Designation: B1014 – 20

Standard Specification for Welded Copper and Copper Alloy Condenser and Heat Exchanger Tubes with a Textured Surface(s)[1]

This standard is issued under the fixed designation B1014; 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.

1. Scope

1.1 This specification describes the production of welded copper and copper alloy tubes with a longitudinal seam free of filler metal produced from sheet or strip up to 1.5 in. (38.1 mm), in diameter for use in surface condensers, evaporators, heat exchangers, and general engineering applications. The following coppers or copper alloys are involved:

Copper UNS Nos.	Type of Copper
C10100[A]	Oxygen-Free-Electronic (OFE)
C10200[A]	Oxygen-Free, without residual deoxidants (OF)
C10300[A]	Oxygen-Free, low phosphorus (OFXLP)
C10800[A]	Oxygen-Free Copper, low phosphorus (OFLP)
C12000[A]	Phosphorus-Deoxidized, low residual phosphorus (DLP)
C12200[A]	Phosphorus-Deoxidized, high residual phosphorus (DHP)
C14200	Phosphorus-Deoxidized, arsenical (DPA)
C15630	Nickel Phosphorus
C19200	Phosphorized, 1 % iron
C23000	Red Brass, 85 %
C44300	Admiralty, Arsenical
C44400	Admiralty, Antimonial
C44500	Admiralty, Phosphorized
C60800	Aluminum Bronze
C68700	Aluminum Brass, Arsenical
C70400	Copper-Nickel, 5 %
C70600	Copper-Nickel, 10 %
C70620	Copper-Nickel, 10 % (modified for welding)
C71000	Copper-Nickel, 20 %
C71500	Copper-Nickel, 30 %
C71520	Copper-Nickel, 30 % (modified for welding)
C72200	...

[A] Designations listed in Classification B224.

1.1.1 The *(1)* external tube surface, *(2)* internal tube surface, or *(3)* both internal and external tube surfaces of these tubes shall have a textured surface for improved heat transfer or fluid flow, or both. The strip material used to produce the textured surface tubes have been modified to form a textured surface strip material from a smooth surface strip material by a cold-forming process or series of processes. The produced welded textured tubes may be used in condensers, evaporators, heat exchangers, and other similar heat transfer apparatus in diameters up to and including 1.5 in. (38.1 mm) for various wall thicknesses up to and including 0.07 in. (1.78 mm).

1.2 The tubing sizes and thicknesses usually furnished to this specification are ⅛ in. (3.2 mm) in inside diameter to 1.5 in. (38.1 mm) in outside diameter and 0.015 in. to 0.070 in. (0.4 mm to 1.78 mm), inclusive, in wall thickness. Tubing having other dimensions may be furnished provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than ⅛ in. (3.2 mm) in inside diameter or for a wall thickness smaller than 0.015 in. (0.4 mm).

1.4 Optional supplementary requirements are provided and, when one or more of these are desired, each shall be so stated in the order.

1.5 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5.1 *Exception*—Values given in inch-pound units are the standard except for grain size, which is stated in SI units.

1.6 The following safety hazards caveat pertains to the test method described in this specification: *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *Mercury has been designated by many regulatory agencies as a hazardous substance that can cause serious medical issues. Mercury, or its vapor, has been demonstrated to be hazardous to health and corrosive to materials. Use caution when handling mercury and mercury-containing products. See the applicable product Safety Data Sheet (SDS) for additional information. The potential exists that selling mercury or mercury-containing products, or both, is prohibited by local or national law. Users must determine legality of sales in their location.*

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the*

[1] This specification is under the jurisdiction of ASTM Committee B05 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.04 on Pipe and Tube.

Current edition approved Oct. 1, 2020. Published November 2020. DOI: 10.1520/B1014-20.

Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

B153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing
B154 Test Method for Mercurous Nitrate Test for Copper Alloys
B170 Specification for Oxygen-Free Electrolytic Copper—Refinery Shapes
B224 Classification of Coppers
B577 Test Methods for Detection of Cuprous Oxide (Hydrogen Embrittlement Susceptibility) in Copper
B601 Classification for Temper Designations for Copper and Copper Alloys—Wrought and Cast
B846 Terminology for Copper and Copper Alloys
B858 Test Method for Ammonia Vapor Test for Determining Susceptibility to Stress Corrosion Cracking in Copper Alloys
B950 Guide for Editorial Procedures and Form of Product Specifications for Copper and Copper Alloys
B968/B968M Test Method for Flattening of Copper and Copper-Alloy Pipe and Tube
E3 Guide for Preparation of Metallographic Specimens
E8/E8M Test Methods for Tension Testing of Metallic Materials
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E53 Test Method for Determination of Copper in Unalloyed Copper by Gravimetry
E62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods) (Withdrawn 2010)[3]
E112 Test Methods for Determining Average Grain Size
E118 Test Methods for Chemical Analysis of Copper-Chromium Alloys (Withdrawn 2010)[3]
E243 Practice for Electromagnetic (Eddy Current) Examination of Copper and Copper-Alloy Tubes
E255 Practice for Sampling Copper and Copper Alloys for the Determination of Chemical Composition
E478 Test Methods for Chemical Analysis of Copper Alloys
E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)
E2575 Test Method for Determination of Oxygen in Copper and Copper Alloys by Inert Gas Fusion

2.2 *ASME Code:*[4]

ASME Boiler and Pressure Vessel Code Application

3. Terminology

3.1 *Definitions*—For definitions of terms related to copper and copper alloys, refer to Terminology B846.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *lengths, mill, n*—straight lengths, including ends that are conveniently manufactured in the mills.

3.2.1.1 *Discussion*—Full-length pieces are usually 10 ft, 12 ft, or 20 ft (3 m, 3.7 m, or 6.1 m) and subject to established length tolerances.

3.2.2 *lengths, stock, n*—straight lengths that are mill cut and stored in advance of orders.

3.2.2.1 *Discussion*—Stock lengths are usually 6 ft to 20 ft (1.8 m to 6.1 m) and subject to established tolerances.

3.2.3 *% of secondary pattern, n*—combination of secondary characters.

3.2.4 *plain ending, n*—portion of the tube that has no surface texture.

3.2.5 *primary character, n*—largest texture impressed on material.

3.2.6 *primary pattern, n*—combination of primary characters.

3.2.7 *secondary characters, n*—fadeout texture impressed on material.

3.2.8 *textured surface, n*—impressing a series of non-linear characters on textures into the material with the intent of improving heat transfer and fluid flow characteristics in the final welded tube.

3.3 *Symbols (Textured Tube Nomenclature):*

3.3.1 *D*—outside tube diameter-nominal

3.3.2 D_i—inside tube diameter

3.3.3 *ID1*—top of primary to bottom of secondary

3.3.4 *ID2*—top of primary to top of secondary

3.3.5 *ID3*—top of secondary to top of secondary

3.3.6 *ID4*—top of primary to bottom of primary at intersection of the base (each on opposite sides of the tube)

3.3.7 *ID5*—top of primary to top of primary (each on opposite sides of the tube)

3.3.8 *ID6*—top of secondary to bottom of secondary

3.3.9 *Pa*—angle of the primary character unit (if any)

3.3.10 *Pa*—angle of the secondary character unit (if any)

3.3.11 *Pc*—primary pattern center spacing

3.3.12 *Pd*—primary pattern character diameter

3.3.13 *Phi*—primary pattern height (inside)

3.3.14 *Pho*—primary pattern height (outside)

3.3.15 *Sc*—secondary pattern center spacing

3.3.16 *Sd*—secondary pattern character diameter

3.3.17 *Shi*—secondary pattern character (inside)

