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.

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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

[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.

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

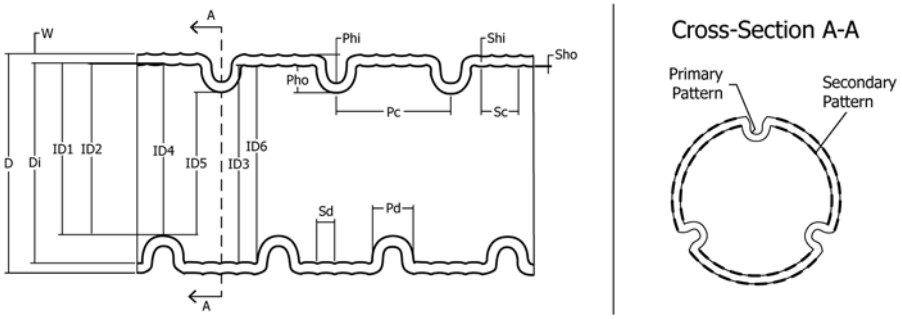
3.3.16 *Sd*—secondary pattern character diameter

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)



(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:

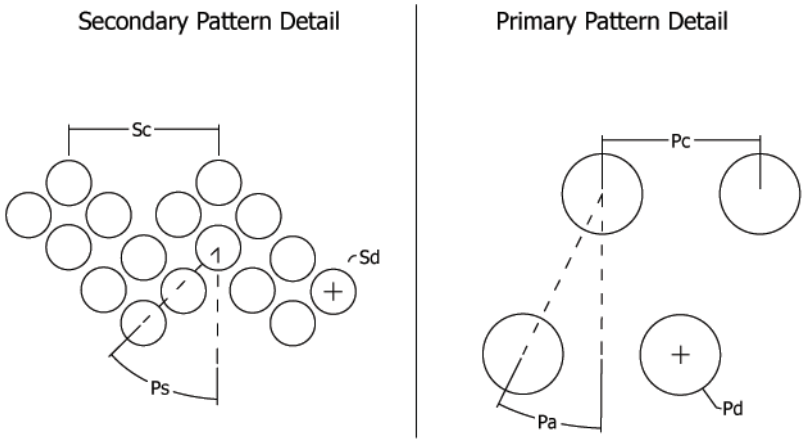
5.1.1 ASTM designations and year of issue.

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

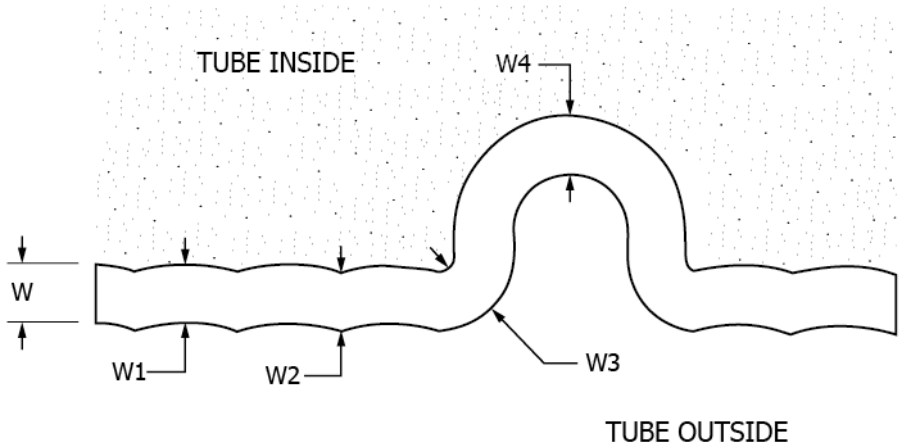


FIG. 3 Details regarding Wall Thickness of Representative Sample Geometry of Patterns Used to Texture Flat Strip Material before it is Used to Create Welded Tube

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.

11.3 *Microscopical Examination:*

11.3.1 Tubes produced of coppers C12000 shall be free of cuprous oxide as determined by Procedure A of Test Methods B577.

11.3.2 When specified in the ordering information, microphotographs of the manufacture's test specimens shall be provided.

11.4 *Hydrogen Embrittlement Susceptibility Test (when specified)*—Samples of Copper UNS Nos. C12000 and C12200 shall be capable of passing the embrittlement test of Procedure B of Test Methods B577. The actual performance of this test is not mandatory under the terms of this specification unless specified at the time of ordering.

