Designation: B 359/B 359M – 9802

Standard Specification for Copper and Copper-Alloy Seamless Condenser and Heat Exchanger Tubes With Integral Fins[1]

This standard is issued under the fixed designation B 359/B 359M; 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] This specification is under the jurisdiction of ASTM Committee ~~B-5~~ B05 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.04 on Pipe and Tube.

Current edition approved Oct. 10, ~~1998.~~ 2002. Published ~~January 1999.~~ December 2002. Originally ~~published as B 359 – 60.~~ approved in 1960. Last previous edition approved in 1998 as B 359 – 95~~8~~.

1. Scope *

1.1 This specification[2] ~~describes~~ establishes the requirements for seamless copper and copper alloy tubing on which the external or internal surface, or both, has been modified by a cold-forming process to produce an integral enhanced surface for improved heat transfer.

1.2 *Units*—The values stated in either in-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems could result in nonconformance with the specification.

1.3 The tubes are typically used in surface condensers, evaporators, and heat ~~exchangers and are normally made from~~ exchangers.

1.4 The product shall be produced of the following coppers or copper ~~alloys:~~ alloys, as specified in the ordering information.

Copper or Copper Alloy UNS No.	Type of Metal
C10100	Oxygen-free electronic
C10200	Oxygen-free without residual deoxidants
C10300	Oxygen-free, extra low phosphorus
C10800	Oxygen-free, low phosphorus
~~C12000~~	~~DLP Phosphorized, low residual phosphorus~~
C12000	DLP Phosphorized, low residual phosphorus (See Note 1)
~~C12200~~	~~DHP, Phosphorized, high residual phosphorus~~
C12200	DHP, Phosphorized, high residual phosphorus (See Note 1)
~~C14200~~	~~DPA Phosphorized arsenical~~
C14200	DPA Phosphorized arsenical (See Note 1)
C19200	Phosphorized, 1 % iron
C23000	Red Brass
C44300	Admiralty Metal Types B,
C44400	C, and
C44550	D
C60800	Aluminum Bronze
C68700	Aluminum Brass Type B
C70400	95-5 Copper-Nickel
C70600	90-10 Copper-Nickel
C70620	90-10 Copper-Nickel (Modified for Welding)
C71000	80-20 Copper-Nickel Type A
C71500	70-30 Copper-Nickel
C71520	70-30 Copper-Nickel (Modified for Welding)
C72200	Copper-Nickel

NOTE ~~1—Refer to Practice E 527 for explanation of Unified Numbering System (UNS).~~

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SB-359 in Section II of that Code.

***A Summary of Changes section appears at the end of this standard.**

1.2 The 1—Designations listed in Classification B 224.

1.5 The following safety hazard caveat pertains only to the test methods described in this specification.

1.2.1 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 and health practices and determine the applicability of regulatory limitations prior to use.NOTE 2—A complete metric companion, B 359M, has been developed; therefore, no metric equivalents are presented.*

1.6 Product produced in accordance with the Supplementary Requirements section for military applications shall be produced only to the inch-pound system of this specification.

2. Referenced Documents

2.1 *ASTM Standards:*

B 153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing[3]

B 154 Test Method for Mercurous Nitrate Test for Copper and Copper Alloys[3]

B 170 Specification for Oxygen-Free Electrolytic Copper—Refinery Shapes[3]

B 359M Specification 224 Classification of Coppers[3]

B 601 Classification for Temper Designations for Copper and Copper-Alloy Seamless Condenser Copper Alloys—Wrought and Heat Exchanger Tubes with Integral Fins [Metric] Cast[3]

B 846 Terminology for Copper and Copper Alloys[3]

B 858 Test Method for Determination of Susceptibility to Stress Corrosion Cracking in Copper Alloys Using the Ammonia Vapor Test[3]

B 900 Practice for Packaging of Copper and Copper-Alloy Mill-Products for U. S. Government Agencies[3]

E 3 Test Methods of Preparation of Metallographic Specimens[4]

E 8 Test Methods for Tension Testing of Metallic Materials[4]

E 8M Test Methods for Tension Testing of Metallic Materials (Metric)[4]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[5]

E 53 Test Methods for Chemical Analysis Determination of Copper in Unalloyed Copper by Gravimetry[6]

E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)[6]

E 112 Test Methods for Determining Average Grain Size[4]

E 118 Test Methods for Chemical Analysis of Copper-Chromium Alloys[6]

E 243 Practice for Electromagnetic (Eddy-Current) Examination of Copper and Copper-Alloy Tubes[7]

E 255 Practice for Sampling Copper and Copper Alloys for Determination of Chemical Composition[6]

E 478 Test Methods for Chemical Analysis of Copper Alloys

E 527 Practice for Numbering Metals and Alloys (UNS)[86]

3. General Requirements

3.1 Product described by this specification shall typically be furnished with unenhanced ends, but may be furnished with enhanced ends or stripped ends from which the O.D. enhancement has been removed by machining.

3.1.1 The enhanced sections of the tube in the as-fabricated temper are in the cold-worked condition produced by the enhancing operation.

3.1.2 The unenhanced sections of the tube shall be in the annealed or light drawn temper, and shall be suitable for rolling-in operations.

4. Terminology

34.1 For the definitions of terms related to copper and copper alloys, refer to Terminology B 846.

4.2 *Definitions:*

3.1.1

4.2.1 *flattening, v*—this term shall be interpreted as that condition which allows a micrometer caliper, set at three times the wall thickness, to pass over the tube freely throughout the flattened part, except at the points where the change in element of flattening takes place.

3.1.2 *lengths*—straight pieces

4.3 *Definitions of product.*

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[3] *Annual Book of ASTM Standards,* Vol 02.01.

[4] *Annual Book of ASTM Standards,* Vol 03.01.

[5] *Annual Book of ASTM Standards,* Vol 14.02.

[6] *Annual Book of ASTM Standards,* Vol 03.05.

[7] *Annual Book of ASTM Standards,* Vol 03.03.

Annual Book of ASTM Standards, Vol 01.01.

[8] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

3.1.2.1 *lengths, specific*—straight lengths that are uniform in length, as specified, and subject Terms Specific to established length tolerances.

3.1.3 *tube, seamless This Standard:*—a tube produced with a continuous periphery in all stages of operation.

3.1.3.1

4.3.1 *tube condenser, n*—see *tube, heat exchanger.*

3.1.3.2 *tube, heat exchanger*—a tube manufactured to special requirements as to dimensional tolerances, finish, and temper for use in condensers and other heat exchangers.