3.3.18 *Sho*—secondary pattern height (outside)

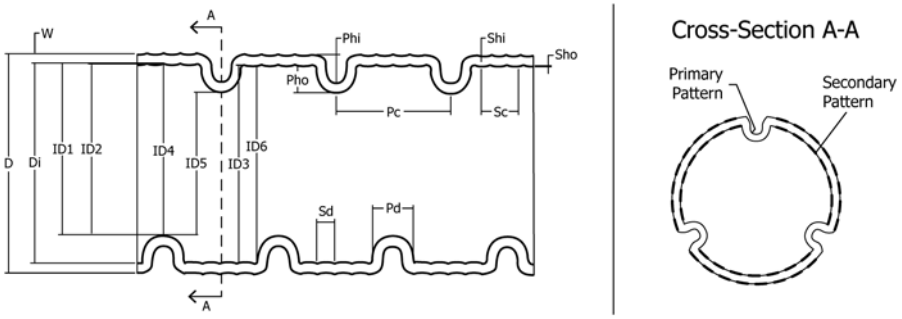
3.3.19 *W*—wall thickness (no pattern)

3.3.20 *W1*—wall thickness peak inside to valley outside (secondary pattern)

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.



(a) Longitudinal view (b) Cross-sectional view

FIG. 1 Views of Representative Textured Tube Showing Variables that Describe Possible Primary and Secondary Texturizations that may be Applied to Inside Surface of Tube, Outside Surface of Tube, or Both Inside and Outside Surfaces of Tube

3.3.21 *W2*—wall thickness valley inside to peak outside (secondary pattern)

3.3.22 *W3*—wall thickness base of primary pattern

3.3.23 *W4*—wall thickness in wall of the primary character

3.4 Fig. 1 illustrates a representative textured tube showing variables that describe the possible primary and secondary enhancements that may be applied to the inside surface of a tube, outside surface of the tube, or both the inside and outside surfaces of the tube *(a)* longitudinal view *(b)* cross-sectional view.

3.5 Fig. 2 details are regarding the sample representative geometry of the patterns used to enhance the flat strip material before it is used to create a welded tube. One, both, or more patterns may be used and combined. Each pattern is made up of a variety of possible shapes. See Fig. 2(a) Sample secondary (background) surface and Fig. 2(b) Sample primary surface.

3.6 In Fig. 3, details are given regarding the wall thickness of the representative sample geometry of the patterns used to enhance the flat strip material before it is used to create a welded tube.

4. Types of Welded Tubes

4.1 The following types of welded tubes are manufactured under this specification:

4.1.1 *As-Welded Tube*—A condition created as a result of forming sheet or plate into tubular form and welding without subsequent heat treatment or cold work.

4.1.2 Welded and annealed tube annealed to produce a uniform grain size appropriate to the specified annealed temper.

5. Ordering Information

5.1 Include the following specified choices when placing orders for product under this specification, as applicable:

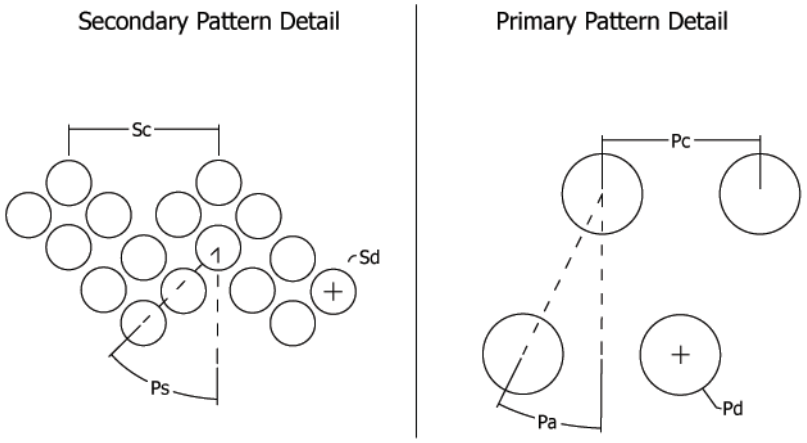
5.1.1 ASTM designations and year of issue.

