*	Manganese
4*xxx*	Silicon
5*xxx*	Magnesium
6*xxx*	Magnesium and silicon
7*xxx*	Zinc
8*xxx*	Other elements (e.g., iron or tin)
9*xxx*	Unassigned

The major benefit for understanding this designation system is that a great deal will be known about the alloy just from knowledge of the series of which it is a member, for example:

- 1*xxx* series alloys are pure aluminum and its variations; compositions of 99.0% or more aluminum are by definition in this series. Within the 1*xxx* series, the last two of the four digits in the designation indicate the minimum aluminum percentage. These 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%. As with the rest of the alloy series, the second digit indicates modifications in impurity limits or intentionally added elements. Compositions of the 1*xxx* series do not respond to any solution heat treatment but may be strengthened modestly by strain hardening.
- 2*xxx* series alloys have copper as their main alloying element, and because copper will go in significant amounts into solid solution in aluminum, these alloys will respond to solution heat treatment and are referred to as heat treatable.
- 3*xxx* series alloys are based on manganese and are strain hardenable. These alloys do not respond to solution heat treatment.
- 4*xxx* series alloys are based on silicon; some alloys are heat treatable, others are not, depending on the amount of silicon and the other alloying constituents.
- 5*xxx* series alloys are based on magnesium. They are strain hardenable, but not heat treatable.
- 6*xxx* series alloys have both magnesium and silicon as their main alloying elements, which combine as magnesium silicide (Mg_2Si) following solid solution. Alloys in this series are heat treatable.
- 7*xxx* series alloys have zinc as their main alloying element, often with significant amounts of copper and magnesium. They are heat treatable.
- 8*xxx* series contain one or more of several less frequently used major alloying elements such as iron or tin. The characteristics of this series depend on the major alloying element(s).

The compositions of a representative group of widely used commercial aluminum alloys are given in Table 2, taken from *Aluminum Standards and Data* (see Chapter 8, “Selected References”).

Cast Aluminum Alloys Designation System

The designation system for cast aluminum alloys is similar in some respects to that for wrought alloys but has a few very important differences as noted by the following description.

Table 2 Nominal chemical composition of wrought aluminum alloys

	Percent of alloying elements; aluminum and normal impurities constitute remainder							
Alloy	Silicon	Copper	Manganese	Magnesium	Chromium	Nickel	Zinc	Titanium
1050	...	...		99.50% min aluminum		...	...	...
1060	...	...		99.60% min aluminum		...	...	...
1100	...	0.12		99.0% min aluminum		...	...	...
1145	...	...		99.45% min aluminum		...	...	...
1175	...	...		99.75% min aluminum		...	...	...
1200	...	...		99.00% min aluminum		...	...	...
1230	...	...		99.30% min aluminum		...	...	...
1235	...	...		99.35% min aluminum		...	...	...
1345	...	...		99.45% min aluminum		...	...	...
1350(a)	...	...		99.50% min aluminum		...	...	...
2011(b)	...	5.5	...	...	...	...	...	...
2014	0.8	4.4	0.8	0.50	...	...	...	...
2017	0.50	4.0	0.7	0.6	...	...	...	...
2018	...	4.0	...	0.7	...	2.0	...	...
2024	...	4.4	0.6	1.5	...	...	...	...
2025	0.8	4.4	0.8	...	...	...	...	...
2036	...	2.6	0.25	0.45	...	...	...	...
2117	...	2.6	...	0.35	...	...	...	...
2124	...	4.4	0.6	1.5	...	...	...	...
2218	...	4.0	...	1.5	...	2.0	...	...
2219(c)	...	6.3	0.30	...	...	...	...	0.06
2319(c)	...	6.3	0.30	...	...	...	...	0.15
2618(d)	0.18	2.3	...	1.6	...	1.0	...	0.07
3003	...	0.12	1.2	...	...	...	...	...
3004	...	...	1.2	1.0	...	...	...	...
3005	...	...	1.2	0.40	...	...	...	...
3105	...	...	0.6	0.50	...	...	...	...
4032	12.2	0.9	...	1.0	...	0.9	...	...
4043	5.2	...	...	...	...	...	...	...
4045	10.0	...	...	...	...	...	...	...
4047	12.0	...	...	...	...	...	...	...
4145	10.0	4.0	...	...	...	...	...	...
4343	7.5	...	...	...	...	...	...	...
4643	4.1	...	...	0.20	...	...	...	...
5005	...	...	...	0.8	...	...	...	...
5050	...	...	...	1.4	...	...	...	...
5052	...	...	...	2.5	0.25	...	...	...
5056	...	...	0.12	5.0	0.12	...	...	...
5083	...	...	0.7	4.4	0.15	...	...	...
5086	...	...	0.45	4.0	0.15	...	...	
5154	...	...	...	3.5	0.25	...	...	...
5183	...	...	0.08	4.8	0.15	...	...	...
5252	...	...	...	2.5	...	...	...	...
5254	...	...	...	3.5	0.25	...	...	...
5356	...	...	0.12	5.0	0.12	...	...	0.13