3.1.3.3 *tube, heat exchangers with integral enhanced surface*—a tube having an external or internal surface, or both, modified by a cold forming operation, to produce an enhanced surface for improved heat transfer. The enhancement may take the form of longitudinal or helical fins or ridges, or both, as well as modifications thereto.

3.1.4 *unaided eye*—corrective spectacles necessary to obtain normal vision may be used.

4. in Terminology B 846.

5. Ordering Information

4.1 Purchase

5.1 Include the following information when placing orders for tubes described in under this specification should include the following, as required, to describe the tubes adequately.

4.1.1 ASTM specification:

5.1.1 ASTM designation and year of issue,

45.1.2 Copper or Copper Alloy UNS No. designation (see 1.4 and Section 7),

45.1.3 Temper (see Section 8),

45.1.4 Dimensions: diameter, wall thickness, length and location of unenhanced surfaces and total tube length. Configuration of enhanced surfaces shall be as agreed upon between the manufacturer and the purchaser. (Refer to (See Figs. 1-3).

45.1.5 Whether the product is to be subsequently welded for UNS Alloy C72200, UNS Alloys C 70620 and C71520 are welding grades of C70600 and C71500,

45.1.6 Quantity, and

45.1.7 CeIf product is for the U.S. government.

5.2 The following options are available and shall be specified at the time of placing the order, when required,

4.1.8 Mill test report, when required,

4.1.9 When required:

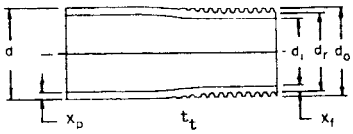
5.2.1 When heat identification or traceability is required, and

4.1.10 When required,

5.2.2 When tubes are for Boiler and Pressure Vessel code application, which should then be ordered according to ASME SB 359.

5. General Requirements

5.1 Tubes described by this specification shall normally be furnished with unenhanced ends, but may be furnished with enhanced ends or stripped ends from which the O.D. enhancement has been removed by machining.



d - Outside Diameter of Unenhanced Section

d_o - Outside Diameter of the Enhanced Section

d_r - Root Diameter of the Enhanced Section

d_i - Inside Diameter of the Enhanced Section

x_p - Wall Thickness of the Unenhanced Section

x_r - Wall Thickness of the Unenhanced Section

t_t - Transition Taper

NOTE—The outside diameter over the enhanced section will not normally exceed the outside diameter of the unenhanced section.

FIG. 1 Outside Diameter Enhanced Tube Nomenclature

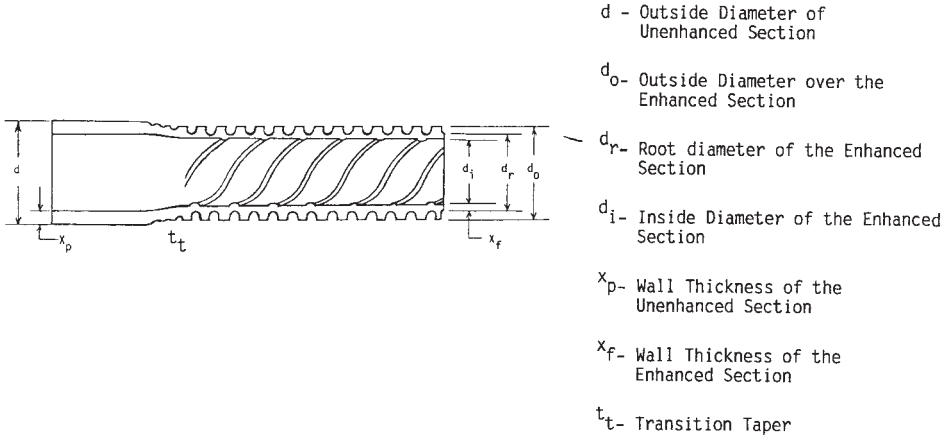


FIG. 2 Outside Diameter and Inside Diameter Enhanced Tube Nomenclature

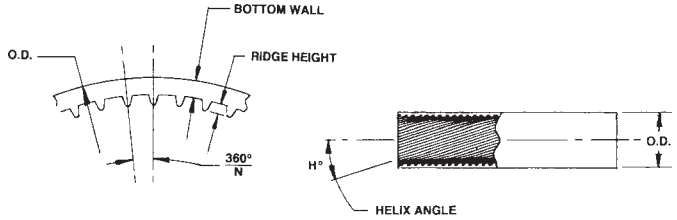


FIG. 3 Inside Diameter Enhanced Tube Nomenclature

~~5.1.1 The enhanced sections~~ SB 359,

5.2.3 Flattening test (see 11.2),

5.2.4 Certification (see Section 22), when required,

5.2.5 Mill test report (see Section 23), when required, and

5.2.6 Stress relief annealing (see 9.4), when required.

5.3 In addition, when material is purchased for agencies of the ~~tube in~~ U.S. government, it shall conform to the ~~as-fabricated temper are~~ requirements specified in the ~~cold-worked condition produced by the enhancing operation. The unenhanced sections of the tube shall be~~ Supplementary Requirements section, when specified in the ~~annealed~~ contract or ~~light drawn temper, and shall be suitable for rolling-in operations.~~ purchase order.

6. Materials and Manufacture

6.1 *Materials*:

6.1.1 The material of manufacture shall be of such quality and purity that the finished products shall ~~conform to~~ have the ~~requirements~~ properties and characteristics prescribed in this specification for the applicable alloy and temper.

6.2 *Manufacture*:

6.2.1 The seamless copper and copper alloy tubing shall ~~be cold-worked to~~ have the ~~specified size. To comply with this specification, the~~ internal or external surface, or both, modified by a cold forming process to produce an integral enhanced ~~and unenhanced material must~~ surface for improved heat transfer.

6.2.2 The cut ends of the tubes shall be ~~homogeneous.~~

~~6.2 Due~~ deburred.

6.2.3 Due to the discontinuous nature of the processing of castings into wrought products, it is not practical to identify specific casting analysis with a specific quantity of finished material.

6.3~~2~~.4 When heat identification is required, the purchaser shall specify the details desired in the purchase order or contract.

7. Chemical Composition

7.1 The tubes shall conform to the chemical requirements specified in Table 1 for copper or copper alloy specified in the ordering information.

7.2 These specification limits do not preclude the presence of ~~other elements. Limits for~~ unnamed ~~elements may be established by~~ elements. By agreement between the manufacturer, or supplier and purchaser, analysis may be required and limits established for elements not specified.

