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Aluminium and aluminium alloys — Wrought products — Temper designations

Aluminium et alliages d'aluminium — Produits corroyés — Désignation des états métallurgiques

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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Foreword

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This document was prepared by Technical Committee ISO/TC 79, *Light metals and their alloys*, Subcommittee SC 9, *Symbolization*.

This fourth edition cancels and replaces the third edition (ISO 2107:2007), of which it constitutes a minor revision. The changes are as follows:

— Clause 2 has been added;

— some terms and definitions have been updated and some new terms have been added in Clause 3;

— Clause 4 has been modified to "Basic temper" with some definitions updated and subdivisions added;

— Annex A has been added.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Aluminium and aluminium alloys — Wrought products — Temper designations

1 Scope

This document establishes temper designations as required for identification for all product forms of wrought aluminium and aluminium alloys.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
temper
condition of the metal produced by mechanical and/or thermal processing, or both, typically characterized by a certain structure and specified properties

3.2
working
forming of solid metal

3.3
hot working
forming of solid metal after pre-heating

Note 1 to entry: Strain hardening will or will not occur during hot working.

3.4
cold working
forming of solid metal without preheating

Note 1 to entry: Plastic deformation of metal at such temperature and strain-rate that strain hardening occurs.

3.5
strain-hardening
modification of a metal structure, by cold working, resulting in an increase in strength and hardness, generally with loss of ductility

3.6
solution heat-treating
heating of an alloy at a suitable temperature for a sufficient time to allow one or more soluble constituents to enter into solid solution, where they are retained in a supersaturated state after quenching (rapid cooling)

3.7
ageing
treatment of a metal aiming at a change in its properties by precipitation of intermetallic phases from supersaturated solid solution

Note 1 to entry: Ageing can be a treatment at room temperature (natural ageing) or a thermal treatment (artificial ageing).

3.8
annealing
thermal treatment to soften metal by reduction or removal of strain hardening resulting from cold working and/or by coalescing precipitates from solid solution

3.9
heat treatable alloy
alloy which can be strengthened by a suitable thermal treatment

3.10
non-heat-treatable alloy
alloy which is strengthened by working and not by thermal treatment

3.11
stress-relieving
reduction of internal residual stresses by thermal or mechanical means

4 Basic temper designations

The temper designations are based on the sequences of basic treatments used to produce the various tempers. Property limits (mechanical or physical) apply to individual alloy-temper-product combinations.

Regional temper designations are provided in Annex A.

The temper designation follows the alloy designation; these are separated by a hyphen.

Basic temper designations consist of letters. If subdivisions of the basic tempers are required, these are indicated by one or more digits following the letter of the basic temper. These digits relate to a specific sequence of basic treatments, but only those treatments or operations recognized as significantly influencing the product characteristics are indicated.

Should some other variation of the same sequence of basic operations be applied to the same alloy, resulting in different characteristics, then additional digits are added to the designation.

Throughout this document, generalized examples of tempers are shown, as follows:

— "X" denotes an unspecified digit (e.g. H2X is generalized to indicate appropriate temper designations in the series H21 to H29);

— "XX" denotes two unspecified digits (e.g. HXX4 is generalized to indicate appropriate temper designations in the H114 to H194 series, the H224 to H294 series, and the H324 to H394 series);

— "_" denotes one or multiple unspecified digits (e.g. T_51 is generalized to indicate appropriate temper designations such as T351, T651, T6151, T7351, T7651, etc.).

4.1 F — as fabricated

This designation applies to the products of shaping processes in which no special control over thermal conditions or strain-hardening is employed. For wrought products, there are no mechanical property limits specified.

4.2 O — annealed

This designation applies to wrought products that are annealed to obtain the lowest strength temper, and to cast products that are annealed to improve ductility and dimensional stability. The O may be followed by a digit other than zero to indicate a product in the annealed condition having special characteristics.

NOTE Products achieving the required annealed properties after hot forming processes can be designated as O temper.

4.3 H — strain-hardened

This designation applies to products that have their strength increased by strain-hardening with or without supplementary thermal treatments to produce some reduction in strength. The letter H is always followed by at least two digits, the first indicating the specific combination of basic operations and the second indicating the degree of strain hardening. A third digit indicates a variation of a two-digit temper and is used when the mechanical properties, or other characteristics, differ from those of the two-digit H temper to which it is added.

