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Draft Indian Standard

ALUMINIUM AND ITS ALLOYS — TEMPER DESIGNATION

(Second Revision)

ICS 77.120.10

Ores and Feed Stock for Aluminium Industry, its Metals/Alloys and Products Sectional Committee, MTD 07	Last date for receipt of comments is **03 April 2024**

FOREWORD

This Indian Standard (Second Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Ores and Feed Stock for Aluminium Industry, its Metals/Alloys and Products Sectional Committee, had been approved by the Metallurgical Engineering Division Council.

Keeping in view the industrial and trade practices followed in the country in this field, the main modifications made in this revision are as follows:

a) New Temper designation — W solution heat-treated added in Clause 5.5.

b) New subdivision of H Temper : H4X Strain-hardened and lacquered or painted added and third digit after H added in Clause 6.

c) Annex A (informative) : Demonstration of response to heat treatment added.

While formulating this standard assistance is drawn from International Standard ISO 2107:2007; Aluminium and Aluminium Alloy : Temper designations.

This standard was first published in 1969 and subsequently revised in 1993. This revision has been brought out to bring the standard in the latest style and format of the Indian Standards. In addition, a clause on references has been added and the references have been updated.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2: 2022 ‘Rules for rounding off numerical values (*second*

revision)'. The number of significant places retained in the rounded of value should be the same as that of the specified in this standard.

Draft Indian Standard

ALUMINIUM AND ITS ALLOYS — TEMPER DESIGNATION
(Second Revision)

1 SCOPE

This standard covers temper designations for cast and wrought products of aluminium and aluminium alloys.

2 REFERENCES

The following standards contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of these standards.

IS No.	*Title*
IS 5047	Glossary of terms relating to aluminium and aluminium alloys:
(Part 1) : 1986	Unwrought and wrought metals (*second revision*)
(Part 2) : 1979	Plant and operations, thermal treatment, control and testing, finishing

3 TERMINOLOGY

For the purpose of this standard following definitions as given in IS 5047 (Part 1) and IS 5047 (Part 2) shall apply.

3.1 Annealing

Thermal treatment to soften metal by removal of stress resulting from cold working or by coalescing precipitates from solid solution.

3.2 Ageing

Precipitation from supersaturated solid solution resulting in a change in properties of an alloy, usually occurring slowly at room temperature (natural ageing) and more rapidly at elevated temperatures (artificial ageing).

3.3 Artificial Ageing (Precipitation Treatment)

The controlled heating of solution heat-treated material above room temperature for required duration in order to increase its hardness, proof stress and tensile strength.

3.4 Cast Product (Casting)

Metallic shapes formed by pouring molten metal into a mould.

3.5 Cold Working

Plastic deformation, i.e., permanent deformation of metal at such temperatures that strain-hardening occurs.

3.6 Hot Working

Plastic deformation, i.e., permanent deformation of metal at such temperatures that no strain-hardening occurs.

3.7 Flattening

The Flattening of plate or sheet by passing it between a series of staggered rollers of small diameter.

3.8 Natural Ageing (Age Hardening)

The increase in hardness and tensile properties and reduction in ductility which occurs at room temperature after solution treatment and quenching of most heat-treatable alloys. The change in properties is substantially complete within four to five days.

3.9 Partial Annealing (Temper Annealing)

The low temperature treatment of cold-worked material to effect limited softening without causing recrystallization, this treatment is used to obtain certain intermediate tempers.

3.10 Strain-Hardening

Modification of a metal structure, by cold working, resulting in an increase in strength and hardness but with loss of ductility.

3.11 Solution Heat-Treating

Heating an alloy at a suitable temperature for a sufficient time to allow soluble constituents to enter into solid solution where they are retained in a supersaturated state after quenching (rapid cooling).

3.12 Stabilizing

A low temperature treatment applied to cold-worked aluminium-magnesium alloys to provide mechanical properties which will remain constant.

3.13 Stretching

The levelling of rolled materials or the straightening of extruded or drawn materials by imparting the minimum permanent extension required to remove distortion.

3.14 Straightening

The removal of longitudinal distortions.

3.15 Temper

Condition produced by either mechanical or thermal treatment, or both, and characterized by a certainstructure and mechanical properties.

3.16 Working

Deformation of metal, either hot or cold, by shaping processes including rolling, extruding, forging, drawing.

3.17 Wrought Product

A product which has been subjected to mechanical working by such processes as rolling, extrusion, forging, etc.

4 BASIS OF CODIFICATION

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.

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 International Standard, generalized examples of tempers are shown, as follows:

a) "X" denotes an unspecified digit (e.g., H2 X is generalized to indicate appropriate temper designations in the series H21 to H29);

b) "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); and

c) "_" 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.)

5 BASIC TEMPER DESIGNATION

5.1 — M as Manufactured

This designation applies to the products of shaping processes in which no special control over thermal conditions or strain-hardening is applied. For this temper, there are no mechanical property limits specified. This temper designation is applicable for cast products only.

5.2 — F as Fabricated

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

5.3— O Annealed

This designation applies to wrought products which are fully annealed to obtain the lowest strength condition and to cast products which are annealed to improve ductility and dimensional stability.

5.4— H strain-hardened

This designation applies to products subjected to the application of cold work after annealing (or after hotforming), or to a combination of cold work and partial annealing or stabilizing, in order to achieve the specified mechanical properties. 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.

5.5 — W solution heat-treated

This designation describes an unstable temper. It applies only to alloys which 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 h.

5.6 — T thermally treated to produce stable tempers other than M, F, O or H

This designation 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 indicating the specific sequence of treatments.

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; and

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.

