





# Standard Specification for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock<sup>1</sup>

This standard is issued under the fixed designation B 111; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

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

<sup>e1</sup> NOTE—Paragraph 4.1.9 has been editorially corrected in November 2000.

<sup>e2</sup> NOTE—Referenced Documents were editorially corrected in November 2003.

## 1. Scope\*

1.1 This specification<sup>2</sup> covers seamless tube and ferrule stock of copper and various copper alloys up to 3/8 in., inclusive, in diameter, for use in surface condensers, evaporators, and heat exchangers. Tubes for this application are normally made from the following coppers or copper alloys:<sup>3</sup>

Copper or Copper Alloy UNS No.	Previously Used Designation	Type of Metal
C10100	OFE	Oxygen-free electronic
C10200	OF <sup>A</sup>	Oxygen-free without residual deoxidants
C10300	...	Oxygen-free, extra low phosphorus
C10800	...	Oxygen-free, low phosphorus
C12000	DLP <sup>A</sup>	Phosphorized, low residual phosphorus
C12200	DHP <sup>A</sup>	Phosphorized, high residual phosphorus
C14200	DPA <sup>A</sup>	Phosphorized, arsenical
C19200	...	Phosphorized, 1 % iron
C23000	...	Red Brass
C28000	...	Muntz Metal
C44300	...	Admiralty Metals, B, C, and D
C44400	...	...
C44500	...	...
C60800	...	Aluminum Bronze
C61300	...	...
C61400	...	Aluminum Bronze, D
C68700	...	Aluminum Brass, B
C70400	...	95-5 Copper-Nickel
C70600	...	90-10 Copper-Nickel
C71000	...	80-20 Copper-Nickel
C71500	...	70-30 Copper-Nickel
C71640	...	Copper-nickel-iron-manganese
C72200	...	...

<sup>A</sup> Designations listed in Classification B 224.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee B05 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.04 on Pipe and Tube.

Current edition approved March 10, 1998. Published February 1999. Originally published as B 111 – 37 T. Last previous edition B 111 – 95.

<sup>2</sup> For ASME Boiler and Pressure Vessel Code applications, see related Specification SB-111 in Section II of the Code.

<sup>3</sup> The UNS system for copper and copper alloys (see Practice E 527) is a simple expansion of the former standard designation system accomplished by the addition of a prefix “C” and a suffix “00.” The suffix can be used to accommodate composition variations of the base alloy.

NOTE 1—A complete metric companion to Specification B 111 has been developed—B 111M; therefore, no metric equivalents are presented in this specification.

NOTE 2—**Warning:** Mercury is a definite health hazard in use and disposal. (See 12.1.)

1.2 The following safety hazards caveat pertains only to the test methods portion, Section 18, of 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 and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

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

### 2.2 ASTM Standards:

- B 153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing<sup>4</sup>
- B 154 Test Method for Mercurous Nitrate Test for Copper and Copper Alloys<sup>4</sup>
- B 170 Specification for Oxygen-Free Electrolytic Copper—Refinery Shapes<sup>4</sup>
- B 224 Classification of Coppers<sup>4</sup>
- E 8 Test Methods for Tension Testing of Metallic Materials<sup>5</sup>
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications<sup>6</sup>
- E 53 Test Methods for Chemical Analysis of Copper<sup>7</sup>
- E 54 Test Methods for Chemical Analysis of Special Brasses and Bronzes<sup>7</sup>
- E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)<sup>7</sup>
- E 75 Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys<sup>7</sup>

<sup>4</sup> Annual Book of ASTM Standards, Vol 02.01.

<sup>5</sup> Annual Book of ASTM Standards, Vol 03.01.

<sup>6</sup> Annual Book of ASTM Standards, Vol 14.02.

<sup>7</sup> Annual Book of ASTM Standards, Vol 03.05.

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

- E 112 Test Methods for Determining Average Grain Size<sup>5</sup>
- E 243 Practice for Electromagnetic (Eddy Current) Examination of Copper and Copper-Alloy Tubes<sup>8</sup>
- E 255 Practice for Sampling Copper and Copper Alloys for the Determination of Chemical Composition<sup>7</sup>
- E 478 Test Methods for Chemical Analysis of Copper Alloys<sup>7</sup>
- E 527 Practice for Numbering Metals and Alloys (UNS)<sup>9</sup>

**3. Terminology**

3.1 Definitions:

3.1.1 lengths, *n*—straight pieces of the product.