4.4 W — solution heat-treated

This designation describes an unstable temper applicable only to alloys that spontaneously age at room temperature after solution heat-treatment. This designation is specific only when the period of natural ageing is indicated, e.g. W 1/2 hr.

4.5 T — precipitation hardened to produce stable tempers other than F, O or H

This designation applies to products that are precipitation hardened, with or without supplementary strain hardening, to produce stable tempers. The T is always followed by one or more digits indicating the specific sequence of treatments.

5 Subdivisions of O temper designations

A digit following the O, when used, indicates a product in the annealed condition having special characteristics. 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.

5.1 O1 — high-temperature annealed to accentuate ultrasonic response and provide dimensional stability

This designation applies to wrought products that are thermally treated at approximately the same time and temperature required for solution heat-treatment and slow cooled to room temperature in order to accentuate ultrasonic response and/or to provide dimensional stability. It is applicable to products that are to be machined prior to solution heat-treatment by the user. Mechanical property limits are not specified.

5.2 O3 — homogenized

This designation applies to continuously cast drawing stock or strip, which are subjected to a high temperature soaking treatment to eliminate or reduce segregations, thus improving subsequent formability and/or response to solution heat-treatment.

6 Subdivisions of H temper designations

6.1 General

Subdivisions are made according to the basic operations described in Clause 4 and the final degree of strain hardening as described in 6.2 to 6.5.

6.2 First digit after H

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

a) H1X Strain-hardened only.

These designations apply to products that are strain-hardened to obtain the desired strength without supplementary thermal treatment.

b) H2X Strain-hardened and partially annealed.

These designations apply to products that are strain-hardened more than the desired final amount, and then reduced in strength to the desired level by partial annealing. For alloys that age-soften at room temperature, the H2X tempers have the same minimum ultimate tensile strength as the corresponding H3X tempers. For other alloys, the H2X tempers have the same minimum ultimate tensile strength as the corresponding H1X tempers and slightly higher elongation.

c) H3X Strain-hardened and stabilized.

These designations apply to products that are strain-hardened and whose mechanical properties are stabilized either by a low-temperature thermal treatment or as a result of heat introduced during fabrication. Stabilization usually improves ductility. This designation is applicable only to those alloys which, unless stabilized, gradually age-soften at room temperature.

d) H4X Strain-hardened and lacquered or painted.

These designations apply to products that are strain-hardened and which are subjected to some thermal operation during the subsequent painting or lacquering operation. The corresponding H2X or H3X mechanical property limits apply.

6.3 Second digit after H

The second digit following the designation H1, H2, H3, and H4 indicates the degree of strain hardening, as identified by the minimum value of the ultimate tensile strength.

a) HX8 has been assigned to the hardest tempers normally produced. The minimum tensile strength of tempers HX8 may be determined from Table 1 and is based on the minimum tensile strength of the alloy in the annealed temper.

Table 1 — Determination of HX8 minimum tensile strength

Minimum tensile strength in annealed temper MPa	Increase in tensile strength to HX8 temper MPa
up to 40	55
45 to 60	65
65 to 80	75
85 to 100	85
105 to 120	90
125 to 160	95
165 to 200	100
205 to 240	105
245 to 280	110
285 to 320	115
325 and over	120

b) Tempers between O (annealed) and HX8 are designated by numerals 1 to 7:

1) HX4 designates tempers whose ultimate tensile strength is approximately midway between that of the O temper and that of the HX8 tempers;

2) HX2 designates tempers whose ultimate tensile strength is approximately midway between that of the O temper and that of the HX4 tempers;

3) HX6 designates tempers whose ultimate tensile strength is approximately midway between that of the HX4 tempers and that of the HX8 tempers;

4) HX1, HX3, HX5 and HX7 designate tempers intermediate between those defined above.

The ultimate tensile strength of the odd-numbered intermediate (-HX1, -HX3, -HX5 and -HX7) tempers, determined as described above, when not ending in 0 or 5, shall be rounded to the next higher 0 or 5 MPa.

c) HX9 designates tempers whose minimum ultimate tensile strength exceeds that of the HX8 tempers by 10 MPa or more.