11.5 *Cleanness of Interior Surface (when specified):*

11.5.1 Tube shall have the capability of meeting an internal cleanliness test.

11.5.2 Cleanliness tests need not be performed except when specified in the contract or purchase order.

11.5.3 After evaporation of the cleaning solvent, the residue weight from the tube shall not exceed 0.0035 g/ft (0.038 g/m^2) of the interior surface.

11.6 *Microscopical Examination for Susceptibility to Hydrogen Embrittlement (when specified):*

11.6.1 Tubes shall be essentially free of cuprous oxide as determined by Procedure A of Test Methods B577.

11.6.2 Tubes furnished in all coppers shall be capable of passing the embrittlement test specified in Procedure B of Test Methods B577. Hydrogen embrittlement testing need not be performed except when specified in the contract or purchase order.

11.7 *Pressure Rating (when specified)*—Tube assemblies tested to comply with the requirements of the following shall not rupture, burst, or leak. Tests shall be conducted at ambient temperature.

11.7.1 *Burst Method*—The tube assembly shall withstand, without failure, a pressure equal to three times the design pressure marked on the component.

11.8 *Fatigue Method (when specified)*—The tube assembly shall be tested in accordance with one or both of the following procedures agreed upon between the producer and customer.

11.8.1 Two assemblies shall be completely filled with an incompressible, inert fluid to exclude all air, and connected to a hydraulic pump system. The pressure shall be raised gradually and maintained for 1 min to three times the design pressure marked on the component.

11.8.2 Three assemblies shall be completely filled with an incompressible, inert fluid to exclude all air, and connected to a hydraulic pump system. Assemblies shall be tested for a minimum of 250 000 cycles in accordance with the following:

11.8.2.1 Upper pressure test value shall be equal to the design pressure marked on the component.

11.8.2.2 Lower pressure test value shall be 0 psig ± 5 psig.

11.8.2.3 Pressure within each sample shall be raised and lowered such that the full specified upper and lower pressure cyclic values are maintained for at least 0.1 s.

11.8.3 Following the specified number of test cycles, the test pressure shall be increased and maintained for 1 min without rupture, burst, or lead at one and one-half times the design pressure marked on the component.

12. Other Requirement

12.1 *Grain Size*—The tubing specified shall conform to the grain size requirements agreed upon between the manufacturer and the purchaser.

12.2 *Nondestructive Tests:*

12.2.1 *Hydrostatic, Pneumatic, or Nondestructive Test*—Each tube shall be subjected to either the hydrostatic, pneumatic, or the nondestructive test. The purchaser may specify which test is to be used, and values will be specified between the producer and the customer.

12.2.1.1 After enhancing and tube production operations, each tube is subject to a nondestructive electromagnetic test (eddy current) and/or other nondestructive test and/or either a pneumatic or hydrostatic test (depending what is specified by the purchaser).

(1) Tubes normally shall be tested in the as-fabricated condition but, as the option agreed upon by the manufacturer and purchaser, may be tested in the annealed condition.

12.2.1.2 *Nondestructive Test*—Test inspection of the tube can be performed in line or post production by passing the tube through an encircling coil or passing an insertion probe through the tube. This evaluation is required to evaluate the entire cross-section of the produced textured tube.

12.2.1.3 As welded and annealed tube shall be tested in either temper as agreed upon between the manufacturer and the purchaser.

12.2.1.4 The reference used to adjust the sensitivity setting of the apparatus shall be sound and of the same nominal alloy, textured configuration, heat treatment, similar condition, and similar nominal dimensions as the lot of tubes to be tested on a production basis. Record the serial number of the reference standard and make it part of the certified report. The standard shall have four holes not larger than 0.031 in. (0.787 mm) in diameter drilled radially through the textured wall in each of four successive planes at 0°, 90°, 180°, and 270°. Use a suitable drill jig to guide the drill taking care to avoid distortion of the sample hole or the wall. Locate one hole in the weld for welded tubes. If a minimum wall thickness value is specified, a sample defect will be included in the standard. Samples defect should be spaced at least 4 in. (10 cm) from the end of the tube. Space the artificial defects approximately 16 in. (406 mm) apart to provide signal resolution adequate for interpretation. Drawings of the reference standard shall be produced and available, if requested. Discard and replace the reference standard when erroneous signals are produced from mechanical, metallurgical, or other damage to the tube. The reference standard should be run at the end of the production run to ensure that there has been a reliable calibrated reading of the instrument during the production run. If the reference readings at the end of the run do not agree with those readings taken at the start of production, a detailed evaluation of the tubes is required, and the tubes need to be reevaluated.

