***भारतीय मानक***

***Indian Standard***

 **IS 5052 : 2024**

 ***एल्युमिनियम और उसकी मिश्रधातु ― टेम्पर अभिनाम***

 *(दूसरा* पुनरीक्षण )

 **Aluminium and Its Alloys ― Temper**

 **Designations**

( *Second Revision )*

 ICS 77.120.10

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 भारतीय मानक ब्यूरो

 BUREAU OF INDIAN STANDARDS

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Ores and Feed Stock for Aluminium Industry, its Metals/Alloys and Products Sectional Committee, MTD 07

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.

This standard was first published in 1969 and subsequently revised in 1993. To align the standard with current industrial practices ,the temper designations for wrought products mentioned in ISO 2107:2023; ‘Aluminium and aluminium alloy ― Wrought products ― Temper designations’ has been added, the temper designation pertaining to cast products : ‘ M as manufactured’ mentioned in 1993 version of this standard is retained in this revision. Annex A (informative): ‘Demonstration of response to heat treatment’ has been added.

While formulating this standard assistance is drawn from International Standard:

 ISO 2107 : 2023 ‘Aluminium and aluminium alloy ― Wrought products ― Temper designations’.

The composition of the committee responsible for the formulation of this standard is given in Annex B.

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.

*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 and those given in IS 5047 (Part 1) and IS 5047 (Part 2) shall apply.

**3.1 Annealing** ― The softening of material by heating to and holding at a temperature sufficient to cause recrystallization.

**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 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.

**3.4 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.

**3.5 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.

**3.6 Cast Product (Casting)** ― Metallic shapes formed by pouring molten metal into a mould.

**3.7 Cold Working** ― Plastic deformation, i.e., permanent deformation of metal at such temperatures that strain-hardening occurs.

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

**3.9 Hot Working** ― Plastic deformation, i.e., permanent deformation of metal at such temperatures that no strain-hardening occurs.

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

**3.11 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.

**3.12 Strain-Hardening** ― Modification of a metal structure, by cold working, resulting in an increase in strength and hardness but with loss of ductility.

**3.13 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).

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

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

**3.16 Straightening** ― The removal of longitudinal distortions.

**3.17 Temper** ― Condition of the metal produced by either mechanical or thermal treatment, or both, and characterized by a certain structure and mechanical properties.

**3.18 Wrought Product ―** A product which has been subjected to mechanical working by such processes as rolling, extrusion, forging, etc.

**3.19 Heat Treatable Alloy** **―**Alloy which can be strengthened by a suitable thermal treatment.

**3.20 Non Heat-treatable Alloy ―** Alloy which is strengthened by working and not by thermal treatment.

**3.21 Stress-Relieving** **―** reduction of internal residual stresses by thermal or mechanical means.

**4 BASIS OF CODIFICATION**

**4.1** 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.

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

**4.3** 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.

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

**4.5** Throughout this standard, generalized examples of tempers are shown as follows:

1. ‘X’ denotes an unspecified digit (for example: H2 X is generalized to indicate appropriate temper designations in the series H21 to H29);
2. “XX” denotes two unspecified digits (for example: 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
3. ‘\_’ denotes one or multiple unspecified digits (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 hot forming), 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, example: 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 **5** 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:

1. H1X Strain-hardened only;

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

1. 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.

1. 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.

1. 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.

1. 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**

|  |  |  |
| --- | --- | --- |
| **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 60 | 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.

1. 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.

1. 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;
2. H112 applies to products that may acquire some strain-hardening from working at an elevated temperature or from a limited amount of cold work, and for which there are mechanical property limits;
3. H116 applies to products made of those alloys of the 5xxx group in which the magnesium content is 3 percent 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);
4. H321 applies to products made of those alloys of the 5xxx group in which the magnesium content is 3 percent 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);
5. HXX4 applies to pattern 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
6. 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:

1. **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.

1. **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.

1. **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.

1. **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.

1. **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.

1. **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.

1. **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 4).

1. **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.

1. **T9:** Solution heat-treated artificially aged and then cold-worked; and

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

1. **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:

1. The solution heat-treatment and/or the precipitation heat-treatment (ageing);
2. The amount of cold work after solution heat-treatment; and
3. 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*

1. 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.
2. Plate: 1.5 percent to 3 percent permanent set (deformation);
3. Sheet: 0.5 percent to 3 percent permanent set;
4. Rolled or cold-finished rod and bar: 1 percent to 3 percent permanent set; and
5. Hand or ring forgings, rolled rings: 1 percent to 5 percent permanent set.
6. 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.
7. Extruded rod, bar, profiles and tube: 1 percent to 3 percent permanent set; and
8. Drawn tube: 0.5 percent to 3 percent permanent set.
9. T\_511: 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 may receive minor straightening after stretching to comply with standard tolerances.
10. Extruded rod, bar, profiles and tube: 1 percent to 3 percent permanent set; and
11. Drawn tube: 0.5 percent to 3 percent 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 percent to 5 percent.

**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 T 7 Type Tempers**

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

1. Improve corrosion characteristics, such as stress corrosion resistance, and/or exfoliation-corrosion resistance; and
2. 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

**FIG 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**

*(Foreword)*

**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.

1. T42: solution heat-treated from annealed or F temper and naturally aged to a substantially stable condition;
2. T62: solution heat-treated from annealed or F temper and artificially aged; and
3. 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:

1. T3 to T82 capability demonstration for response to ageing;
2. T4 to T62 capability demonstration for response to ageing;
3. T4 to T762 capability demonstration for response to overageing;
4. T6 to T732 capability demonstration for response to overageing; and
5. 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.

**ANNEX B**

(*Foreword*)

**COMMITTEE COMPOSITION**

Ores and Feedstock for Aluminium Industry, its Metals/Alloys and Products Sectional Committee, MTD 07

|  |  |  |
| --- | --- | --- |
| *Organization* |  | *Representative(s)* |
| CSIR — Institute of Minerals and Materials Technology, Bhubaneswar |  | Dr Kali Sanjay ***(Chairperson)*** |
| Aluminium Association of India, Bengaluru |  | Shri Anil Mathew  |
|  |  Shri T. Vimal Raj (*Alternat*e) |
| Aluminium Secondary Manufacturers Association, New Delhi |  | Shri Naveen Pant |
|  |  Shri Praveen Dixit (*Alternat*e) |
| Bharat Aluminium Company Limited, New Delhi |  | Shrimati Anjali Pawar |
|  |  Shri Jitendra Kumar Verma (*Alternat*e) |
| Century Extrusions Limited, Kolkata |  | Shri V. Jhunjhunwala |
|  |  Shri Sanjay Singh Sehrawat (*Alternat*e) |
| Century Metal Recycling Limited, Faridabad |  | Shri Mohan Agarwal |
| CSIR — Advanced Materials and Processes Research Institute, Bhopal |  | Dr D. P. Mondal  |
| CSIR — National Metallurgical Laboratory, Jamshedpur |  | Dr Kanai Sahoo |
|  |  Dr. V. C. Srivastava (*Alternat*e) |
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| National Aluminium Company Limited, Bhubaneswar |  | Shri Tarun Kant  |
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|  |  Shri Ram Sandipam (*Alternat*e) |
| BIS Directorate General |  | Shri Sanjiv Maini, Scientist ‘F’ And Director and Head (Metallurgical Engineering) [Representing Director General (*Ex-officio*)] |

*Member Secretary*

SHRI ASHISH PRABHAKAR WAKLE

SCIENTIST ‘D’/JOINT DIRECTOR

(METALLURGICAL ENGINEERING), BIS