(continued)

Listed herein are designations and chemical composition limits for some wrought unalloyed aluminum and for wrought aluminum alloys registered with the Aluminum Association. This 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. (a) Formerly designated EC. (b) Lead and bismuth, 0.40 each. (c) Vanadium, 0.10; zirconium 0.18. (d) Iron, 1.1. (e) Lead and Bismuth, 0.55 each. (f) Zirconium, 0.14. (g) Zirconium, 0.12. (h) Zirconium, 0.18. (i) Iron, 0.7. (j) Boron, 0.02. (k) Iron, 0.35.

Table 2 (continued)

	Percent of alloying elements; aluminum and normal impurities constitute remainder							
Alloy	Silicon	Copper	Manganese	Magnesium	Chromium	Nickel	Zinc	Titanium
5454	...	...	0.08	2.7	0.12	...	...	...
5456	...	...	0.08	5.1	0.12	...	...	...
5457	...	...	0.30	1.0	...	...	...	...
5554	...	...	0.08	2.7	0.12	...	...	0.12
5556	...	...	0.08	5.1	0.12	...	...	0.12
5652	...	...	...	2.5	0.25	...	...	...
5654	...	...	...	3.5	0.25	...	...	0.10
5657	...	...	...	0.8	...	...	...	...
6003	0.7	...	...	1.2	...	...	...	...
6005	0.8	...	...	0.50	...	...	...	...
6053	0.7	...	...	1.2	0.25	...	...	...
6061	0.6	0.28	...	1.0	0.20	...	...	...
6063	0.40	...	...	0.7	...	...	...	...
6066	1.4	1.0	0.8	1.1	...	...	...	...
6070	1.4	0.28	0.7	0.8	...	...	...	...
6101	0.50	...	...	0.6	...	...	...	...
6105	0.8	...	...	0.6	...	...	...	...
6151	0.9	...	...	0.6	0.25	...	...	...
6162	0.6	...	...	0.9	...	...	...	...
6201	0.7	...	...	0.8	...	...	...	...
6253	0.7	...	...	1.2	0.25	...	2.0	...
6262(e)	0.6	0.28	...	1.0	0.09	...	...	...
6351	1.0	...	0.6	0.6	...	...	...	...
6463	0.40	...	...	0.7	...	...	...	...
6951	0.35	0.28	...	0.6	...	...	...	...
7005(f)	...	...	0.45	1.4	0.13	...	4.5	0.04
7008	...	...	...	1.0	0.18	...	5.0	...
7049	...	1.6	...	2.4	0.16	...	7.7	...
7050(g)	...	2.3	...	2.2	...	...	6.2	...
7072	...	...	...	...	...	...	1.0	...
7075	...	1.6	...	2.5	0.23	...	5.6	...
7108(h)	...	...	...	1.0	...	...	5.0	...
7175	...	1.6	...	2.5	0.23	...	5.6	...
7178	...	2.0	...	2.8	0.23	...	6.8	...
7475	...	1.6	...	2.2	0.22	...	5.7	...
8017(i)	...	0.15	...	0.03	...	...	...	...
8030(j)	...	0.22	...	...	...	...	...	...
8176(i)	0.09	...	...	...	...	...	...	...
8177(k)	...	...	...	0.08	...	...	...	...