7.2.1 *Copper Alloy C19200*—Copper may be taken as the difference between the sum of results for all specified elements and 100 %. When all elements specified, including copper, are determined, their sum shall be 99.8 % minimum.

7.2.2 For alloys in which copper is specified as the remainder, copper may be taken as the difference between the sum of the results for all specified elements and 100 % for the particular alloy.

TABLE 1 Chemical Requirements

Copper or Copper Alloy UNS No.	Composition, %												
	Copper[A]	Tin	Alumi-num	Nickel, incl Cobalt	Lead, max	Iron	Zinc	Manganese	Arsenic	Antimony	Phosphorus	Chromium	Other Named Ele-ments
~~C10100~~	~~99.99 min[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~~
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]	. . .											
~~C10200~~[D]	~~99.95 min~~	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
C10200[D,E]	99.95 min	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
~~C10300~~	~~99.95 min[E]~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~0.001–0.005~~	~~. . .~~	~~. . .~~
C10300	99.95 min[C,F]	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.001–0.005	. . .	. . .
~~C10800~~	~~99.95 min[E]~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~0.005–0.012~~	~~. . .~~	~~. . .~~
C10800	99.95 min[C,F]	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.005–0.012	. . .	. . .
~~C12000~~	~~99.90 min~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~0.004–0.012~~	~~. . .~~	~~. . .~~
C12000	99.90 min[C]	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.004–0.012	. . .	. . .
~~C12200~~	~~99.9 min~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~		~~0.015–0.040~~	~~. . .~~	
C12200	99.9 min[C]	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .		0.015–0.040	. . .	
~~C14200~~	~~99.40 min~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~0.15–0.50~~	~~. . .~~	~~0.015–0.040~~	~~. . .~~	~~. . .~~
C14200	99.4 min[C]	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.15–0.50	. . .	0.015–0.040	. . .	. . .
~~C19200~~	~~98.7 min~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~0.8–1.2~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~0.01–0.04~~	~~. . .~~	~~. . .~~
C19200	98.5 min[G]	. . .	. . .	. . .	. . .	0.8–1.2	0.20 max	. . .	. . .	. . .	0.01–0.04	. . .	. . .
~~C23000~~	~~84.0–86.0~~	~~. . .~~	~~. . .~~	~~. . .~~	~~0.05~~	~~0.05 max~~	~~remainder~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~
C23000	84.0–86.0[G]	. . .	. . .	. . .	0.05	0.05 max	remainder	. . .	. . .	. . .	. . .	. . .	. . .
~~C44300~~	~~70.0–73.0~~	~~0.9–1.2~~	~~. . .~~	~~. . .~~	~~0.07~~	~~0.06 max~~	~~remainder~~	~~. . .~~	~~0.02–0.06~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~
C44300	70.0–73.0[H]	0.9–1.2	. . .	. . .	0.07	0.06 max	remainder	. . .	0.02–0.06	. . .	. . .	. . .	. . .
~~C44400~~	~~70.0–73.0~~	~~0.9–1.2~~	~~. . .~~	~~. . .~~	~~0.07~~	~~0.06 max~~	~~remainder~~	~~. . .~~	~~. . .~~	~~0.02–0.10~~	~~. . .~~	~~. . .~~	~~. . .~~
C44400	70.0–73.0[H]	0.9–1.2	. . .	. . .	0.07	0.06 max	remainder	. . .	. . .	0.02–0.10	. . .	. . .	. . .
~~C44500~~	~~70.0–73.0~~	~~0.9–1.2~~	~~. . .~~	~~. . .~~	~~0.07~~	~~0.06 max~~	~~remainder~~	~~. . .~~	~~. . .~~	~~. . .~~	~~0.02–0.10~~	~~. . .~~	~~. . .~~
C44500	70.0–73.0[H]	0.9–1.2	. . .	. . .	0.07	0.06 max	remainder	. . .	. . .	. . .	0.02–0.10	. . .	. . .
~~C60800~~	~~remainder~~	~~. . .~~	~~5.0–6.5~~	~~. . .~~	~~0.10~~	~~0.10 max~~	~~. . .~~	~~. . .~~	~~0.02–0.35~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~
C60800	remainder[C,I]	. . .	5.0–6.5	. . .	0.10	0.10 max	. . .	. . .	0.02–0.35	. . .	. . .	. . .	. . .
~~C68700~~	~~76.0–79.0~~	~~. . .~~	~~1.8–2.5~~	~~. . .~~	~~0.07~~	~~0.06 max~~	~~remainder~~	~~. . .~~	~~0.02–0.06~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~
C68700	76.0–79.0[C,I]	. . .	1.8–2.5	. . .	0.07	0.06 max	remainder	. . .	0.02–0.06	. . .	. . .	. . .	. . .
~~C70400~~	~~remainder~~	~~. . .~~	~~. . .~~	~~4.8–6.2~~	~~0.05~~	~~1.3–1.7~~	~~1.0 max~~	~~0.30–0.8~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~
C70400	remainder[C,I]	. . .	. . .	4.8–6.2	0.05	1.3–1.7	1.0 max	0.30–0.8	. . .	. . .	. . .	. . .	. . .
~~C70600~~	~~remainder~~	~~. . .~~	~~. . .~~	~~9.0–11.0~~	~~0.05~~	~~1.0–1.8~~	~~1.0 max[E]~~	~~1.0 max~~	~~. . .~~	~~. . .~~	~~F~~	~~. . .~~	~~. . .~~
C70600	remainder[C,I]	. . .	. . .	9.0–11.0	0.05	1.0–1.8	1.0 max	1.0 max	. . .	. . .	. . .	. . .	. . .
~~C70620~~	~~86.5 min[C,I]~~	~~. . .~~	~~. . .~~	~~9.0–11.0~~	~~0.02~~	~~1.0–1.8~~	~~0.5 max~~	~~1.0 max~~	~~. . .~~	~~. . .~~	~~0.02 max~~	~~. . .~~	~~0.05 C max~~ ~~0.02 S max~~
C70620	86.5 min[C,I]	. . .	. . .	9.0–11.0	0.02	1.0–1.8	0.5 max	1.0 max	. . .	. . .	0.02 max	. . .	0.05 C max 0.02 S max
~~C71000~~	~~remainder~~	~~. . .~~	~~. . .~~	~~19.0–23.0~~	~~0.05~~	~~0.50–1.0~~	~~1.0 max[E]~~	~~1.0 max~~	~~. . .~~	~~. . .~~	[E]	~~. . .~~	~~F~~
C71000	remainder[C,I,J]	. . .	. . .	19.0–23.0	0.05	1.0 max	1.0 max	1.0 max	. . .	. . .		. . .	. . .
~~C71500~~	~~remainder~~	~~. . .~~	~~. . .~~	~~29.0–33.0~~	~~0.05~~	~~0.40–1.0~~	~~1.0 max[E]~~	~~1.0 max~~	~~. . .~~	~~. . .~~	~~F~~	~~. . .~~	~~F~~
C71500	remainder[C,I]	. . .	. . .	29.0–33.0	0.05	0.40–1.0	1.0 max	1.0 max	. . .	. . .	. . .	. . .	. . .
C71520	65.0 min	. . .	. . .	29.0–33.0	0.02	0.40–1.0	0.50 max	1.0 max	. . .	. . .	0.02 max	. . .	0.05 C max 0.02 S max
~~C72200~~	~~remainder~~	~~. . .~~	~~. . .~~	~~15.0–18.0~~	~~0.05~~	~~0.50–1.0~~	~~1.0 max[E]~~	~~1.0 max~~	~~. . .~~	~~. . .~~	~~F~~	~~0.30–0.70~~	~~F~~
C72200	remainder[C,G,J]	. . .	. . .	15.0–18.0	0.05	0.50–1.0	1.0 max	1.0 max	. . .	. . .	. . .	0.30–0.70	0.03 Si 0.03 Ti