5.1.2 Copper [Alloy] UNS No. (or other internationally recognized copper [alloy]) designation.

5.1.3 *Heat Treatment*—Annealing may be performed in-line, post-production, or customer-specified.

5.1.4 Temper (Section 8).

5.1.5 *Dimensions*—Specified in English or SI units with one-unit system used throughout.



(a) Sample secondary (background) surface (b) Sample primary surface

NOTE 1—One, both, or more patterns may be used and combined; each pattern made up of a variety of possible shapes.

FIG. 2 Details regarding Sample Representative Geometry of Patterns Used to Texture Flat Strip Material before it is Used to Create Welded Tube

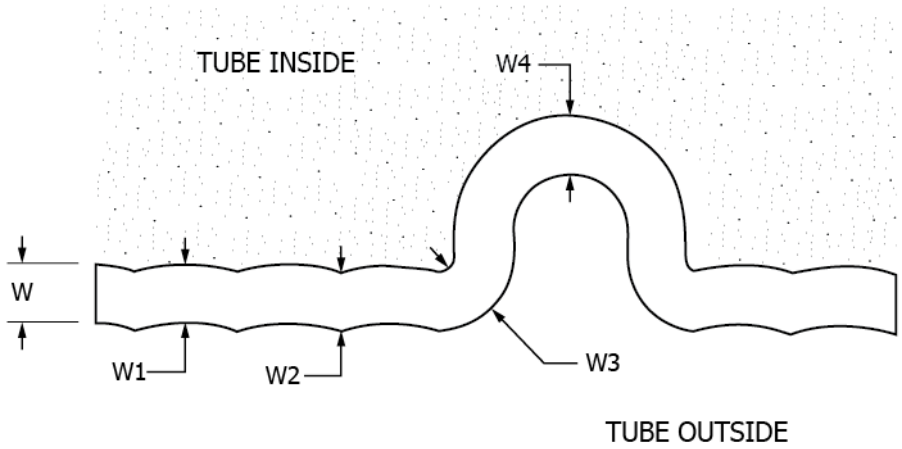


FIG. 3 Details regarding Wall Thickness of Representative Sample Geometry of Patterns Used to Texture Flat Strip Material before it is Used to Create Welded Tube

5.1.5.1 See Fig. 1 for the nominal tube outside diameter and nominal tube wall thickness (wall thickness of the smooth strip material); average effective wall thickness of the finished tube and minimum (specified wall thickness of the tube); wall thickness of the finished tube will be specified; length and location of untextured surfaces (if any); and the total tube length or random lengths.

5.1.5.2 *Configuration of Textured Surfaces*—See Fig. 2 (secondary pattern, secondary pattern depth, secondary pattern height, pitch of the secondary pattern, pitch of the primary pattern depth, and so forth) shall be as agreed upon between the manufacturer and purchaser.

5.1.5.3 Additional specifications may include the various inside or outside diameters (see Fig. 1); textured wall thickness values (see Fig. 3); length and location of untextured sections; tube end finish, if required; effective diameter and wall thickness of the textured section; number of secondary enhancement character units per unit length; number of primary enhancement character units per unit length; and the total tube length.