Listed herein are designations and chemical composition limits for some wrought unalloyed aluminum and for wrought aluminum alloys registered with the Aluminum Association. This 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. (a) Formerly designated EC. (b) Lead and bismuth, 0.40 each. (c) Vanadium, 0.10; zirconium 0.18. (d) Iron, 1.1. (e) Lead and Bismuth, 0.55 each. (f) Zirconium, 0.14. (g) Zirconium, 0.12. (h) Zirconium, 0.18. (i) Iron, 0.7. (j) Boron, 0.02. (k) Iron, 0.35.

The cast alloy designation system also has four digits, and the first digit specifies the major alloying constituent(s) as shown in Table 3. However, a decimal point is used between the third and fourth digits to make clear that these are designations used to identify alloys in the form of castings or foundry ingot.

As for the wrought alloy designation system, the various digits of the cast alloy system convey information about the alloy:

- The first digit indicates the alloy group, as can be seen in Table 3. For 2*xx.x* through 8*xx.x* alloys, 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. Note that in Table 3, the 6*xx.x* series is shown last and for cast alloys is designated as the unused series.
- The second and third digits identify the specific aluminum alloy or, for the aluminum 1*xx.x* series, indicate purity. 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. For the 1*xx.x* group, the second two of the four digits in the designation indicate the minimum aluminum percentage. These digits are the same as the two digits to the right of the decimal point in the minimum aluminum percentage when expressed to the nearest 0.01%.
- The fourth digit indicates the product form: *xxx*.0 indicates castings, and *xxx*.1, for the most part, indicates ingot having limits for alloying elements the same as or very similar to those for the alloy in the form of castings. A fourth digit of *xxx*.2 may be used to indicate that the ingot has composition limits that differ from but fall within the *xxx*.1 limits; this typically represents the use of tighter limits on certain impurities to achieve specific properties in the finished cast product produced from that ingot.

A letter before the numerical designation indicates a modification of the original alloy or an impurity limit. These serial letters are assigned in alphabetical sequence starting with A, but omitting I, O, Q, and X, with X being reserved for experimental alloys. Note that explicit rules have been established for determining whether a proposed composition is a modification of an existing, or whether it is a new, alloy.

Table 4 presents the nominal compositions of a representative group of commercial aluminum casting alloys.

Table 3 Cast alloy designation system

Alloy	Main alloying element
1*xx.x*	Pure aluminum, 99.00% max
2*xx.x*	Copper
3*xx.x*	Silicon, with added copper and/or magnesium
4*xx.x*	Silicon
5*xx.x*	Magnesium
7*xx.x*	Zinc
8*xx.x*	Tin
9*xx.x*	Other elements
6*xx.x*	Unused series