[A] Copper (including silver).

[B] 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, mercury, zinc, phosphorus, selenium, tellurium, manganese, cadmium, and oxygen present in the sample.

[C] Other impurity maximums for C10100 shall be: bismuth, cadmium and mercury 0.0001 each, oxygen 0.0005, selenium 0.0003, silver 0.0025, sulfur 0.0015, and tellurium 0.0002.

[D] Oxygen in C10200 shall be 0.0010 max.

[E] Copper plus sum of named elements shall be 99.95 % min.

[F] ~~Copper plus sum of named elements shall be 99.95 % min.~~

[G] Cu + Sum of Named Elements, 99.8 % min.

[H] Cu + Sum of Named Elements, 99.6 % min.

[I] Cu + Sum of Named Elements, 99.5 % min.

[J] 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, and sulfur and carbon 0.05 % max.

7.2.2.1 When analyzed, copper plus the sum of results for specified elements shall ~~be as~~ conform with the requirements shown in the following ~~table.~~
table:

Copper Alloy UNS No.	Copper Plus Named Elements, % min
C60800	99.5
C70400	99.5
C70600	99.5

C70620	99.5
C71000	99.5
C71500	99.5
C71520	99.5
C72200	99.8

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

7.2.3.1 When all specified elements are determined, the sum of results plus copper shall be as follows:

Copper Alloy UNS No.	Copper Plus Named Elements, % min
C23000	99.8
C44300, C44400, C44500	99.6
C68700	99.5

8. Temper

8.1 Tempers, as defined in Classification B 601 and this document, are as follows:

8.1.1 The tube, after enhancing, shall be supplied, as specified, in the annealed (O61) or as-fabricated temper.

8.1.1.1 The enhanced sections of tubes in the as-fabricated temper are in the cold-worked condition produced by the fabricating operation.

8.1.1.2 The unenhanced sections of tubes in the as-fabricated temper are in the temper of the tube prior to enhancing, annealed (O61), or light drawn (H55), and suitable for rolling-in operations.

8.1.1.3 Copper ~~a~~ Alloy UNS Nos. C23000, C44300, C44400, C44500, C60800, and C68700, furnished in the as-fabricated temper, ~~must~~ shall be stress relief annealed after enhancing and be capable of meeting the requirements of the ~~mercurous nitrate test~~ stress-corrosion susceptibility requirement in Section 12. Stress-relief annealing of the copper and other copper alloys described by this specification is not required.

~~8.1.3.1 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 alloys C23000, C44300, C44400, C44500, C60800, and C68700 be subjected to a stress relieving thermal treatment subsequent to straightening. When required, this must be specified on 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.~~

~~8.1.4 The enhanced sections of tubes in the annealed temper shall show complete recrystallization when examined in the cross-section of the tube at a magnification of 75 diameters. Average grain size shall be within the limits agreed upon between the manufacturer and purchaser, when measured in the wall of the tube outside of the enhanced area.~~

9. Grain Size of Annealed Temper

9.1 Samples of annealed-temper (O61) tubes selected for test shall be subjected to microscopical e~~P~~xamination at a magnification of 75 diameters and shall show uniform and complete recrystallation.

9.2 Average grain size shall be within limits agreed upon between the manufacturer and purchaser, when measured in the wall of the tube outside of the enhanced area.

9.3 The requirements of this section do not apply to product shipped in the as-fabricated temper.

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 must be specified on 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 *Tensile Property Requirements*:

10.1.1 Prior to the enhancing operation, the tube shall conform to the requirements for tensile properties prescribed in Table 2.

~~10. Expansion Test~~

~~10.1 The unenhanced sections of all tubes selected for test shall conform to the requirements prescribed in Table 3 when tested in accordance with B 153. The expanded tube shall show no cracking or rupture visible to the unaided eye.~~

11. ~~Flattening Test~~

~~11.1 The~~Performance Requirements

11.1 *Expansion Test*—The unenhanced ~~lengths~~ sections of all tubes selected for tests shall ~~be flattened on different elements and a flattened element~~ conform to the requirements prescribed in Table 3 when tested in accordance with Test Method B 153. The