5.1.6 How furnished: straight lengths or coils.

5.1.7 Quantity—total weight, or total length, or number of pieces of each size.

5.1.8 Packaging.

5.1.9 Intended application.

5.2 The following options are available but may not be included unless specified at the time of placing of the order, when required:

5.2.1 Heat identification or traceability details;

5.2.2 Electromagnetic (eddy current) examination;

5.2.3 Embrittlement test;

5.2.4 Expansion test;

5.2.5 Flattening test;

5.2.6 Certification;

5.2.7 Test Report;

5.2.8 Type of welded tube production and any additional weld requirements;

5.2.9 Flash treatment, if any;

5.2.10 Microscopical examination microphotographs;

5.2.11 Customer inspection;

5.2.12 If product is purchased for agencies of the U.S. government (see the Supplementary Requirements section of Guide B950); and

5.2.13 If product is ordered for ASME Boiler and Pressure Vessel Code Application (see Section 20, Certifications).

6. Materials and Manufacture

6.1 *Materials:*

6.1.1 The material of manufacture shall be sheet or strip of one of the listed Copper UNS alloys and may be cold worked or annealed to a suitable finish for processing into the products prescribed herein.

6.1.2 When specified in the contract or purchase order that heat identification or traceability is required, the purchaser shall specify the details desired.

6.2 *Manufacture:*

6.2.1 The textured tubes shall be manufactured from smooth strip material that has been textured by cold working on one or both surfaces before being formed into a tube.

6.2.2 Textured tubes may be furnished with untextured outside surface diameter ends but also may be furnished with textured outside surface diameter ends depending on the specification. Tubes produced with untextured ends may or may not also include untextured sections in areas of the tube other than the ends (landings).

6.2.3 Any tests that are specified and required shall be performed on textured lengths of the tube in accordance with this specification and need not be performed on both the textured and the plain section of the tube.

6.2.4 The enhancements shall be produced by the cold forming of the material strip. To comply with this specification, the enhancement material and smooth tube material shall be considered homogeneous in composition.

6.2.5 The welded (WLD) tubes shall be made from strip material using an automatic welding process with no addition of filler metal.

6.2.5.1 Welding shall be accomplished by any process that produces a fusion weld.

6.2.5.2 *Fusion-Welded Tube*—The edges of the strip shall be brought together and welded, usually by a gas tungsten arc

welding (GTAW) process, without the addition of filler metal, causing a fusion-type joint to be formed with no internal or external flash.

6.2.6 Subsequent to welding and before final heat treatment, the tubes may not be cold worked either in both weld and base metal or in weld area only. Cold working or drawing the tube is not permitted.

7. Chemical Composition

7.1 The heat analysis shall conform to the chemical composition requirements in Table 1 for the Copper or Copper Alloy UNS No. designation specified in the ordering information.

7.2 These composition limits do not preclude the presence of other elements. By agreement between the manufacturer and the purchaser, limits may be established, and analysis required for unnamed elements supplied in the temper required for a smooth tube.

7.3 For Copper Alloy UNS No. C19400, copper may be taken as the difference between the sum of all the elements analyzed and 100 %. When all the elements in Table 1 are analyzed, their sum shall be 99.8 % minimum.

7.3.1 For copper alloys in which copper is specified as the remainder, copper may be taken as the difference between the sum of all the elements analyzed and 100 %.

7.3.1.1 *Copper Alloy UNS Nos. C70400, C70600, C70620, C71000, C71500, and C71520*—When all the elements in Table 1 are analyzed, their sum shall be 99.5 % minimum.

7.3.1.2 *Copper Alloy UNS No. C72200*—When all the elements in Table 1 are analyzed, their sum shall be 99.8 % minimum.

7.3.2 For copper alloys in which zinc is specified as the remainder, either copper or zinc may be taken as the difference between the sum of all the elements analyzed and 100 %.

7.3.2.1 *Copper Alloy UNS No. C23000*—When all the elements in Table 1 are analyzed, their sum shall be 99.8 % minimum.

7.3.2.2 *Copper Alloy UNS Nos. C44300, C44400, and C44500*—When all the elements in Table 1 are analyzed, their sum shall be 99.6 % minimum.

7.3.2.3 *Copper Alloy UNS No. C68700*—When all the elements in Table 1 are analyzed, their sum shall be 99.5 %.

