



Standard Practice for Temper Designations for Copper and Copper Alloys— Wrought and Cast¹

This standard is issued under the fixed designation B 601; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This practice defines the terminology in general use for indicating the temper of copper and copper alloy products. The designations used in ASTM specifications under the jurisdiction of Committee B-5 will conform to this practice.

1.2 It defines the terminology of the processes that produce the tempers and the observable changes in the product that result from the processes.

1.3 It establishes an alphanumeric code for use in designating the product tempers.

1.3.1 The letters in the code identify the type of process used to produce the product temper. For example, “H” indicates a temper resulting from cold working. These letters are frequently the same as those used in temper systems of other metals, and are applied to copper products in accordance with this practice.

1.3.2 The numbers in the code were chosen subjectively for general tempers, and objectively to indicate grain size for annealed tempers or reductions for cold-worked tempers.

1.4 The use of this code is recommended for all product tempers in specifications and published data. Its use will simplify the presentation of property data when in tabular form.

1.5 The property requirements for the tempers are given in applicable product specifications.

1.6 Where the word “product” is used, it means a copper or copper alloy product.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Terminology

2.1 Definitions:

2.1.1 *temper*—the metallurgical structure and properties of

a product resulting from thermal or mechanical processing treatments.

2.2 *Basic Processes Used to Produce the Different Tempers:*

2.2.1 *anneal (annealing)*—a thermal treatment to change the properties or grain structure of the product.

2.2.1.1 When applied to a cold-worked product having a single phase; to produce softening by recrystallization or recrystallization and grain growth, with the accompanying changes in properties.

2.2.1.2 When applied to a product having two or more phases: to produce softening by changes in phase relationships which may include recrystallization and grain growth.

2.2.2 *cold work*—controlled mechanical operations for changing the form or cross section of a product and for producing a strain-hardened product at temperatures below the recrystallization temperature.

2.2.3 *drawn stress relieved (DSR)*—a thermal treatment of a cold-drawn product to reduce residual stress variations, thus reducing susceptibility of product to stress corrosion or season cracking, without significantly affecting its tensile strength or microstructure.

2.2.4 *hot working*—controlled mechanical operations for shaping a product at temperatures above the recrystallization temperature.

2.2.5 *order strengthening*—a thermal treatment of a cold-worked product at a temperature below its recrystallization temperature causing ordering to occur to obtain an increase in yield strength.

2.2.6 *precipitation heat treatment*—a thermal treatment of a solution heat-treated product to produce property changes such as hardening, strengthening, and conductivity increase by precipitation of constituents from the supersaturated solid solution. This treatment has also been called “age hardened” and “precipitation hardened.”

2.2.7 *quench hardening*—a treatment for copper-aluminum alloy products consisting of heating above the betatizing temperature followed by quenching to produce a hard martensitic structure.

2.2.8 *solution heat treatment*—a thermal treatment of a product to put alloying elements into solution in the base metal by heating into the temperature range of solid solubility,

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followed by cooling at a sufficient rate to retain them in a supersaturated solid solution.

2.2.9 *spinodal heat treatment*—a thermal treatment of a solution heat-treated product to produce property changes such as hardening, strengthening, and conductivity increase by spinodal decomposition of a solid solution. This treatment has also been called “age hardened,” “spinodal hardened,” or “spinodally decomposed.”

2.2.10 *strain hardening*—the increase in strength and hardness and decrease in ductility as a result of permanent deformation of the structure by cold working.

2.2.11 *stress relief*—a treatment of a product to reduce residual stresses.

2.2.11.1 *by thermal treatment*—without causing recrystallization.

2.2.11.2 *by mechanical treatment*—without causing a significant change in size.

2.2.12 *temper annealing*—a thermal treatment above the eutectoid temperature for copper-aluminum alloy products to minimize the presence of the stable eutectoid structure.

2.2.13 *tempering*—a thermal treatment of a quench-hardened product to improve ductility.

2.2.14 *thermal treatment*—a controlled heating; time at maximum temperature-cooling cycle as needed to satisfy the property and grain structure requirements of the temper.

3. Classification of Tempers

NOTE 1—In the following paragraphs, tempers are classified according to terminology used by U.S. manufacturers of copper and copper alloy products and are arranged in alphabetical order with their designated code letters.

3.1 *Annealed Tempers, O*—Tempers produced by annealing to meet mechanical property requirements.

3.2 *Annealed Tempers, OS*—Tempers produced by annealing to meet standard or special grain size requirements.

3.3 *Manufactured Tempers, M*—Tempers produced in the product by the primary manufacturing operations of casting and hot working and controlled by the methods employed in the operations.

3.4 *Cold-Worked Tempers, H*—Tempers produced by controlled amounts of cold work.