12.2.1.5 Adjust the test unit to obtain an optimum signal-to-noise ratio with the minimum sensitivity required to detect all artificial defects in the reference standard on a repeatable basis. Equipment adjustments maintained during calibration shall be the same settings for evaluation of the production tubes. Tube speed during calibration should be approximately the same speed as for production.

12.2.1.6 Set aside or mark tubes showing an indication in excess of any signal obtained from artificial defects in the reference standard and subject them to retest or rejection.

12.2.1.7 Tubes causing irrelevant signals because of debris and like effects shall be considered to conform should they not cause output signals beyond acceptable limits when retested. Tubes causing irrelevant signals because of visible and identifiable handling marks (that is, mishandling marks on the surface) shall be considered to conform, provided the wall thickness in the textured and untextured areas is not less than the minimum specified by the customer.

12.2.1.8 Tubes causing relevant signals because of an injurious defect (incomplete welds, splits, embedded debris, broken tool impressions, and inside diameter (ID) defects) or other defects, or both, that reduce the wall thickness below the minimum specified by customer shall be rejected. If after retest and examination, no source for the reject signal can be discerned, the tube shall be rejected.

12.2.1.9 The electronic test apparatus shall also be standardized after any change in test system settings, change of operator, equipment repair, or interruption because of power loss or shutdown.

12.2.2 *Pneumatic Test*—After the production of a textured tube, each tube may be subjected to an internal pneumatic leak test for 5 s without showing evidence of leakage. Any evidence of leakage shall be cause for rejection. The test method used shall permit easy visual detection of any leakage, such as using the air under water at a minimum of 60 psi (0.415 MPa) or using pneumatic leak method.

12.2.3 *Air Underwater Pressure Test*—Each tube may be tested with the acceptance criteria and shall be agreed upon between the manufacturer and purchaser.

12.2.4 *Pressure Differential Test*—Each tube may be tested, and the procedure and acceptance criteria shall be agreed upon between the manufacturer and purchaser.

12.2.5 *Hydrostatic Test*—When examined with this test method, each tube shall be tested using the wall thickness of the plain strip material that was used to produce that textured surface.

12.2.6 Each tube shall be capable of withstanding a purchase order indicated internal hydrostatic pressure sufficient to subject the tube to an agreed upon fiber stress without leakage. Any leakage shall be cause for tube rejection.

13. Dimensions, Mass, and Permissible Variations

13.1 *Diameter*—The outside diameter of the untextured sections shall not exceed the diameter tolerances as measured by "go" and no go" ring gauges. The outside diameter of the textured sections shall not exceed the diameter of the plain sections involved, as determined by a "go" ring gauge unless otherwise specified values are agreed upon between the producer and the customer. The dimensions of the ring gauges shall be as described in 13.1.1. Alternative methods of measurement able to measure the inside diameter (ID) include electronic or optical methods with the same tolerance and accuracy.

13.1.1 The ID dimension of the "no go" ring gauge shall be equal to the ID5 tube diameter minus the maximum tolerance (specified in Table 4) plus 0.002 in. (0.0508 mm) or other agreed maximum tolerance variation values agreed upon between the producer and the customer. The length of the "no go" ring gauge shall be 1 in. (25.4 mm) minimum.

13.2 *Wall Thickness*—The starting material strip wall thickness shall conform to the requirements for tube wall thickness tolerances prescribed in accordance with Table 5. Wall thickness tolerances shall be ±0 % of nominal wall for all tubing sizes or other agreed tolerance variations values agreed upon between the producer and the customer. Strip material may be redistributed, but material may not be removed.

13.2.1 The point-to-point wall thickness of textured and untextured sections of the tube shall not exceed the thickness tolerances given in Table 5 unless otherwise agreed to between the manufacturer and purchaser. No tube wall thickness at any point shall be less than the minimum thickness requirements for wall thickness prescribed in Table 5, which is specified for the plain sections or in the textured sections unless the customer and manufacturer agree after evaluating test data of similarly produced textured tubes. Wall thickness shall be evaluated using any instrument (that is, pointed micrometer, optical, microscopic, and so forth) that is capable of satisfying the required accuracy.

13.3 *Length*—The length of the tubes shall not be less than that specified but may exceed the specified value by the amounts given in Table 6.

13.3.1 The length of plain ends, as measured from the tube end to the first enhancement character, shall not be less than that specified but may exceed the specified value by ½ in. (12.7 mm).