8. Temper

8.1 The textured tube produced shall normally be supplied in the temper required for a smooth tube. When specified by the purchaser for bending, coiling, or other fabricating operations, textured and untextured portions of the tube may be stress relieved annealed or solution annealed.

8.2 Material shall be furnished in the heat-treated condition in accordance with the requirements of smooth tubes.

8.3 Tempers, as defined in Classification B601 of the various tube types, are as follows:

8.3.1 *Textured Strip As-Welded:*

8.3.1.1 As-welded textured strip produced from annealed strip WM50,

8.3.1.2 As-welded textured strip produced from half-hard strip WM02, and

8.3.1.3 As-welded textured strip produced from hard strip WM04.

8.3.2 *Welded and Annealed:*

8.3.2.1 Welded textured strip and annealed WO61, and

8.3.2.2 Welded textured strip and light annealed W050.

9. Grain Size for Annealed Welded Tube

9.1 Grain size shall be the standard requirement for all products in the annealed tempers.

9.2 Acceptance or rejection based upon grain size shall be by an examination at a magnification of 75 diameters. The grain size shall be determined in the wall of the textured tube. The microstructure shall show complete recrystallization.

9.3 Average grain size shall be within limits agreed upon between the manufacturer and purchaser.

9.4 Some annealed tubes, when subjected to aggressive environments, may be subject to stress-corrosion cracking failure because of the residual tensile stresses developed in straightening. For such applications, it is recommended that tubes of Copper Alloy UNS Nos. C23000, C44300, C44400, C44500, C60800, and C68700 be subjected to a stress relieving thermal treatment subsequent to straightening. When required, this shall be specified in the purchase order or contract. Tolerance for roundness and length, and the condition for straightness for tube so ordered shall be to the requirements agreed upon between the manufacturer and purchaser.

10. Mechanical Property Requirements

10.1 For the textured tube produced, the untextured portion of the textured tube shall conform to the values in Table 2.

10.1.1 Welded or welded/annealed tubes furnished under this specification shall conform to the tensile strength requirements prescribed in Table 3 when tested in accordance with Test Methods E8/E8M.

10.1.2 The tubing specified shall conform to the tensile values prescribed here or values agreed upon between the producer and the customer.

10.1.3 Acceptance or rejection based on mechanical properties shall depend only on tensile strength.

10.2 *Minimum Wall Thickness*—A method to measure minimum wall thickness is determined in 13.2. The minimum wall thickness specification should be specified in the purchase order. Tolerances will vary in the textured portion. Wall thickness tolerances for welded tubes are shown in Table 4.

10.3 If disagreement arises between the grain size requirement and the mechanical property requirements for annealed tempers, the mechanical property requirements take precedence.

10.4 *Brinell or Rockwell Hardness Requirements:*

10.4.1 Hardness test Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot. If hardness values are taken from textured tube sections, cross-sectional micro-hardness values should be taken.