3.5 *Cold-Worked (Drawn), Stress-Relieved Tempers, HR*—Tempers produced by controlled amounts of cold work followed by stress relief.

3.5.1 *Order-Strengthening Tempers, HT*—Tempers produced by controlled amounts of cold work followed by a thermal treatment to produce order strengthening.

3.6 *Heat-Treated Tempers, T*—Tempers that are based on heat treatments followed by rapid cooling.

3.6.1 *Quench-Hardened Tempers, TQ*—Tempers produced by quench-hardening treatments.

3.6.2 *Solution Heat-Treated Temper, TB*—Tempers produced by solution heat-treating precipitation hardenable or spinodal hardenable alloys.

3.6.3 *Solution Heat-Treated and Cold-Worked Tempers, TD*—Tempers produced by controlled amounts of cold work of solution heat-treated precipitation hardenable or spinodal hardenable alloys.

3.6.4 *Precipitation Heat-Treated Temper, TF*—Tempers

produced by precipitation heat treatment of precipitation-hardenable alloys.

3.6.5 *Spinodal Heat Treated Temper, TX*—Tempers produced by spinodal heat treatment of spinodal hardenable alloys.

3.6.6 *Cold-Worked and Precipitation Heat-Treated Tempers, TH*—Tempers produced in alloys that have been solution heat treated, cold worked, and precipitation heat treated.

3.6.7 *Cold-Worked and Spinodal Heat-Treated Tempers, TS*—Tempers produced in alloys that have been solution heat treated, cold worked, and spinodal heat treated.

3.6.8 *Mill-Hardened Tempers, TM*—Tempers of heat-treated materials as supplied by the mill resulting from combinations of cold work and precipitation heat treatment or spinodal heat treatment.

3.6.9 *Precipitation Heat-Treated or Spinodal Heat-Treated and Cold-Worked Tempers, TL*—Tempers produced by cold working the precipitation heat-treated or spinodal heat-treated alloys.

3.6.10 *Precipitation Heat-Treated or Spinodal Heat-Treated, Cold-Worked, and Thermal Stress-Relieved Tempers, TR*—Tempers produced in the cold-worked precipitation heat-treated or spinodal heat-treated alloys by thermal stress relief.

3.7 *Tempers of Welded Tubes, W*—(Welded tubes are produced from strip of various tempers and essentially have the temper of the strip except in the heat-affected zone.)

3.7.1 *Tube, As-Welded Tempers, WM*—Tempers that result from forming and welding when producing tube.

3.7.2 *Tube, Welded and Annealed Temper, WO*—Temper that results from forming, welding, and annealing when producing tube.

3.7.3 *Tube, Welded and Cold-Worked Tempers, WH*—Tempers that result from forming, welding, and cold working when producing tube.

3.7.4 *Tube, Welded, Cold-Worked and Stress-Relieved Tempers, WR*—Tempers that result from forming, welding, cold working, and stress relieving when producing tube.

3.7.5 *Tube, Welded, and Fully Finished Tempers, O, OS, H*—Tempers that result from both annealing a welded and cold-worked tube, or cold working, a welded cold-worked and annealed tube. With these treatments, the weld area has been transformed into a wrought structure, and the usual temper designations apply.

4. Temper Designation Codes

NOTE 2—Also shown are regular temper terms that are being retained for an indefinite period.

4.1 *Annealed Tempers, O:*

4.1.1 *Annealed to Meet Mechanical Properties, O:*

Annealed Tempers—O	Temper Names
O10	Cast and Annealed (Homogenized)
O11	As Cast and Precipitation Heat Treated
O20	Hot Forged and Annealed
O25	Hot Rolled and Annealed
O30	Hot Extruded and Annealed
O31	Extruded and Precipitation Heat Treated
O40	Hot Pierced and Annealed
O50	Light Anneal
O60	Soft Anneal

O61	Annealed	HR02	½ Hard and Stress Relieved
O65	Drawing Anneal	HR04	Hard and Stress Relieved
O68	Deep Drawing Anneal	HR06	Extra Hard and Stress Relieved
O70	Dead Soft Anneal	HR08	Spring and Stress Relieved
O80	Annealed to Temper—⅛ Hard	HR10	Extra Spring and Stress Relieved
O81	Annealed to Temper—¼ Hard	HR12	Special Spring and Stress Relieved
O82	Annealed to Temper—½ Hard	HR20	As-finned

4.1.2 Annealed to Meet Nominal Average Grain Size, OS:

Annealed Tempers, with Grain Size Prescribed—OS	Temper Designations Nominal Avg Grain Size, mm
OS005	0.005
OS010	0.010
OS015	0.015
OS025	0.025
OS035	0.035
OS045	0.045
OS050	0.050
OS060	0.060
OS065	0.065
OS070	0.070
OS100	0.100
OS120	0.120
OS150	0.150
OS200	0.200

4.2 Cold-Worked Tempers, H:

4.2.1 Cold-Worked Tempers to Meet Standard Requirements

Based on Cold Rolling or Cold Drawing, H:

Cold-Worked Tempers—H	Temper Names
H00	⅛ Hard
H01	¼ Hard
H02	½ Hard
H03	¾ Hard
H04	Hard
...	...
H06	Extra Hard
...	...
H08	Spring
...	...
H10	Extra Spring
...	...
H12	Special Spring
H13	Ultra Spring
H14	Super Spring
...	...