TABLE 2 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	9 [C]
C10100, C10200, C10300, C10800, C12000, C12200, C14200	O61	annealed	30 [205]	9 [62][C]
C10100, C10200, C10300, C10800, C12000, C12200, C14200	H55	light-drawn	36	30
C10100, C10200, C10300, C10800, C12000, C12200, C14200	H55	light-drawn	36 [250]	30 [205]
C19200	O61	annealed	38	12
C19200	O61	annealed	38 [260]	12 [85]
C23000	O61	annealed	40	12
C23000	O61	annealed	40 [275]	12 [85]
C44300, C44400, C44500	O61	annealed	45	15
C44300, C44400, C44500	O61	annealed	45 [310]	15 [105]
C60800	O61	annealed	50	19
C60800	O61	annealed	50 [345]	19 [130]
C68700	O61	annealed	50	18
C68700	O61	annealed	50 [345]	18 [125]
C70400	O61	annealed	38	12
C70400	O61	annealed	38 [260]	12 [85]
C70600	O61	annealed	40	
C70600	O61	annealed	40 [275]	15 [105]
C70620	O61	annealed	40 [275]	15 [105]
C71000	O61	annealed	45	16
C71000	O61	annealed	45 [310]	16 [110]
C71500	O61	annealed	52	
C71500	O61	annealed	52 [360]	18 [125]
1520	O61	annealed	52 [360]	18
C71520	O61	annealed	52 [360]	18 [125]
C72200	O61	annealed	45	16
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 3 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
H55	light-drawn	C10100, C10200, C10300, C10800, C12000, C12200, C14200	20
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	30
O61	annealed	C70600, C70620	30
O61	annealed	C71000	30
O61	annealed	C71500	30
O61	annealed	C71500, C71520	30
O61	annealed	C72200	30

expanded tube shall show no cracking or rupture visible to the unaided eye. (Corrective spectacles necessary to obtain normal vision may eye.

11.2 *Flattening Test*:

11.2.1 When specified in the contract or purchase order, the flattening test described in the test method section in 18.4 shall be performed.

11.2.1.1 During inspection, the flattened areas of the test-specimen shall be free of defects, but blemishes of a nature that do not interfere with the intended application are acceptable.)

12. Other Requirements

12.1 *Mercurous Nitrate Test or Ammonia Vapor Test*:

12.1.1 EThe mercurous nitrate or ammonia vapor test is required only for Copper Alloys UNS Nos. C23000, C44300, C44400, C44500, C60800, and C68700. (**Warning**—Mercury is a definite health hazard and therefore equipment for the detection and

removal of mercury vapor produced in volitization is recommended. The use of rubber gloves in testing is adviseable.)

12.1.2 The test specimens, cut 6 in. [150 mm] in length from the enhanced section shall withstand, without cracking, an immersion in the standard mercurous nitrate solution ~~as prescribed~~ in Test Method B 154 ~~without cracking. The enhanced specimens~~ or immersion in the ammonia vapor solution as defined in Test Method B 858.

12.1.3 Unless otherwise agreed upon between the manufacturer, or supplier, and the purchaser, the manufacturer shall ~~include~~ have the ~~finished tube ends.~~

~~12.2 This~~ option of using either the mercurous nitrate test or the ammonia vapor test. If agreement cannot be reached, the mercurous nitrate test standard shall be utilized.

12.1.4 If the ammonia vapor test is ~~required only~~ selected, the appropriate risk level pH value for ~~copper alloys C23000, C44300, C44400, C44500, C60800,~~ the test solution shall be agreed upon by the manufacturer and ~~C6~~ purchaser, or alternately, if the purchaser defers to the manufacturer's expertise for the selection of the test pH value, the minimum value selected shall be 9.8~~700~~.

13~~2~~.2 *Non-~~d~~Destructive Testing*:

13~~2~~.2.1 Each tube shall be subjected to a non-destructive test. Tubes shall normally be tested in the as-fabricated temper but, at the option of the manufacturer, may be tested in the annealed temper. Unless otherwise specified, the manufacturer shall have the option of testing the tubes by one of the following test ~~methods.~~

~~13.1.1 *Eddy-Current Test*—The~~ methods:

12.2.1.1 *Non-Destructive Examination for Defects*:

(1) The tubes shall be passed through an eddy-current testing unit adjusted per the requirements of 19~~8~~.3.3 to provide information on the suitability of the tube for the intended application.

~~13.1.1.1 Tubes~~

(2) Tubes causing irrelevant signals because of moisture, soil, and like effects may be reconditioned and retested. Such tubes shall be considered to conform, should they not cause output signals beyond the acceptable limits.

~~13.1.1.2 Tubes~~

(3) Tubes causing irrelevant signals because of visible and identifiable handling marks may be retested by the hydrostatic test prescribed in 13~~2~~.2.1.2 or the pneumatic test prescribed in ~~13.1.3.~~

~~13.1.1.3 Unless~~ 12.2.1.3.

(4) Unless otherwise agreed, tubes meeting the requirements of either test shall be considered to conform if the tube dimensions are within the prescribed limits.

13~~2~~.2.1.2 *Hydrostatic Test*—Each tube, without showing evidence of leakage, shall withstand an internal hydrostatic pressure sufficient to subject the material in the unenhanced region of the tube to a fiber stress of 7000 psi [48 Mpa], as determined by the following equation for thin hollow cylinders under tension.:

$$P = \frac{2St/}{(D - 0.8t)} \quad (1)$$

$$P = \frac{2St}{(D - 0.8t)} \quad (1)$$

~~where~~

~~*P*~~

where:

P = hydrostatic pressure, ~~Psig,~~

~~*t*~~

psig,

[Mpa],

t = thickness of tube wall, in., [mm],

D = outside diameter of tube, in., [mm], and ~~*S*~~

S = allowable fiber stress of the material, psi [Mpa].

The tube need not be tested at a hydrostatic pressure over 1000 psi [6.9 MPa] unless so specified.

13~~2~~.2.1.3 *Pneumatic Test*—Each tube, after enhancing, shall withstand a minimum internal air pressure of 250 psig [1.7 Mpa] for 5 s and any evidence of leakage shall be cause for rejection. The test method used shall permit easy visual detection of any leakage, such as having the tube under water, or by the pressure differential method.

13~~2~~.2.2 *ASME Pressure Vessel Code*:

12.2.2.1 When tubes are specified to meet the requirements of the ASME Boiler and Pressure Vessel Code, a pressure test as described in 13~~2~~.2.1.2 or 13~~2~~.2.1.3 is required.

14~~3~~. Dimensions, Mass, and Permissible Variations

14~~3~~.1 *Tube Diameter*—:

13.1.1 The outside diameter of the unenhanced sections shall not vary by more than the amount shown in Table 4 for the appropriate dimensional system, as measured by "go" and "no go" ring gages. The diameter over the enhanced sections shall not

TABLE 4 Diameter Tolerances

Specified Diameter, in. [mm]	Tolerance, in. [mm]
~~0.500 and under~~	~~±0.002~~
0.500 [12.0] and under	±0.002
~~Over 0.500–0.740, incl~~	~~±0.0025~~
Over 0.500–0.740 [12.0–18.0], incl	±0.0025
~~Over 0.740–1.000, incl~~	~~±0.003~~
Over 0.740–1.000 [18.0–25.0], incl	±0.003

exceed the diameter of the plain sections involved, as determined by a "go" ring gage, unless otherwise specified.