10.4.2 The hardness value shall be evaluated in both the textured and untextured sections (if both are present).

TABLE 1 Chemical Composition

Copper or Copper Alloy UNS No. (see Practice E527)	Composition, %												
	Copper	Tin	Aluminum	Nickel, incl Cobalt	Lead, max	Iron	Zinc	Manganese	Arsenic	Antimony	Phosphorus	Chromium	Other Named Elements
C10100	99.99 min[A, B]	0.0002 max	...	0.0010 max	0.0005	0.0010 max	0.0001 max	0.00005 max	0.0005 max	0.0004 max	0.0003 max	...	Te 0.0002
C10200	99.95 min[C, D, E]	...	...	...	...	...	...	...	...	...	...	...	...
C10300	99.95 min[C, F, G]	...	...	...	...	...	...	...	...	...	0.001 to 0.005	...	...
C10800	99.95 min[C, F, G]	...	...	...	...	...	...	...	...	...	0.005 to 0.012	...	...
C12000	99.90 min[C]	...	...	...	...	...	...	...	...	...	0.004 to 0.012	...	...
C12200	99.9 min[C]	...	...	...	...	...	...	...	...	...	0.015 to 0.040	...	...
C14200	99.4 min[C]	...	...	...	...	...	...	...	0.15 to 0.50	...	0.015 to 0.040	...	...
C15630	remainder[C, H]	...	...	0.60 to 0.90[I]	...	...	...	...	...	...	0.015 to 0.040	...	...
C19200	98.5 min[J]	...	...	...	...	0.8 to 1.2	0.20 max	...	...	...	0.01 to 0.04	...	...
C23000	84.0–86.0[J]	...	...	...	0.05	0.05 max	remainder	...	...	...	...	...	...
C44300	70.0–73.0[K]	0.9 to 1.2	...	...	0.07	0.06 max	remainder	...	0.02 to 0.06	...	...	...	...
C44400	70.0–73.0[K]	0.9 to 1.2	...	...	0.07	0.06 max	remainder	...	...	0.02 to 0.10	...	...	...
C44500	70.0–73.0[K]	0.9 to 1.2	...	...	0.07	0.06 max	remainder	...	...	...	0.02 to 0.10	...	...
C60800	remainder[C, H]	...	5.0 to 6.5	...	0.10	0.10 max	...	...	0.02 to 0.35	...	...	...	...
C68700	76.0–79.0[C, H]	...	1.8 to 2.5	...	0.07	0.06 max	remainder	...	0.02 to 0.06	...	...	...	...
C70400	remainder[C, H]	...	...	4.8 to 6.2	0.05	1.3 to 1.7	1.0 max	0.30 to 0.8	...	...	...	...	...
C70600	remainder[C, H]	...	...	9.0 to 11.0	0.05	1.0 to 1.8	1.0 max	1.0 max	...	...	...	...	...
C70620	86.5 min[C, H]	...	...	9.0 to 11.0	0.02	1.0 to 1.8	0.5 max	1.0 max	...	...	0.02 max	...	0.50 C max 0.02 S max
C71000	remainder[C, H, L]	...	...	19.0 to 23.0	0.05	1.0 max	1.0 max	1.0 max	...	...	...	...	...
C71500	remainder[C, H]	...	...	29.0 to 33.0	0.05	0.40 to 1.0	1.0 max	1.0 max	...	...	...	...	...
C71520	65.0 min[G, H]	...	...	29.0 to 33.0	0.02	0.40 to 1.0	0.50 max	1.0 max	...	...	0.02 max	...	0.05 C max 0.02 S max
C72200	remainder[C, J, L]	...	...	15.0 to 18.0	0.05	0.50 to 1.0	1.0 max	1.0 max	...	...	...	0.30 to 0.70	0.03 Si 0.03 Ti

[A] This value is exclusive of silver and shall be determined by difference of "impurity total" from 100 %. "Impurity total" is defined as the sum of sulfur, silver, lead, tin, bismuth, arsenic, antimony, iron, nickel, zinc, phosphorus, selenium, tellurium, manganese, cadmium, and oxygen present in the sample.
[B] Other impurity maximums for C10100 shall be bismuth and cadmium 0.0001 each, oxygen 0.0005, selenium 0.0003, silver 0.0025, and sulfur 0.0015.
[C] Copper (including silver).
[D] Oxygen in C10200 shall be 0.0010 max.
[E] Cu is determined by the difference in the impurity total and 100 %.
[F] Copper plus sum of named elements shall be 99.95 % min.
[G] Includes P.
[H] Cu + Sum of Named Elements, 99.5 % min.
[I] Not including Co.
[J] Cu + Sum of Named Elements, 99.8 % min.
[K] Cu + Sum of Named Elements, 99.6 % min.
[L] When the product is for subsequent welding applications, and so specified in the contract or purchase order, zinc shall be 0.50 % max, lead 0.02 % max, phosphorus 0.02 % max, sulfur 0.02 % max, and carbon 0.05 % max.