4.2.2 Cold-Worked Tempers to Meet Standard Requirements

Based on Temper Names Applicable to Particular Products, H:

Cold-Worked Tempers—H	Temper Names
H50	Extruded and Drawn
H52	Pierced and Drawn
H55	Light Drawn, Light Cold-Worked
H58	Drawn General Purpose
H60	Cold Heading, Forming
H63	Rivet
H64	Screw
H66	Bolt
H70	Bending
H80	Hard Drawn
H85	Medium Hard-Drawn Electrical Wire
H86	Hard-Drawn Electrical Wire
H90	As-finned

4.3 Cold-Worked Tempers with Added Treatments:

4.3.1 Cold Worked and Stress Relieved, HR:

	Temper Names
HR01	¼ Hard and Stress Relieved

4.3.2 Drawn and Stress Relieved, HR:

	Temper Name
HR50	Drawn and Stress Relieved

4.3.3 Cold Rolled and Order Strengthened, HT:

	Temper Names
HT04	Hard Temper and Treated
HT08	Spring Temper and Treated
...	...

4.3.4 Hard Drawn End Annealed, HE:

	Temper Name
HE80	Hard Drawn and End Annealed

4.4 As-Manufactured Tempers, M:

	Temper Names
M01	As Sand Cast
M02	As Centrifugal Cast
M03	As Plaster Cast
M04	As Pressure Die Cast
M05	As Permanent Mold Cast
M06	As Investment Cast
M07	As Continuous Cast
M10	As Hot Forged—Air Cooled
M11	As Forged—Quenched
M20	As Hot Rolled
M25	As Hot Rolled and Rerolled
M30	As Hot Extruded
M40	As Hot Pierced
M45	As Hot Pierced and Rerolled

4.5 Heat-Treated Tempers, T:

4.5.1 Quench Hardened, TQ:

	Temper Names
TQ00	Quench Hardened
TQ30	Quench Hardened and Tempered
TQ50	Quenched Hardened and Temper Annealed
TQ55	Quench Hardened and Temper Annealed, Cold Drawn and Stress Relieved
TQ75	Interrupted Quench

4.5.2 Solution Heat Treated, TB:

	Temper Name
TB00	Solution Heat Treated (A)

4.5.3 Solution Heat Treated and Cold Worked, TD:

	Temper Names
TD00	Solution Heat Treated and Cold Worked: ⅛ Hard
TD01	Solution Heat Treated and Cold Worked: ¼ Hard (¼ H)
TD02	Solution Heat Treated and Cold Worked: ½ Hard (½ H)
TD03	Solution Heat Treated and Cold Worked: ¾ Hard (¾ H)
TD04	Solution Heat Treated and Cold Worked: Hard (H)

4.5.4 Solution Heat Treated and Precipitation Heat Treated, TF:

	Temper Name
TF00	Precipitation Hardened (AT)

TF01	Precipitation Heat-Treated Plate—Low Hardness (ATLH)
TF02	Precipitation Heat-Treated Plate—High Hardness (ATHH)

Temper Names

TR01	Precipitation Heat Treated or Spinodal Heat Treated, ¼ Hard and Stress Relieved
TR02	Precipitation Heat Treated or Spinodal Heat Treated, ½ Hard and Stress Relieved
TR04	Precipitation Heat Treated or Spinodal Heat Treated, Hard and Stress Relieved

4.5.5 Solution Heat Treated and Spinodal Heat Treated, TX:

Temper Name

TX00	Spinodal Hardened (AT)
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4.5.6 Solution Heat Treated, Cold Worked, and Precipitation Heat Treated, TH:

Temper Names

TH01	¼ Hard and Precipitation Heat Treated (¼ HT)
TH02	½ Hard and Precipitation Heat Treated (½ HT)
TH03	¾ Hard and Precipitation Heat Treated (¾ HT)
TH04	Hard and Precipitation Heat Treated (HT)

4.5.7 Cold-Worked Tempers and Spinodal Heat Treated to Meet Standard Requirements Based on Cold Rolling or Cold Drawing, TS:

Temper Names

TS00	⅛ Hard and Spinodal Hardened (⅛ TS)
TS01	¼ Hard and Spinodal Hardened (¼ TS)
TS02	½ Hard and Spinodal Hardened (½ TS)
TS03	¾ Hard and Spinodal Hardened (¾ TS)
TS04	Hard and Spinodal Hardened
...	...
TS06	Extra Hard and Spinodal Hardened
...	...
TS08	Spring and Spinodal Hardened
...	...
TS10	Extra Spring and Spinodal Hardened
...	...
TS12	Special Spring and Spinodal Hardened
TS13	Ultra Spring and Spinodal Hardened
TS14	Super Spring and Spinodal Hardened

4.5.8 Mill Hardened, TM:

Manufacturing Designations

TM00	AM
TM01	¼ HM
TM02	½ HM
TM03	¾ HM
TM04	HM
TM05	SHM
TM06	XHM
TM08	XHMS

4.5.9 Precipitation Heat Treated or Spinodal Heat Treated and Cold Worked, TL:

Temper Names

TL00	Precipitation Heat Treated or Spinodal Heat Treated and ⅛ Hard
TL01	Precipitation Heat Treated or Spinodal Heat Treated and ¼ Hard
TL02	Precipitation Heat Treated or Spinodal Heat Treated and ½ Hard
TL04	Precipitation Heat Treated or Spinodal Heat Treated and Hard
TL08	Precipitation Heat Treated or Spinodal Heat Treated and Spring
TL10	Precipitation Heat Treated or Spinodal Heat Treated and Extra Spring

4.5.10 Precipitation Heat Treated or Spinodal Heat Treated, Cold Worked, and Thermal Stress Relieved, TR:

4.6 Tempers of Welded Tube, W:

4.6.1 As-Welded, WM:

Temper Names

WM50	As-Welded from Annealed Strip
WM00	As-Welded from ⅛ Hard Strip
WM01	As-Welded from ¼ Hard Strip
WM02	As-Welded from ½ Hard Strip
WM03	As-Welded from ¾ Hard Strip
WM04	As-Welded from Hard Strip
WM06	As-Welded from Extra Hard Strip
WM08	As-Welded from Spring Strip
WM10	As-Welded from Extra Spring Strip
WM15	As-Welded from Annealed Strip, Thermal Stress Relieved
WM20	As-Welded from ⅛ Hard Strip, Thermal Stress Relieved
WM21	As-Welded from ¼ Hard Strip, Thermal Stress Relieved
WM22	As-Welded from ½ Hard Strip, Thermal Stress Relieved

4.6.2 Welded Tube and Annealed, WO:

Temper Names

WO50	Welded and Light Annealed
WO60	Welded and Soft Annealed
WO61	Welded and Annealed

4.6.3 Welded Tube and Light Cold-Worked, WC:

Temper Name

WC55	Welded and Light Cold-Worked
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4.6.4 Welded Tube and Cold Drawn, WH:

Temper Names

WH00	Welded and Drawn: Eighth Hard
WH01	Welded and Drawn: Quarter Hard
WH02	Welded and Drawn: Half Hard
WH03	Welded and Drawn: Three Quarter Hard
WH04	Welded and Drawn: Hard
WH06	Welded and Drawn: Extra Hard
WH55	Welded and Cold Reduced or Light Drawn
WH58	Welded and Cold Reduced or Drawn, General Purpose
WH80	Welded and Reduced or Hard Drawn

4.6.5 Welded Tube, Cold Drawn, and Stress Relieved, WR:

Temper Names

WR00	Welded, Drawn, and Stress Relieved from: Eighth Hard
WR01	Welded, Drawn, and Stress Relieved from: Quarter Hard
WR02	Welded, Drawn, and Stress Relieved from: Half Hard
WR03	Welded, Drawn, and Stress Relieved from: Three Quarter Hard
WR04	Welded, Drawn, and Stress Relieved from: Hard
WR06	Welded, Drawn, and Stress Relieved from: Extra Hard

4.6.6 Welded Tube, Fully Finished, O, OS, H:

4.6.6.1 Fully Finished Tube, Annealed to Meet Property Requirements:

Temper Names

O— & OS—	Use appropriate designation for property or grain size requirements. See 4.1.1 or 4.1.2
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4.6.6.2 Fully Finished Tube, Drawn to Meet Property Requirements:

	Temper Names
H—	Use appropriate designation for property requirement. See 4.2.1.

5. Keywords

5.1 copper and copper alloys; temper designation

SUMMARY OF CHANGES

Committee B05 has identified the location of selected changes to this standard since the B 601 - 99 issue that may impact the use of this standard:

- (1) Added the TF01 Precipitation Heat-Treated Plate—Low Hardness (ATLH) temper to 4.5.4,
- (2) Added the TF02 Precipitation Heat-Treated Plate—High Hardness (ATHH) temper to 4.5.4, and
- (3) Added the TM03 ($\frac{3}{4}$ HM) temper to 4.5.8.

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