3.1.1.1 specific, *n*—straight lengths that are uniform in length, as specified, and subject to established length tolerances.

3.1.2 tube, *seamless, n*—a tube produced with a continuous periphery in all stages of the operations.

3.1.2.1 tube, *condenser, n*—See tube, heat exchanger.

3.1.2.2 tube, *ferrule, n*—a tube from which metal rings or collars (ferrules) are made for use in installing condenser tubes.

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

3.2 Description of Term Specific to This Standard:

3.2.1 capable of—the test need not be performed by the producer of the material. However, should subsequent testing by the purchaser establish that the material does not meet these requirements, the material shall be subject to rejection.

**4. Ordering Information**

4.1 Orders for material under this specification shall include the following information:

4.1.1 Quantity of each size (number of pieces and number of feet),

4.1.2 Material (Section 1),

4.1.3 Form (tube or ferrule stock),

4.1.4 Temper (Section 7),

4.1.5 Whether tension test is required (Section 7),

4.1.6 Whether a pressure test is to be used instead of the eddy current test (see 13.1),

4.1.7 Dimensions, the diameter, wall thickness, whether minimum or nominal wall, and length (see Section 14),

4.1.8 Whether cut ends of the tube are to be deburred (see 15.1),

4.1.9 If the product is to be subsequently welded (see Table 1 and Footnotes G and H).

4.1.10 Specification number and year of issue,

4.1.11 Certification, if required (see 22.1), and

4.1.12 Mill test report, if required (see 24.1).

<sup>8</sup> Annual Book of ASTM Standards, Vol 03.03.

<sup>9</sup> Annual Book of ASTM Standards, Vol 01.01.

**TABLE 1 Chemical Requirements**

Copper or Copper Alloy UNS No.	Composition, %												
	Copper <sup>A</sup>	Tin	Aluminum	Nickel, incl Cobalt	Lead, max	Iron	Zinc	Manganese	Arsenic	Antimony	Phosphorus	Chromium	Other Named Elements
C10100	99.99 min <sup>B</sup>	...	...	...	0.0010	...	0.0001 max	...	...	...	0.0003 max	...	C
C10200 <sup>D</sup>	99.95 min	...	...	...	...	...	...	...	...	...	...	...	...
C10300	99.95 min <sup>E</sup>	...	...	...	...	...	...	...	...	...	0.001–0.005	...	...
C10800	99.95 min <sup>E</sup>	...	...	...	...	...	...	...	...	...	0.005–0.012	...	...
C12000	99.90 min	...	...	...	...	...	...	...	...	...	0.004–0.012	...	...
C12200	99.9 min	...	...	...	...	...	...	...	...	...	0.015–0.040	...	...
C14200	99.40 min	...	...	...	...	...	...	...	0.15–0.50	...	0.015–0.040	...	...
C19200	98.7 min	...	...	...	...	0.8–1.2	...	...	...	...	0.01–0.04	...	...
C23000	84.0–86.0	...	...	...	0.05	0.05 max	remainder	...	...	...	...	...	...
C28000	59.0–63.0	...	...	...	0.30	0.07 max	remainder	...	...	...	...	...	...
C44300	70.0–73.0	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	...	...	...
C44500	70.0–73.0	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	...	...	...	...
C61300	remainder	0.20–0.50	6.0–7.5	0.15 max	0.01	2.0–3.0	0.10 max	0.20 max	...	...	0.015 max	...	F,G
C61400	remainder	...	6.0–8.0	...	0.01	1.5–3.5	0.20 max	1.0 max	...	...	...	...	...
C68700	76.0–79.0	...	1.8–2.5	...	0.07	0.06 max	remainder	...	0.02–0.10	...	...	...	...
C70400	remainder	...	...	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 <sup>H</sup>	1.0–1.8	1.0 max <sup>H</sup>	1.0 max	...	...	H	...	H
C71000	remainder	...	...	19.0–23.0	0.05 <sup>H</sup>	0.50–1.0	1.0 max <sup>H</sup>	1.0 max	...	...	H	...	H
C71500	remainder	...	...	29.0–33.0	0.05 <sup>H</sup>	0.40–1.0	1.0 max <sup>H</sup>	1.0 max	...	...	H	...	H
C71640	remainder	...	...	29.0–32.0	0.05 <sup>H</sup>	1.7–2.3	1.0 max <sup>H</sup>	1.5–2.5	...	...	H	...	H
C72200	remainder	...	...	15.0–18.0	0.05 <sup>H</sup>	0.50–1.0	1.0 max <sup>H</sup>	1.0 max	...	...	H	0.30–0.70	H