13.3.2 The length of textured sections and landings (untextured portions) shall be as specified ±¼ in. (6.4 mm).

13.4 *Squareness of Cut*—The angle of the cut of the end of any tube may depart from square by not more than 0.016 in. (0.4064 mm). See Table 7 for squareness of cut.

13.5 *Straightness*—If produced in lengths, the tube shall be reasonably straight and free of bends or kinks.

TABLE 5 Wall Thickness Tolerances for Welded Tube

Wall Thickness, in. (mm)	Outside Diameter, in. (mm) Plus and Minus
	¼ (6.4) to 1.5 (38.1)
0.016 (0.406) to 0.021 (0.533), incl	0.0013 (0.033)
Over 0.021 (0.533) to 0.026 (0.660), incl	0.0015 (0.038)
Over 0.026 (0.660) to 0.037 (0.940), incl	0.002 (0.051)
Over 0.037 (0.940) to 0.050 (1.27), incl	0.002 (0.051)
Over 0.050 (1.27) to 0.073 (1.85), incl	0.0025 (0.064)
Over 0.073 (1.85) to 0.130 (3.30), incl	0.003 (0.076)
Over 0.130 (3.30) to 0.156 (3.96), incl	0.0035 (0.089)

TABLE 6 Length Tolerances

Specified Length, ft (mm)	Tolerance, all Plus, in. (mm)
Up to 20 (6000), incl	⅛ (3.2)
Over 20 to 30 (6000 to 10 000), incl	5⁄32 (4.0)
Over 30 to 60 (10 000 to 18 000), incl	¼ (6.4)

TABLE 7 Squareness of Cut

Specified Outside Diameter, in. (mm)	Tolerance, in. (mm)
Up to ⅝ (16.0), incl	0.010 (0.25)
Over ⅝ (16.0)	0.016 in./in. (0.016 mm/mm) of diameter

14. Workmanship, Finish, Surface Condition, Repair, and Appearance

14.1 Roundness, straightness, uniformity of wall thickness, and condition of inner and outer surfaces of the tube shall be such as to make it suitable for the intended application. Unless otherwise specified on the purchase order, the cut ends of the tubes shall be deburred by use of a rotating wire wheel or other suitable tool.

14.2 Annealed-temper (O61, O62) or stress-relieved tubes shall be clean and smooth but may have a superficial, dull, iridescent film on both the inside and outside surfaces. Tubes in the as-fabricated temper may have a superficial film of finning lubricant on the surfaces.

15. Sampling

15.1 The lot size, portion size, and selection of sample pieces shall be as follows:

15.1.1 *Lot Size*—600 tubes or 10 000 lb (4550 kg), or fraction of either, whichever constitutes the greater weight.

15.1.2 *Portion Size*—Sections from two individual lengths of finished product.

15.1.3 Samples taken for the purpose of testing shall be selected in a manner that will correctly represent the material furnished and avoid needless destruction of finished material when samples representative of the material are available from other sources.

15.2 *Chemical Composition:*

15.2.1 Samples for determining composition shall be taken in accordance with Practice E255. The minimum weight of the composite sample shall be 150 g.

15.2.2 Instead of sampling in accordance with Practice E255, the manufacturer shall have the option of sampling at the time castings are poured or sampling the semi-finished product. When samples are taken during manufacture, sampling of the finished product is not required and the minimum number of samples to be taken shall be as follows:

15.2.2.1 When samples are taken at the time castings are poured, one sample shall be taken for each group of castings poured simultaneously from the same source of molten metal.

15.2.3 When samples are taken from the semi-finished product, one sample shall be taken to represent each 10 000 lb (4550 kg), or fraction thereof, except that not more than one sample shall be required per piece.

16. Specimen Preparation

16.1 *Chemical Analysis:*

16.1.1 Sample preparation shall be in accordance with Practice E255.

16.1.2 Preparation of the analytical test specimen shall be the responsibility of the reporting laboratory.

16.2 *Grain Size:*

16.2.1 Specimens for the microscopic examination shall be prepared in accordance with Guide E3.

16.2.2 The surface of the specimen shall approximate a radial longitudinal section of the tube.

16.3 *Expansion Test Specimen*—Test Specimens shall conform to the requirements of the Specimen Preparation section of Test Method B153.

16.4 *Flattening Test (Test Method B968/B968M)*—A test specimen shall be cut to a length that will allow the tube to be flattened at three (3) places along the length, with each flattened area to be at least 2 in. (50 mm) in length. When the temper is other than annealed, the sample may be annealed prior to testing.