Table 4 Nominal chemical compositions of aluminum alloy castings

	Percent of alloying elements; aluminum and normal impurities constitute remainder									
Alloy	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Nickel	Zinc	Titanium	Notes
201.0	. . .	. . .	4.6	0.35	0.35	. . .	. . .	. . .	0.25	(a)
204.0	. . .	. . .	4.6	. . .	0.25	. . .	. . .	. . .	. . .	
A206.0	. . .	. . .	4.6	0.35	0.25	. . .	. . .	. . .	0.22	
208.0	3.0	. . .	4.0	. . .	. . .	. . .	. . .	. . .	. . .	
213.0	2.0	1.2	7.0	. . .	. . .	. . .	. . .	2.5	. . .	
222.0	. . .	. . .	10.0	. . .	0.25	. . .	. . .	. . .	. . .	
224.0	. . .	. . .	5.0	0.35	. . .	. . .	. . .	. . .	. . .	(b)
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	
295.0	1.1	. . .	4.5	. . .	. . .	. . .	. . .	. . .	. . .	
308.0	5.5	. . .	4.5	. . .	. . .	. . .	. . .	. . .	. . .	
319.0	6.0	. . .	3.5	. . .	. . .	. . .	. . .	. . .	. . .	
328.0	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	. . .	. . .	. . .	. . .	(c)
356.0	7.0	. . .	. . .	. . .	0.32	. . .	. . .	. . .	. . .	
A356.0	7.0	. . .	. . .	. . .	0.35	. . .	. . .	. . .	. . .	(c)
357.0	7.0	. . .	. . .	. . .	0.52	. . .	. . .	. . .	. . .	
A357.0	7.0	. . .	. . .	. . .	0.55	. . .	. . .	. . .	0.12	(c, d)
359.0	9.0	. . .	. . .	. . .	0.6	. . .	. . .	. . .	. . .	
360.0	9.5	. . .	. . .	. . .	0.5	. . .	. . .	. . .	. . .	
A360.0	9.5	. . .	. . .	. . .	0.5	. . .	. . .	. . .	. . .	(c)
380.0	8.5	. . .	3.5	. . .	. . .	. . .	. . .	. . .	. . .	
A380.0	8.5	. . .	3.5	. . .	. . .	. . .	. . .	. . .	. . .	(c)
383.0	10.5	. . .	2.5	. . .	. . .	. . .	. . .	. . .	. . .	
384.0	11.2	. . .	3.8	. . .	. . .	. . .	. . .	. . .	. . .	
B390.0	17.0	. . .	4.5	. . .	0.55	. . .	. . .	. . .	. . .	
413.0	12.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	
A413.0	12.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	
443.0	5.2	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	
B443.0	5.2	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	(c)
C443.0	5.2	(e)								
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	. . .	. . .	. . .	.18	6.8	. . .	. . .	. . .	0.18	
										(f)
705.0	. . .	. . .	. . .	0.5	1.6	0.30	. . .	3.0	. . .	
707.0	. . .	. . .	. . .	0.50	2.1	0.30	. . .	4.2	. . .	

(continued)

Values are nominal (i.e., average of range of limits for elements for which a range is specified). (a) Also contains 0.7% silver. (b) Also contains 0.10% vanadium and 0.18% zirconium. (c) For this alloy, impurity limits are significantly lower than for the similar alloy listed just above. (d) Also contains 0.055% beryllium. (e) May contain higher iron (up to 2.0% total) than 443.0 and A443.0. (f) Also contains 0.005% beryllium and 0.005% boron. (g) Also contains 6.2% tin.

Table 4 (continued)

Alloy	Percent of alloying elements; aluminum and normal impurities constitute remainder									
	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Nickel	Zinc	Titanium	Notes
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	...	...	(g)
851.0	2.5	...	1.0	...	...	...	0.50	...	...	(g)
852.0	...	...	2.0	...	0.75	...	1.2	...	...	(g)

Values are nominal (i.e., average of range of limits for elements for which a range is specified). (a) Also contains 0.7% silver. (b) Also contains 0.10% vanadium and 0.18% zirconium. (c) For this alloy, impurity limits are significantly lower than for the similar alloy listed just above. (d) Also contains 0.055% beryllium. (e) May contain higher iron (up to 2.0% total) than 443.0 and A443.0. (f) Also contains 0.005% beryllium and 0.005% boron. (g) Also contains 6.2% tin.

Designations for Experimental Aluminum Alloys

Experimental alloys of either the wrought or cast aluminum series are indicated with the addition of the prefix X. This prefix is dropped when the alloy is no longer experimental. However, during development and before an alloy is designated as experimental, a new composition may be identified by a serial number assigned by the originating organization. Use of the serial number is discontinued when the composition is registered with the Aluminum Association and the ANSI H35.1 designation is assigned.

Aluminum Alloy Temper Designation System

Basic Temper Designations

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

- *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 hr.
- *T, thermally treated to produce stable tempers other than F, O, or H:* 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.

Subdivisions of the Basic Tempers

The temper designation system is based on sequences of basic treatments used to produce different tempers and their variations. Subdivisions of the basic tempers, discussed next, are indicated by one or more digits (descriptor digits) following the letter.

Subdivisions of the Basic H Tempers. The first number(s) following the letter 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 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.