14.3.2 *Wall Thickness*—No tube shall be less than the minimum thickness specified in the plain sections or in the enhanced sections.

14.3.3 *Length*—:

13.3.1 The length of the tubes shall not be less than that specified when measured at a temperature of 68°F [20°C], but may exceed the specified value by the amounts shown in Table 5, for the appropriate dimensional system.

14.3.3.1 2 The length of the unenhanced end(s), as measured from the tube end to the first fin disk impression, shall not be less than that specified, but may exceed the specified value by ½ ~~inch.~~

~~14.4~~ in. [13 mm].

13.4 *Squareness of Cut*—The departure from squareness of the end of any tube shall not exceed the tolerance stated in Table 6, for the appropriate dimensional system.

15.4. Workmanship, Finish and Appearance

15.4.1 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.

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

16.5. Sampling

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

16.5.1.1 *Lot Size*—600 tubes or 10 000 ~~lbs~~ lb [4550 kg] or fraction of either, whichever constitutes the greater weight.

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

16.5.1.2.1 Samples taken for purposes of test 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.

16.5.2 *Chemical Composition*—:

15.2.1 Samples for determining composition shall be taken in accordance with Practice E 255. The minimum weight of the composite sample shall be 150 g.

16.5.2.1 2 Instead of sampling in accordance with Practice E 255, 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 the course of manufacture, sampling of the finished product is not required and the minimum number of samples to be taken shall be as follows:

16.5.2.1 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.

16.5.2.1 2.2 When samples are taken from the semi-finished product, one sample shall be taken to represent each 10 000 ~~lbs~~ lb [4550 kg] or fraction thereof, except that not more than one sample shall be required per piece.

17.6. Number of Tests and Retest

17.6.1 *Tests*:

TABLE 5 Length Tolerances

Specified Length, ft [mm]	Tolerance, all Plus, in. [mm]
~~Up to 20, incl~~	~~⅛~~
Up to 20, incl	⅛ [3.2]
~~Over 20–30, incl~~	~~5/32~~
Over 20–30, incl	5/32 [4.0]
~~Over 30–60, incl~~	~~¼~~
Over 30–60, incl	¼ [6.4]

TABLE 6 Squareness of Cut

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

176.1.1 *Chemical Analysis*—Chemical composition shall be determined as the arithmetic mean of at least two replicate determinations of each specified element.

17.1.2 All other tests specified in sections 8-12

16.1.2 *Grain Size*—For annealed temper only, two tubes shall be conducted on specimens taken selected from each lot and each tube shall be tested to verify the requirements of Section 9.

16.1.3 *Tensile Property Requirements*—Two tubes shall be selected from each lot prior to enhancement and each tube shall be tested to verify the samples requirements of Section 10.

16.1.4 *Expansion Test*—Two tubes shall be selected from each lot prior to enhancement and each tube shall be tested to verify the requirements in 11.1.

16.1.5 *Flattening Test*—One tube shall be selected from each lot prior to enhancement and each tube shall be tested to verify the requirements of 11.2.

16.1.6 *Mercurous Nitrate Test or Ammonia Vapor Test*—Two tubes shall be selected from each lot prior to enhancement and each tube shall be tested to verify the requirements of 162.1.2.

176.2 *Retest*:

176.2.1 One retest shall be permitted for each requirement under the same conditions stated for the original test.

176.2.2 Should the result of a retest fail to conform with the requirements of the product specification, the material shall be rejected.

187. Specimen Preparation

187.1 *Chemical Analysis*:

17.1.1 Sample preparation shall be in accordance with Practice E 255.

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

187.2 *Grain Size*:

17.2.1 Specimens for the microscopic examination shall be prepared in accordance with Test Methods E 3.

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

187.3 *Expansion Test Specimen*:

17.3.1 Test Specimens shall conform to the rexquirements of the Specimen Preparations Section of Test Method B 153.

17.4 *Flattening Test*:

17.4.1 A test specimen shall be of suitable cut to a length so that they can will allow the tube to be expanded flattened at three (3) places along the required amount. Both ends shall either length, with each flattened area to be faced square at least 2 in. [50 mm] in a lathe, or suitably prepared so as to have a smooth surface free from scratches or burrs, and with both edges slightly chambered.

18.4 Specimens for length. When the flattening test require no special preparation, but shall be of temper is other than annealed, the length necessary sample may be annealed prior to accommodate the test.

18.5 Specimens testing.

17.5 *Mercurous Nitrate or Ammonia Vapor Test*:

17.5.1 Specimens for the mercurous nitrate test shall be 6 inches in. [150 mm] in length and shall be taken from the enhanced and unenhanced portion of each sample.

187.6 *Tension Tests*:

17.6.1 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 E 8, or E 8M for the SI System, 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 E 8 or E 8M shall be used.

187.6.12 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.

187.6.23 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 gage length, or distance between grips for a full section specimen.

198. Test Methods

198.1 *Chemical Composition*:

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

19.1.2 In case of disagreement concerning chemical composition of a Copper Alloy UNS No. C10100, refer to the Test Method Section of Specification B 170.

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

19.2.1 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).[D] D).

Element	Range	Test Method
Copper	99.75 to 99.99	E 53, Electrolytic
Copper	70.0 to 99.75	E 478, Electrolytic
Tin	0.9 to 1.2	E 478, Photometric
Aluminum	1.8 to 6.5	E 478
Nickel, inc. Cobalt	4.8 to 33.0	E 478, Gravimetric
Lead	0.05 to 0.10	E 478, Atomic Absorption
Iron	0.04 to 1.8	E 478
Zinc	14.0 to 30.0	E 478, Titrimetric
Zinc	to 1.0	E 478, Atomic Absorption
Manganese	to 1.0	E 62
Arsenic	0.02 to 0.5	E 62
Antimony	0.02 to 0.1	E 62
Phosphorus	0.001 to 0.04	E 62
Chromium	0.30 to 0.70	E 118

19.3 The

18.3 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	E 112
Expansion (pin test)	B 153
Mercurous Nitrate	B 154
Tension	E 8
Tension	E 8, E 8M as applicable
Eddy-Current Test	E 243
Ammonia Vapor Test	B 858

19.3.1

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

19.3.2 *Test Method B 154*—(**Warning:**—tThis test method involves the use of a mercury compound which that is classified as a health hazard in use and disposal.)