6.3 Second digit after H

The second digit following the letter H indicates the final degree of strain hardening, as identified by the minimum value of the ultimate tensile strength.

a) 8 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;

Sl No.	**Minimum tensile strength in annealed temper MPa**	**Increase in tensile strength to HX8 temper Mpa**
(1)	(2)	(3)
i)	up to 40	55
ii)	45 to 80	65
iii)	65 to 80	75
iv)	85 to 100	85
v)	105 to 120	90
vi)	125 to 160	95
vii)	165 to 200	100
viii)	205 to 240	105
ix)	245 to 280	110
x)	285 to 320	115
xi)	325 and over	120

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

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, shall be rounded to the nearest multiple of 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. 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 toqualify as annealed, but not so much or so consistent an amount of strain-hardening that they qualify asHX1;

b) H112 applies to products that may acquire some strain-hardening from working at an elevatedtemperature or from a limited amount of cold work, and for which there are mechanical property limits;

c) H116 applies to products made of those alloys of 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 not greater than 65° C (150° F);

d) H321 applies to products made of those alloys of 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 not greater than 65° C (150° F);

e) HXX4 applies to patterned or embossed sheet and strip fabricated from the corresponding HXX temper. The mechanical properties of the embossed or engraved product differs from those of the original temper; and

f) HXX5 applies to welded tube. Depending on the alloy and geometry of the tube, the mechanical property limits may differ from those of the corresponding HXX temper for strip.

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 2).

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, may 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 inmechanical property limits.

c) T3: Solution heat-treated 3), 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-treated3) 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-treated3) 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-treated3) 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 4).

h) T8: Solution heat-treated3) , 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 3) , artificially aged and then cold-worked; and

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, or in which the effect of cold work, in flattening or straightening, is recognized in mechanical property limits.

The T-temper designations and definitions are summarized in Table 2.

Table 2 Summary of Processing for achieving T-temper

(*Clause* 7.1)

Sl No.	Ageing	Cold worked	Cooled from elevated temperature	Solution heat-treated [a]
(1)	(2)	(3)	(4)	(5)
i)	Natural	No	T1	T4
		Yes	T2	T3
ii)	Artificial	No	T5	T6, T7
		Yes — before ageing	T10	T8
		Yes — after ageing	—	T9

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:

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

b) The amount of cold work after solution heat-treatment; and

c) The stress-relieving operation.

These additional digits may be assigned and standardized as described in clause 4 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, 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;

    1) plate: 1.5 % to 3 % permanent set (deformation);

    2) sheet: 0.5 % to 3 % permanent set;

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

    4) hand or ring forgings, rolled rings: 1 % to 5 % permanent set.

b) T_510: applies to extruded rod, bar, profiles 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;and

    1) extruded rod, bar, profiles and tube: 1 % to 3 % permanent set; and

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

c) T_511: applies to extruded rod, bar, profiles and tube, and to drawn tube when stretched to the indicatedamounts 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.

    1) extruded rod, bar, profiles and tube: 1 % to 3 % permanent set; and

    2) 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 (example 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

These designations apply to products that are artificially overaged in order to:

a) improve corrosion characteristics, such as stress corrosion resistance, and/or exfoliation-corrosionresistance; and

b) obtain a compromise between the above properties and the strength.

It is recommended that the following guidelines be applied when standardizing new alloy-temper-product combinations:

1) T79: very limited overageing;

2) T76: limited overageing to provide high strength with good resistance to exfoliation corrosion;

3) T74: limited overageing, between T73 and T76, to provide acceptable strength and resistance to exfoliation and stress corrosion; and

4) T73: fully overaged to provide the highest stress-corrosion resistance.

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

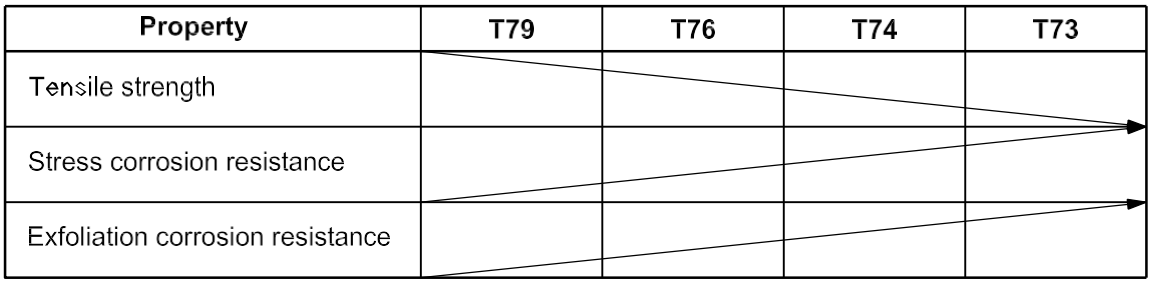

Figure 1 — Summary of generalized relationships for some T7X temper properties

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

ANNEX A

(Informative)

DEMONSTRATION OF RESPONSE TO HEAT TREATMENT

A-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; and

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.

A-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:

a) T3 to -T82 capability demonstration for response to ageing;

b) T4 to -T62 capability demonstration for response to ageing;

c) T4 to -T762 capability demonstration for response to overageing;

d) T6 to -T732 capability demonstration for response to overageing; and

e) T351 to -T42 capability demonstration for response to re-solution heat-treating.

A-3 TEMPER DESIGNATIONS FOR PURCHASER/USER HEAT TREATMENT

Temper designation T_2 should also be applied to wrought products heat-treated by the purchaser/user, in accordance with the applicable heat-treatment specification, in order to achieve the properties applicable to the final temper