6.4 Third digit after H

The third digit, when used, indicates a variation of a two-digit temper. It is used when the degree of control of temper or the mechanical properties or both differ from, but are close to, that (or those) for the two-digit H temper designation to which it is added, or when some other characteristic is significantly affected. Numerals 1-9 are arbitrarily defined to indicate a variation of a two-digit H-temper with the exception of the specifically defined three-digit designations.

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

a) 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-hardening that they qualify as HX1.

b) H112 applies to products that can acquire some temper from working at an elevated temperature and for which there are mechanical property limits.

c) H116 applies to products manufactured from alloys in the 5xxx group in which the magnesium content is 3 % nominal or more. These products are strain-hardened at the last operation to specified stable tensile property limits, and to meet specified levels of corrosion resistance in

accelerated-type corrosion tests. Corrosion tests include inter-granular and exfoliation tests. This temper is suitable for continuous service at temperatures no greater than 65 °C (150° F).

d) H321 applies to products from alloys in the 5xxx group in which the magnesium content is 3 % nominal or more. These products are thermally stabilized at the last operation to obtain specified stable tensile property limits, and to meet specified levels of corrosion resistance in accelerated-type corrosion tests. Corrosion tests include inter-granular and exfoliation tests. This temper is suitable for continuous service at temperatures no greater than 65 °C (150° F).

e) H1X8 applied to products manufactured from alloys in the 5xxx series, for which magnesium content is 3 % nominal or more. Products are strain-hardened at the last operation to specified stable tensile property limits and are capable of meeting specified levels of corrosion resistance in accelerated-type corrosion tests after a thermal treatment that is intended to demonstrate improved corrosion performance in ambient conditions. Corrosion tests include inter-granular and exfoliation tests. This temper is suitable for continuous service at temperatures no greater than 65 °C (150° F).

f) HXX4 and HXX5 applies to patterned or embossed sheet and strip fabricated from the listed HXX temper. The mechanical properties of the embossed or engraved product differs from those of the original temper. The following three-digit H temper designations are summarized in Table 2.

Table 2 — Summary of pattern or embossed sheet

Pattern or embossed sheet	Fabricated from
H114	O temper
H124, H224, H324	H11, H21, H31 temper, respectively
H134, H235, 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

6.5 Other digits after H

If necessary, other or additional digits may be used to identify other variations of a subdivision of basic temper H.

7 Subdivisions of T temper designations

7.1 First digits (numerals 1 to 10) after T

The first digit following the letter T is used to identify the specific sequences of basic treatments. Numerals 1 to 10 have been assigned as follows.

NOTE 1 A period of natural ageing at room temperature can occur between or after the operations listed for the T tempers. Control of this period is exercised when it is metallurgically important.

a) T1: Cooled from an elevated-temperature shaping process and naturally aged to a substantially stable condition.

This designation applies to products that are not cold-worked after cooling from an elevated-temperature shaping process, or in which the effect of cold work, in flattening or straightening, will possibly not be recognized in mechanical property limits.

b) T2: Cooled from an elevated-temperature shaping process, cold-worked, and naturally aged to a substantially stable condition.

This designation applies to products that are cold-worked to improve strength after cooling from an elevated-temperature shaping process, or in which the effect of cold work, in flattening or straightening, is recognized in mechanical property limits.

c) T3: Solution heat-treated, cold-worked, and naturally aged to a substantially stable condition.

This designation applies to products that are cold-worked to improve strength after solution heat-treatment, or in which the effect of cold work, in flattening or straightening, is recognized in mechanical property limits.

d) T4: Solution heat-treated and naturally aged to a substantially stable condition

This designation applies to products that are not cold-worked after solution heat-treatment, or in which the effect of cold work, in flattening or straightening, may not be recognized in mechanical property limits.

e) T5: Cooled from an elevated-temperature shaping process and then artificially aged

This designation applies to products that are not cold-worked after cooling from an elevated-temperature shaping process, or in which the effect of cold work in flattening or straightening may not be recognized in mechanical property limits.

f) T6: Solution heat-treated and then artificially aged

This designation applies to products that are not cold-worked after solution heat-treatment, or in which the effect of cold work, in flattening or straightening, may not be recognized in mechanical property limits.

g) T7: Solution heat-treated and overaged/stabilized

This designation applies to products that are artificially aged after solution heat-treatment to carry them beyond a point of maximum strength, in order to provide control of some significant characteristic other than mechanical properties.