19.3.3 *Eddy-Current*—Testing shall follow the procedures of Practice E 243, except that the sensitivity settings of the test equipment shall be adjusted using the hole sizes specified in Table 7 of Specification B 359. this specification. The holes for sensitivity adjustment shall be drilled radially through an unenhanced 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.

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

18.4 *Flattening Test*—Each test specimen shall be flattended in a press at three (3) places along the length, each new place to be rotated on its axis approximately one third turn from the last flattened area. Each flattened area shall be at least 2 in. [50 mm] in length. A flattened test-specimen shall allow a micrometer caliper set at three times the wall thickness to pass freely over the flattened area. The flattened areas of the test specimen shall be inspected for surface defects.

19. Significance of Numerical Limits

2019.1 For purposes of determining compliance with the specified limits of the properties listed in the following table, an observed or calculated value shall be rounded as indicated in accordance with the rounding method of Practice E 29. E 29.

TABLE 7 Diameter of Drilled Holes

Nominal Diameter Over Enhanced or or Unenhanced Section, in. in. [mm]	Diameter of Drilled Drilled Holes, in. [mm]
¼–⅝, incl	0.042 No. 58 drill
¼–⅝ [6.0–16.0], incl	0.042 [1.07]–No. 58 drill
Over ⅝–1, incl	0.046 No. 56 drill
Over ⅝–1, incl	0.046 [1.17]–No. 56 drill

Property	Rounded Unit for Observed or Calculated Value
Chemical Composition	Nearest unit in the last right hand place of figures
~~Tensile Strength, Yield Strength~~	~~Nearest ksi~~
Tensile Strength, Yield Strength	Nearest ksi [Nearest 5 MPa]
Grain Size:	
Up to 0.055 mm, incl.,	Nearest multiple of 0.005 mm
Over 0.055 mm	to the nearest 0.010 mm
Expansion	Nearest 1 %

~~21.~~

20. Inspection

21.1 The manufacturer shall inspect and make the necessary tests to verify that the tubes furnished conform to the requirements of this specification.

21.2 Should the purchaser additionally elect to perform his own inspection, the manufacturer shall, without charge, afford the inspector all reasonable facilities to determine that the tubes being furnished conform to the requirements of this specification.

21.2.1 Except for chemical analysis, all tests and inspections shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere with the operation of the facility.

21.3 When automated finishing and inspection equipment is available at a facility, purchaser and manufacturer may, by mutual agreement, accomplish the final inspection simultaneously.

221. Rejection and Rehearing

21.1 *Rejection*:

21.1.1 Material that fails to conform to the requirements of this specification when inspected or tested by the purchaser, or purchasers agent, may be rejected.

221.1.2 Rejection shall be reported to the manufacturer, or supplier, promptly and in writing.

221.1.3 ~~T~~In case of dissatisfaction with results of the test upon which rejection is based, the manufacturer, or supplier, may make claim for a rehearing~~ w~~.

21.2 *Rehearing*—As a result of product rejection, the manufacturer, or supplier, may make claim for a retest to be conducted by the manufacturer, or supplier, and the purchaser. Samples of~~i~~ the rejected product shall be taken in accordance with the product specification and subjected to test by both parties using the test method(s) specified in the product specification. Alternately, upon agreement of both parties, an independent laboratory may be selected for the test(s) using the test method(s) specified in the product specification.

232. Certification

232.1 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.

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

243. Mill Test Report

243.1 When specified in the purchase order or contract, the manufacturer or supplier shall furnish to the purchaser a manufacturer's test report showing the results of the required tests.

254. Packaging and Package Marking

254.1 The material shall be separated by alloy, size, and temper. It shall be packaged in such a manner as to ensure acceptance by common carrier for transportation and to afford adequate protection from normal hazards of transportation.

254.2 Each shipping unit shall be legibly marked with the name of supplier, purchase order number, metal or alloy designation, temper, size, total length or piece count, or both.

254.3 The specification number shall be shown when specified.

265. Keywords

265.1 condenser; copper; copper alloys; ~~seamless; condenser;~~ heat exchanger; ~~tube;~~ integral fins; seamless; tube; UNS No. C10100; UNS No. C10200; UNS No. C10300; UNS No. C10800; UNS No.C12000; UNS No.C12200; UNS No. C14200; 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

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order, for agencies of the U.S. G government.

S1. Referenced Documents

S1.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein.

S1.1.1 *ASTM Standards:*

D 4727—Specification

B 900 Practice for Packaging of Copper and Copper-Alloy Mill-Products for U. S. Government Agencies

D 4727 Specification for Corrugated and Solid Fiberboard Sheet Stock (Container Grade) and Cut Shapes[9]

S1.1.2 *Military Standards*:[8]

[9] *Annual Book of ASTM Standards*, Vol 03.06. 15.09.

MIL-STD-271— Nondestructive Testing Requirements for Metals
MIL-STD-2035— Nondestructive Testing Acceptance Criteria
S1.1.3 *Military Specifications:*
MIL-C-3993—Copper and Copper Base Alloy Mill Products; Packaging of.
MIL-L-19140—Lumber[9]
MIL-L-19140 Lumber and Plywood, Fire-Retardant Treated

S2. Standard Government Tube Dimensions

S2.1 *Number of Fins*—Tube shall have 19 + 1, −0 fins per inch as averaged over any 12 inch in. length.
S2.2 *Fin Height*—The fin height shall be 0.050 inch, in., minimum.
S2.3 *Dimensions*—Table S1 lists standard tube diameters and wall thickness.
S2.4 *Root Diameter Tolerances*—A tolerance of plus 0.007 inch +0.007 in. and minus 0.003 inch −0.003 in. on the root diameter shall be permitted.
S2.5 *Straightness Tolerance*—The straightness tolerances of Table S2 shall apply to as-finned tube only.
S2.6 The tolerances for outside diameter of the unenhanced ends, specified in Table 5, shall be all negative.