16.5 *Mercurous Nitrate or Ammonia Vapor Test*—Specimens for the mercurous nitrate test when specified shall be 6 in. (150 mm) in length and shall be taken from the textured and untextured portion of each sample.

16.6 *Tension Tests:*

16.6.1 Tension test specimens shall be of the full section of the tube and shall conform to the requirements of the Test Specimen section of Test Methods E8/E8M, unless the limitations of the testing machine precludes the use of such specimen, in which case test specimens conforming to specimen No. 1 of Fig. 13 in Test Methods E8/E8M shall be used.

16.6.2 Whenever test results are obtained from full-sized and machined specimens and they differ, the results from the full-sized specimen shall prevail for determining conformance to the specification.

16.6.3 Although a considerable range of testing speed is permissible, the range of stressing to the yield strength should not exceed 100 ksi/min (690 MPa/min). Above the yield strength, the movement per minute of the testing machine head under load shall not exceed 0.5 in./in. (0.5 mm/mm) of the gauge length, or the distance between grips for a full section specimen.

17. Test Methods

17.1 *Chemical Composition:*

17.1.1 The methods used for routine determination of specification compliance shall be at the discretion of the reporting laboratory.

17.1.2 In case of disagreement concerning chemical composition of Copper Alloy UNS No. C10100, refer to the Test Method section of Specification B170.

17.2 Chemical composition for all other alloys, in case of disagreement, shall be determined as follows:

17.2.1 Test methods for the determination of elements resulting from contractual or purchase order agreements shall be as agreed upon between the manufacturer or supplier and purchaser. (Refer to Table 1, Footnote D).

Element	Range	Test Method
Copper	99.75 to 99.99	E53, Electrolytic
Copper	70.0 to 99.75	E478, Electrolytic
Tin	0.9 to 1.2	E478, Photometric
Aluminum	1.8 to 6.5	E478
Nickel, incl Cobalt	4.8 to 33.0	E478, Gravimetric
Lead	0.05 to 0.10	E478, Atomic Absorption
Iron	0.04 to 1.8	E478
Zinc	14.0 to 30.0	E478, Titrimetric
Zinc	To 1.0	E478, Atomic Absorption
Manganese	To 1.0	E62
Arsenic	0.02 to 0.5	E62
Antimony	0.02 to 0.1	E62
Phosphorus	0.001 to 0.04	E62
Chromium	0.30 to 0.70	E118
Oxygen	0.0005 to 0.0010	E2575

17.3 When specified, the material shall conform to the physical requirements and mechanical properties enumerated in this specification when tested in accordance with the following methods:

Test	ASTM Designation
Grain Size	E112
Expansion (pin test)	B153
Mercurous Nitrate	B154
Tension	E8/E8M
Eddy-Current Test	E243
Ammonia Vapor Test	B858
Flattening Test	B968/B968M

17.3.1 *Grain Size*—The intercept method shall be used to determine grain size in case of dispute.

17.3.2 *Test Method B154*—**Warning—**This test method involves the use of a mercury compound that is classified as a health hazard in use and disposal.

17.3.3 *Nondestructive Testing (NDT)*—Testing shall follow the procedures of Practice E243, except that the sensitivity settings of the test equipment shall be adjusted using the hole sizes specified in Table 8 of this specification. The manufacturer may use a smaller drilled hole standard, if desired. The holes for sensitivity adjustment shall be drilled radially through an untextured portion of the standard tube or through a length of prime surface tube of the same size, temper, and composition. By mutual agreement between the manufacturer or supplier and purchaser, discontinuities of other contours may be used on the calibration standard.

17.3.3.1 Tubes that do not actuate the signaling device on the NDT tester shall be considered as conforming to the requirements of this test.

TABLE 8 Diameter of Drilled Holes

Nominal Diameter Over Textured or Untextured Section in. (mm)	Diameter of Drilled Holes, in. (mm)
¼ to ⅝ (6.0 to 16.0), incl	0.042 (1.07) – No. 58 drill
Over ⅝ to 1 (16.0 to 25.0), incl	0.046 (1.17) – No. 56 drill

18. Inspection

18.1 The manufacturer shall inspect and make the necessary tests to verify that the textured tubes furnished conform to the requirement of the customer purchase order and the requirements specified in this specification.

18.2 Should the purchaser additionally elect to perform their own inspection, the manufacturer shall make provisions for such in accordance with requirement stated in Inspections.