<sup>A</sup>Copper (including silver).

<sup>B</sup>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.

<sup>C</sup>Impurity maximums in ppm for C10100 shall be: antimony 4, arsenic 5, bismuth 1, cadmium 1, iron 10, lead 5, manganese 0.5, mercury 1, nickel 10, oxygen 5, phosphorus 3, selenium 3, silver 25, sulfur 15, tellurium 2, tin 2, and zinc 1.

<sup>D</sup>Oxygen in C10200 shall be 10 ppm max.

<sup>E</sup>Copper plus sum of named elements shall be 99.95% min.

<sup>F</sup>Silicon shall be 0.10% max.

<sup>G</sup>When the product is for subsequent welding applications and is so specified by the purchaser, chromium shall be 0.05% max, cadmium 0.05% max, zinc 0.05% max, and zirconium 0.05% max.

<sup>H</sup>When the product is for subsequent welding applications, and so specified by the purchaser, zinc shall be 0.50% max, lead 0.02% max, phosphorus 0.02% max, sulfur 0.02% max, and carbon 0.05% max.

4.2 When material is purchased for agencies of the U.S. Government, this shall be specified in the contract or purchase order, and the material shall conform to the Supplementary Requirements as defined herein.

## 5. Materials and Manufacture

5.1 The material shall be of such quality and purity that the finished product shall have the properties and characteristics prescribed in this specification, and shall be cold worked to the specified size.

## 6. Chemical Composition

6.1 The material shall conform to the chemical requirements specified in Table 1.

6.2 These specification limits do not preclude the presence of other elements. Limits for unnamed elements may be established by agreement between manufacturer or supplier and purchaser.

6.2.1 *Copper Alloy UNS No. C19200*—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.

6.2.2 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 %.

6.2.2.1 When all the elements in Table 1 are analyzed, their sum shall be as shown in the following table.

Copper Alloy UNS No.	Copper Plus Named Elements, % min
C60800	99.5
C61300	99.8
C61400	99.5
C70400	99.5
C70600	99.5
C71000	99.5
C71500	99.5
C71640	99.5
C72200	99.8

6.2.3 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 %.

6.2.3.1 When all the elements in Table 1 are analyzed, their sum shall be as shown in the following table.

Copper Alloy UNS No.	Copper Plus Named Elements, % min
C23000	99.8
C28000	99.7
C44300	99.6
C44400	99.6
C44500	99.6
C68700	99.5

## 7. Temper

7.1 Tubes of Copper Alloy UNS Nos. C23000, C28000, C44300, C44400, C44500, C60800, C61300, C61400, C68700, and C71000 shall be furnished in the annealed (O) temper unless otherwise specified on the purchase order.

7.2 Tubes of Copper Alloy UNS Nos. C71500 and C71640 shall be supplied in one of the following tempers as specified: (1) annealed (O) or (2) drawn, stress-relieved (HR50).

7.3 Tubes of Copper Alloy UNS Nos. C10100, C10200, C10300, C10800, C12000, C12200, and C14200 shall be supplied in any one of the following tempers, one of which shall be specified: (1) light-drawn (H55), (2) hard-drawn (H80), or (3) hard-drawn, end-annealed.

7.4 Tubes of Copper Alloy UNS No. C19200 shall be supplied in any one of the following tempers, one of which shall be specified: (1) annealed (O), (2) light-drawn (H55), (3) hard-drawn (H80), or (4) hard-drawn, end-annealed.

7.5 Tubes of Copper Alloy UNS Nos. C70400, C70600, and C72200 may be supplied in either light-drawn (H55) or annealed (O) temper.