S3. Sampling

S3.1 *Lot Definition*—For sampling purposes, a lot shall consist of lengths of tubes of the same composition, temper, size, heat treated at the same time in the same furnace, offered for delivery at the same time and identifiable by mill records as originating from one or more heats (melts), as necessary, which conform to the chemical requirements. The total weight of the lot shall not exceed 10 000 pounds.
S3.2 *Visual and Dimensional Examination*—From each lot, a representative sample of tubes shall be selected in accordance with Table S3 for inspection to the requirements of Section 11 13 Dimensions and Permissible Variations and Section 12 14 Workmanship, Finish and Appearance of Specification B 359 this specification and Section 1.2 2 of this supplement.
S3.3 *Destructive Tests*—From each lot a representative sample for flattening, flaring and grain size tests as specified in Specification B 359 this specification shall be selected in accordance with Table S4.
S3.4 *Chemical Analysis*—Samples shall be taken at the time the metal is cast. One sample shall be taken for each group of castings poured from the same source of molten metal. Analysis of all metal compromising the lot shall be performed.

S4. Nondestructive Testing

S4.1 *Eddy Current and Pressure Tests*—Both eddy current and pressure tests are required.

TABLE S1 Dimensions of Integrally Finned Condenser Tubes (minimum wall)

Nominal		Unenhanced Section		Enhanced Section	
Outside Diameter, in.	Wall Thickness, in.	Specified Outside Diameter, in.	SpecWall Thifickned Mss, min., imum Walln.	Specified Root Diameter, in.	Specified MinimumWallInc I., inchInchInchInch. Thickness, Iminch
½	0.032	0.500	0.049	0.375	0.032
½	0.042	0.500	0.058	0.375	0.042
½	0.049	0.500	0.065	0.375	0.049
⅝	0.028	0.625	0.042	0.500	0.028
⅝	0.035	0.625	0.049	0.500	0.035
⅝	0.049	0.625	0.065	0.500	0.049
⅝	0.058	0.625	0.072	0.500	0.058
⅝	0.065	0.625	0.083	0.500	0.065
¾	0.028	0.750	0.049	0.625	0.028
¾	0.035	0.750	0.052	0.625	0.035
¾	0.042	0.750	0.058	0.625	0.042
¾	0.049	0.750	0.065	0.625	0.049
¾	0.058	0.750	0.075	0.625	0.058
¾	0.065	0.750	0.083	0.625	0.065
¾	0.072	0.750	0.086	0.625	0.072
¾	0.083	0.750	0.095	0.625	0.083
¾	0.095	0.750	0.109	0.625	0.095
⅞	0.035	0.875	0.052	0.750	0.035
⅞	0.042	0.875	0.058	0.750	0.042
⅞	0.049	0.875	0.065	0.750	0.049
⅞	0.058	0.875	0.075	0.750	0.058
⅞	0.065	0.875	0.083	0.750	0.065
⅞	0.072	0.875	0.086	0.750	0.072
⅞	0.083	0.875	0.095	0.750	0.083
1	0.042	1.000	0.058	0.875	0.042
1	0.049	1.000	0.065	0.875	0.049
1	0.058	1.000	0.075	0.875	0.058
1	0.065	1.000	0.083	0.875	0.065
1	0.072	1.000	0.086	0.875	0.072
1	0.083	1.000	0.095	0.875	0.083

TABLE S2 Permissible Variations in Straightness of Tube

Length (feet), ft	Maximum Curvature (depth of arc) (, inch).
Over 3 to 6 inclusive	3/16
Over 6 to 8 inclusive	5/16
Over 8 to 10 inclusive	1/2
Over 10	½ inch in any 10 foot portion of the total length
Over 10	½ in. in any 10 ft portion of the total length

TABLE S3 Sampling for Visual and Dimensional Examinations

Lot Size	Sample Size
2–13	All
14–150	13
151–280	20
281–500	29
501–1200	34
1201–3200	42

TABLE S4 Sampling for Destructive Tests

Lot Size	Sample Size
1–25	2
26–50	3
51–90	4
91–150	5
151–280	6
281–500	7
501–1200	8
1201–3200	9

S4.2 *Eddy Current Procedure*—An eddy current test shall be performed which meets the requirements specified in Specification B 359 this specification and MIL-STD-271.

S4.2.1 *Liquid Penetrant Inspection*—Liquid penetrant inspection in accordance with MIL-STD-271 shall be performed on the outside surface and the end surfaces of the smooth ends of the tubes to inspect the area of the tubes missed by the eddy current test due to "end effect." Alternatively, the area of the tube ends missed may be cropped off and discarded. Liquid penetrant acceptance criteria shall be in accordance with MIL-STD-2035.

S5. Cleaning

S5.1 *Cleanness*—Contaminants, such as sulfur or sulfur-bearing compounds or carbon or carbon compounds from lubricants used in forming, machining, or other processing and marking materials used for in-process identification, shall be removed from the material prior to any heat treatment. Tubing shall be acid or abrasive cleaned. Traces of acid or abrasive shall be removed following cleaning.

S6. Preparation for Delivery

S6.1 *Military Agencies*—Material shall be separated by size, and composition and shall be preserved and packaged level A or C, packed level A, B, or C, as specified in the purchase order or contract in accordance with the requirements of MIL-C-3993. Practice B 900. In addition when specified in the contract or purchase order the following shall apply:

S6.1.1 *Fire Retardant Requirements:*

S6.1.1.1 *Lumber and Plywood*—All lumber and plywood including laminated veneer materials used in shipping container and pallet construction, members, blocking, bracing, and reinforcing shall be fire retardant treated materials conforming to MIL-L-19140 as follows:

Level A and B	Type II—weather resistant Category I—general use
Level C	Type I—non weather resistant Category I—general use

S6.1.1.2 *Fiberboard*—Fiberboard used in the construction of boxes including interior packaging forms shall conform to the class-domestic/fire retardant or class-weather resistant/fire retardant materials requirements, as specified in the acquisitioning document, of Specification D 4727.

S6.1.2 Cushioning or wrapping materials shall be provided to prevent damage and to prevent free movement of the container contents. The use of excelsior, newspaper, shredded paper and similar hydroscopic or non-neutral materials and all types of loose

fill materials for packaging applications such as cushioning, fill, stuffing and dunnage is prohibited.

SUMMARY OF CHANGES

~~Subcommittee B05.04~~

Committee B05 has identified the location of selected changes to this standard since the last issue (B 359 – 958) that may impact the use of this standard.

(*1*) ~~Section S3.4 added~~) General rewrite of the document to comply with the ~~Supplementary Requirements section.~~ outline of form including miscellaneous working changes.
(*2*) ~~Section S5 added to the Supplementary Requirements section~~) Addition of alloys C70620 and ~~the balance~~ C71520 for Welding grade.
(*3*) Addition of ~~the sections have been renumbered.~~ Test Method B 858.
(*4*) Revision to caption in Fig. 1.