18.3 Source inspection of the product by the purchaser shall be agreed upon between the manufacturer or supplier and the purchaser as part of the purchase order. In such case, the nature of the facilities needed to satisfy the inspector representing the purchaser that the product is being furnished in accordance with the specification shall be included in the agreement. All testing and inspections shall be conducted so as not to interfere unnecessarily with the operations of the works.

18.4 When mutually agreed upon, the manufacturer or supplier and purchaser shall conduct the final inspection simultaneously.

18.5 For the purpose of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value of a calculated value shall be rounded as indicated in accordance with rounding method of Practice E29.

Property	Rounded Unit for Observed or Calculated Value
Chemical composition	Nearest unit the last right-hand place of figures of the specified limit
Tensile strength	Nearest ksi (5 MPa)
Elongation	Nearest 1 %
Grain size	Uniform grain size appropriate to the specified annealed temper; grain size shall be examined at a magnification of 75 diameters.
Up to 0.055 mm, incl.	Nearest multiple of 0.005 mm
Over 0.055 mm to 0.160 mm, incl.	Nearest 0.01 mm

19. Rejection

19.1 Products that fail to conform to the order requirements (of this specification and conditions of the purchase order) may be rejected. Rejections should be reported to the producer or supplier promptly and in writing.

20. Certifications

20.1 When specified in the purchase order or contract, a manufacturer's certificate of compliance shall be furnished to the purchaser stating that samples representing each lot have been tested and inspected in accordance with this specification and the requirements have been met.

20.2 When material is specified to meet the requirement of ASME Boiler and Pressure Vessel Code, certification is mandatory.

21. Product Marking

21.1 Product marking shall conform to the requirements in the governing plain tube specification. Also include the heat number, the heat-treatment lot identification, and smooth end designation (if it is specified) for those tubes.

22. Packaging and Package Marking

22.1 *Packaging:*

22.1.1 The product shall be separated by size, composition, and temper, and prepared for shipment by common carrier in such a manner as to afford protection from the normal hazards of transportation.

22.2 *Package Marking:*

22.2.1 Each package shall be legibly marked with the metal or alloy designation, temper, size, shape, gross and net weight, and name of supplier. Upon agreement between the purchaser and supplier, the purchase order number shall be indicated on each package or on the shipping documents.

22.2.2 When specified in the contract or purchase order, the product specification number shall be shown.

23. Keywords

23.1 air condition tube; condenser tube; copper tube; evaporator tube; feedwater heater tubes; heat exchanger tube; high temperature applications; refrigeration tube; service applications high; surface enhancement; temperature; textured heat transfer tubes; UNS No. C10100; UNS No. C10200; UNS No. C10300; UNS No. C10800; UNS No. C12000; UNS No. C12200; UNS No. C19200; UNS No. C23000; UNS No. C44300; UNS No. C44400; UNS No. C44500; UNS No. C60800; UNS No. C68700; UNS No. C70400; UNS No. C70600; UNS No. C70620; UNS No. C71000; UNS No. C71500; UNS No. C71520; UNS No. C72200; welded copper tube

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. Minimum Wall Tubes

S1.1 When specified by the purchaser, tubes shall be furnished on a minimum wall basis. Such tubes shall satisfy the minimum wall thickness requirements rather than the nominal wall requirements of this specification. In addition to the marking required by Sections 21 and 22, the tubing shall be marked S1.

S2. Pneumatic Test

S2.1 The tubing shall be examined by a pneumatic test (either air under water or pneumatic leak test).

S3. Unstraightened Tubes

S3.1 When the purchaser specifies tubes unstraightenend after final heat treatment (such as coils), the straightness requirement shall not apply, and the minimum yield strength may be reduced.

S3.2 On the certification, and wherever the grade designating for unstraightened tubing appears, it shall be identified with suffix letter “U.”

S4. Special Applications

S4.1 For special applications, such as hydraulic expansion of tubes into tube sheets, there shall be no dimensional indication of the weld. Tubes ordered to this requirement shall bear the additional marking of NB.

S5. Radiograph Examination

S5.1 The entire length of weld in each welded pipe shall be radiographically examined using X-radiation in accordance with Paragraph UW-51 of Section VIII Division 1 of the ASME Boiler and Pressure Vessel Code. In addition to the marking required by Section 20, each pipe shall be marked “RT” after the specification and grade. Requirements of S5 shall be required in the certification.

NOTE 2—When specified, the special testing in this supplement is intended for special ASME applications and it is permissible to use a 100 % joint efficiency. It is not mandatory for all ASME applications.