NOTE 2 For this purpose, characteristic is something more than mechanical properties. The test method and limit used to evaluate material according to this characteristic are specified at the time of the temper definition.

h) T8: Solution heat-treated, cold worked and then artificially aged

This designation applies to products that are cold-worked to improve strength, or in which the effect of cold work, in flattening or straightening, is recognized in mechanical property limits.

i) T9: Solution heat-treated, artificially aged and then cold-worked

This designation applies to products that are cold-worked to improve strength.

j) T10: Cooled from an elevated-temperature shaping process, cold-worked, and then artificially aged

This designation applies to products that are cold-worked after cooling from an elevated-temperature shaping process to improve strength, or in which the effect of cold work, in flattening or straightening, is recognized in mechanical property limits.

NOTE 3 Solution heat treatment [in c), d), f), g), h) and i)] is achieved by heating cast or wrought products to a suitable temperature, holding at that temperature long enough to allow constituents to enter into solid solution and cooling rapidly enough to hold the constituents in solution. Some 6xxx or 7xxx series alloys attain the same specified mechanical properties, whether furnace solution heat-treated or cooled from an elevated temperature-shaping process with a cooling rate rapid enough to hold constituents in solution. In such cases, when allowed by material specification or purchaser, the temper designations T3, T4, T6, T7, T8 and T9 are used to apply to either process and are appropriate designations, provided the process is controlled to ensure that the product meets specified mechanical properties and, if specified, any other properties (e.g. corrosion resistance).

The T-temper designations and definitions are summarized in Table 3.

Table 3 — Summary of processing for achieving T-tempers

Ageing	Cold worked	Cooled from elevated-temperature shaping process	Solution heat-treated [a]
Natural	No	T1	T4
	Yes	T2	T3
Artificial	No	T5	T6, T7
	Yes — before ageing	T10	T8
	Yes — after ageing	—	T9

[a] See NOTE 3.

7.2 Additional digits added to designations T1 to T10

Additional digits, the first of which shall not be zero, may be added to designations T1 to T10 to indicate a variation in treatment which significantly alters the characteristics of the product with respect to the basic treatment. These digits may relate to one or more of the following:

— the solution heat-treatment and/or the precipitation heat-treatment (ageing);

— the amount of cold work after solution heat-treatment;

— the stress-relieving operation.

These additional digits may be assigned and standardized as described in Clause 3 and in accordance with 7.3.

Variations in treatment that do not alter the characteristics of the product are considered alternative treatments for which additional digits are not assigned.

7.3 Assigned additional digits for stress-relieved T tempers

7.3.1 Stress-relieved by stretching

a) T_51: applies to plate, sheet and rolled or cold-finished rod and bar, die, hand or ring forgings and rolled rings when stretched to the indicated amounts after solution heat-treatment or after cooling from an elevated-temperature shaping process. These products receive no further straightening after stretching:

   — plate: 1,5 % to 3 % permanent set (deformation);

   — sheet: 0,5 % to 3 % permanent set;

   — rolled or cold-finished rod and bar: 1 % to 3 % permanent set;

   — die, hand or ring forgings, rolled rings: 1 % to 5 % permanent set.

b) T_510: applies to extruded rod, bar, profiles (shapes) and tube, and to drawn tube when stretched to 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 % to 3 % permanent set;

   — drawn tube: 0,5 % to 3 % permanent set.

c) T_511: applies to extruded rod, bar, profiles (shapes) and tube, and to drawn tube when stretched to 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 % to 3 % permanent set;

   — drawn tube: 0,5 % to 3 % permanent set.

7.3.2 Stress relieved by compressing

T_52: 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 % to 5 %.