Adding Additional Digits: H Temper. 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., HX8).
- A degree of cold work equal to approximately one-half that for the HX8 temper is indicated by the HX4 temper, and so on.
- For a degree of cold work halfway between the O temper and the HX4 temper, the HX2 temper is used.
- For a degree of cold work halfway between HX4 and HX8, the HX6 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 HX8 by 14 MPa (2 ksi) or more.

Table 5 indicates gains in the tensile strength of wrought alloys in the annealed temper when they are treated to the HX8 temper.

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

- *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 HX1.
- *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 6.

Table 5 Tensile strengths of HX8 tempers

Minimum tensile strength in annealed temper, ksi	Increase in tensile strength to HX8 temper, ksi
Up to 6	8
7–9	9
10–12	10
13–15	11
16–18	12
19–24	13
25–20	14
31–36	15
37–42	16
43 and over	17

Table 5M Tensile strengths of HX8 tempers (metric)

Minimum tensile strength in annealed temper, mPa	Increase in tensile strength to HX8 temper, mPa
Up to 40	55
45–60	62
65–80	69
85–100	76
105–120	83
125–160	90
165–200	97
205–240	103
245–280	110
285–320	115
296 and over	120

Subdivisions of the Basic T Temper. The first number(s) following the letter T designation indicates the specific combination of basic operations:

- *T1, cooled from elevated temperature shaping process and naturally aged to a substantially stable condition:* Applies to products (a) that are not cold worked after cooling from an elevated temperature shaping process or (b) 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 (a) that are cold worked to improve strength after cooling from an elevated temperature shaping process or (b) 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 (a) that are cold worked to improve strength after solution heat treatment or (b) 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 (a) that are not cold worked after solution heat treatment or (b) 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 (a) that are not cold worked after cooling from elevated temperature shaping process or (b) 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 (a) that are not cold worked after solution treatment or (b) 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 (a) 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 (b) 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 (a) that are cold worked to improve strength or (b) 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 (a) that are cold worked to improve strength or (b) 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 cast or wrought shaped products to a suitable temperature
- Holding them at that temperature long enough to allow constituents to enter into solid solution
- Cooling them rapidly enough to hold the constituents in solution to take advantage of subsequent precipitation and the associated strengthening (i.e., precipitation hardening)

Adding Additional Digits: T Temper. 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. The specific additional digits shown in Table 7 have been assigned for stress-relieved tempers of wrought products. The special T-temper desig-

Table 6 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 7 Tempers for stress-relieved products

Temper	Application
Stress relieved by stretching	
TX51	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
TX510	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
TX511	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	
TX52	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	
TX54	Applies to die forgings that are stress relieved by restriking cold in the finish die.

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

nations listed in Table 8 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.

Assigned O-Temper Variations. The following temper designation has been assigned for wrought products that are high-temperature annealed to accentuate ultrasonic response and to provide dimensional stability:

- *O1, thermally treated at approximately the same time and temperature required for solution heat treatment and slow cooled to room temperature:* Applicable to products that are to be machined prior to solution heat treatment by the user. Mechanical property limits are not applicable.

Table 8 Tempers for testing response to heat treatment

Temper	Description
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
T7X2	Solution heat treated from annealed or F temper and artificially overaged to meet the mechanical properties and corrosion resistance limits of the T7X temper

These 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. 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.

Note: As the O temper is not part of the strain-hardened (H) series, variations of O temper shall not apply to products that are strain hardened after annealing and in which the effect of strain hardening is recognized in the mechanical properties or other characteristics.

Summary

This completes an overview of the Aluminum Association Alloy and Temper Designation Systems in the terms described in *Aluminum Standards and Data* and in ANSI H35.1. In the chapters that follow, we will look at the systems in more detail, discuss the meanings of some of the variations, and provide illustrations of the usage of the systems. With this information, heat treaters, fabricators, and end users of aluminum products should be able to better understand the designations and, hence, the practices used in their particular situations.

For more detailed information on any of the discussion presented in this chapter, the reader is referred directly to the master sources (publication information can be found in Chapter 8, "Selected References"):

- *Aluminum Standards and Data* (English/engineering and metric editions)
- *American National Standard Alloy and Temper Designation Systems for Aluminum*
- *Standards for Aluminum Sand and Permanent Mold Casting*