TABLE 2 Expansion Requirements

Temper Designation		Copper or Copper Alloy UNS No.	Expansion of Tube Outside Diameter in Percent of Original Outside Diameter
Standard	Former		
O61	annealed	C10100, C10200, C10300, C10800, C12000, C12200, C14200	30
O62	heavy anneal	C10100, C10200, C10300, C10800, C12000, C12200, C14200	30
H55	light-drawn	C10100, C10200, C10300, C10800, C12000, C12200, C14200	20
O61	annealed	C15630	40
O61	annealed	C19200	30
O61	annealed	C23000	20
O61	annealed	C44300, C44400, C44500	20
O61	annealed	C60800	20
O61	annealed	C68700	20
O61	annealed	C70400	30
O61	annealed	C70600, C70620	30
O61	annealed	C71000	30
O61	annealed	C71500, C71520	30
O61	annealed	C72200	30

TABLE 3 Tensile Requirements

Copper or Copper Alloy UNS No.	Temper Designation		Tensile Strength, min	Yield Strength,[A] min
	Standard	Former	ksi[B] (MPa)	ksi[B] (MPa)
C10100, C10200, C10300, C10800, C12000, C12200, C14200	O61	annealed	30 (205)	9 (62)[C]
C10100, C10200, C10300, C10800, C12000, C12200, C14200	O62	heavy anneal	30 (205)	6.5 (45)[C]
C10100, C10200, C10300, C10800, C12000, C12200, C14200	H55	light-drawn	36 (250)	30 (205)
C15630	O61	annealed	30 (205)	8 (55)
C19200	O61	annealed	38 (260)	12 (85)
C23000	O61	annealed	40 (275)	12 (85)
C44300, C44400, C44500	O61	annealed	45 (310)	15 (105)
C60800	O61	annealed	50 (345)	19 (130)
C68700	O61	annealed	50 (345)	18 (125)
C70400	O61	annealed	38 (260)	12 (85)
C70600	O61	annealed	40 (275)	15 (105)
C70620	O61	annealed	40 (275)	15 (105)
C71000	O61	annealed	45 (310)	16 (110)
C71500	O61	annealed	52 (360)	18 (125)
C71520	O61	annealed	52 (360)	18 (125)
C72200	O61	annealed	45 (310)	16 (110)

[A] At 0.5 % extension under load.
[B] ksi = 1000 psi.
[C] Light straightening operation is permitted.

TABLE 4 Diameter Tolerances

Specified Diameter, in. (mm)	Tolerance, in. (mm)
0.500 (12.0) and under	±0.002 (0.050)
Over 0.500 to 0.740 (12.0 to 18.0), incl.	±0.0025 (0.063)
Over 0.740 to 1.000 (18.0 to 25.0), incl	±0.003 (0.076)
Over 1.000	As agreed upon

10.4.3 The tubing specified shall conform to the hardness values prescribed by values agreed upon between the producer and the customer.

10.4.4 Hardness values for the textured section will be determined using micro-hardness values taken from the cross section.

NOTE 1—For tension and hardness test requirements, the term lot applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of material. When final heat treatment is in a batch type furnace a lot shall include only those tubes of the same size and same heat which are heat treated in the same furnace.

11. Performance Requirements

11.1 *Physical Property Requirement:*

11.1.1 When specified in the contract or purchase order, tube furnished in annealed tempers shall be capable of withstanding expansion in accordance with Test Method B153 to meet the values shown in Table 3.

11.1.2 The expanded tube area shall show no cracking or other defects visible to the unaided eye.

11.1.3 Expansion tests need not be performed except when specified in the contract or purchase order.

11.2 *Flattening Test (when specified)*—When specified in the contract or purchase order, the flattening test in accordance with the test method described in 16.4 shall be performed.