7.3.3 Stress relieved by combined stretching and compressing

T_54 applies to die forgings that are stress-relieved by restriking cold in the finish die.

7.4 Assigned additional digits for stress-relieved W tempers

The same digits as those defined in 7.3.1, 7.3.2 and 7.3.3 may be added to the designation W (e.g. W51; W510; W511; W52; W54) to indicate unstable solution heat-treated and stress-relieved tempers.

7.5 Assigned additional digits for variations of T7 type tempers

The following temper designations have been assigned to wrought products which are artificially overaged to obtain a good compromise among exfoliation corrosion resistance, stress corrosion resistance, fracture toughness and tensile strength.

These designations shall be applied when standardizing new alloy-temper-product combinations:

— T79: very limited overageing to achieve some improved corrosion resistance with limited reduction in strength as compared to the T6 temper.

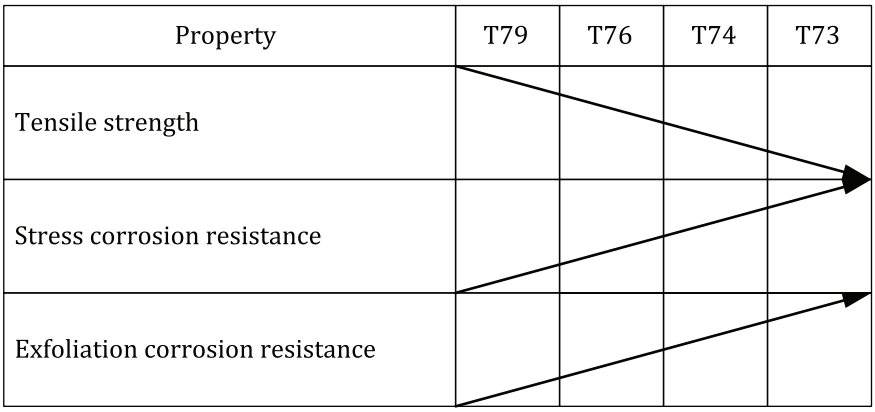
— T76: limited overaged condition to achieve moderate corrosion resistance with some reduction in strength. The T76 temper has lower strength and better corrosion resistance than the T79 temper.

— T74: overaged condition to achieve good corrosion resistance with a greater reduction in strength than the T76 temper. The T74 temper strength and corrosion resistance properties are between those of the T73 and T76 tempers.

— T73: fully overaged condition to achieve the best corrosion resistance of the T7X tempers with a greater reduction in strength than the T74 temper.

— T77: aged condition which provides strength at or near T6 Temper and corrosion resistance similar to the T76 temper.

The relative changes in material properties for the same alloy, during overageing of T7X tempers, are summarized in Figure 1.



NOTE 1 This is a generalized representation. Actual magnitude and combination of properties vary for individual alloys.

NOTE 2 The T77 temper does not fall within the continuous progression of the T7X tempers shown in Figure 1.

Figure 1 — Summary of generalized relationships for some T7X temper properties

7.6 Assigned additional digits for producer/supplier demonstration tempers and purchaser/user processed tempers

7.6.1 Temper designations for producer/supplier — Laboratory demonstration of response to heat treatment

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

a) T42: solution heat-treated from annealed or F temper and naturally aged to a substantially stable condition;

b) T62: solution heat-treated from annealed or F temper and artificially aged;

c) T7_2: solution heat-treated from annealed or F temper and artificially overaged to meet the mechanical properties and corrosion resistance limits of the applicable T7_ temper.

7.6.2 Temper designations for producer/supplier — Demonstration of response to temper conversion

Temper designation T_2 shall be used to indicate wrought-product test material, which has undergone furnace heat-treatment for capability demonstration of temper conversion. When the purchaser requires capability demonstrations from T-temper, the seller shall note “Capability Demonstration” adjacent to the specified and ending tempers. Some examples are:

— “-T3 to -T82 capability demonstration for response to ageing”;

— “-T4 to -T62 capability demonstration for response to ageing”;

— “-T4 to -T762 capability demonstration for response to over ageing”;

— “-T6 to -T732 capability demonstration for response to over ageing”;

— “-T351 to -T42 capability demonstration for response to re-solution heat-treating”.