7.6 Tubes for ferrule stock shall be annealed sufficiently to be fully recrystallized.

NOTE 3—Some tubes, when subjected to aggressive environments, may be subjected to stress-corrosion cracking failure because of the residual tensile stresses developed in straightening. For such applications, it is suggested that tubes of Copper Alloy UNS Nos. C23000, C28000, C44300, C44400, C44500, C60800, C61300, C61400, and C68700 be subjected to a stress-relieving thermal treatment subsequent to straightening. If required, this must be specified on the purchase order or contract. Tolerances for roundness and length, and the condition of straightness, for tube so ordered, shall be to the requirements agreed upon between the manufacturer and the purchaser.

## 8. Mechanical Properties

8.1 Material specified to meet the requirements of the *ASME Boiler and Pressure Vessel Code* shall have tensile properties as prescribed in Table 2.

## 9. Microscopical Examination

9.1 Samples of annealed-temper tubes selected for test shall be subjected to microscopical examination at a magnification of 75 diameters and shall show uniform and complete recrystallization. Materials other than Copper Alloy UNS Nos. C19200 and C28000 shall have an average grain size within the limits of 0.010 to 0.045 mm. These requirements do not apply to tubes of light-drawn (H55), hard-drawn (H80), hard-drawn, end-annealed, or drawn, stress-relieved tempers (HR50).

## 10. Expansion Test

10.1 Tube specimens selected for test shall withstand the expansion shown in Table 3 when expanded in accordance with Test Method B 153. The expanded tube shall show no cracking or rupture visible to the unaided eye.

NOTE 4—The term “unaided eye” as used herein permits the use of corrective spectacles necessary to obtain normal vision.

10.2 Hard-drawn tubes not end annealed are not subject to this test. When tubes are specified end annealed, this test is required and shall be made on the annealed ends.

10.3 Tubes for ferrule stock are not subject to the expansion test.

## 11. Flattening Test

11.1 Test specimens at least 18 in. in length in the annealed condition shall be flattened on different elements throughout the lengths remaining after specimens for the expansion and metallographic tests have been taken. Each element shall be slowly flattened by one stroke of a press. The term “flattened”

**TABLE 2 Tensile Requirements**

Copper or Copper Alloy UNS No.	Temper Designation		Tensile Strength, min ksi <sup>A</sup>	Yield Strength, <sup>B</sup> min ksi <sup>A</sup>	Elongation in 2 in., min %
	Standard	Former			
C10100, C10200, C10300, C10800, C12000, C12200, C14200	H55	light-drawn	36	30	...
C10100, C10200, C10300, C10800, C12000, C12200, C14200	H80	hard-drawn	45	40	...
C19200	H55	light-drawn	40	35	...
C19200	H80	hard-drawn	48	43	...
C19200	O61	annealed	38	12	...
C23000	O61	annealed	40	12	...
C28000	O61	annealed	50	20	...
C44300, C44400, C44500	O61	annealed	45	15	...
C60800	O61	annealed	50	19	...
C61300, C61400	O61	annealed	70	30	...
C68700	O61	annealed	50	18	...
C70400	O61	annealed	38	12	...
C70400	H55	light-drawn	40	30	...
C70600	O61	annealed	40	15	...
C70600	H55	light-drawn	45	35	...
C71000	O61	annealed	45	16	...
C71500	O61	annealed	52	18	...
C71500: Wall thicknesses up to 0.048 in., incl	HR50	drawn, stress-relieved	72	50	12
Wall thicknesses over 0.048 in.	HR50	drawn, stress-relieved	72	50	15
C71640	O61	annealed	63	25	...
C71640	HR50	drawn, stress relieved	81	58	...
C72200	O61	annealed	45	16	...
C72200	H55	light-drawn	50	30	...

<sup>A</sup>ksi = 1000 psi.

<sup>B</sup>At 0.5 % extension under load.

**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	C19200	30
		C23000	20
		C28000	15
		C44300, C44400, C44500	20
		C60800	20
		C61300, C61400	20
		C68700	20
		C70400	30
		C70600	30
		C71000	30
		C71500	30
		C71640	30
		C72200	30
H55	light-drawn	C10100, C10200, C10300, C10800, C12000, C12200	20
		C14200	20
		C19200	20
		C70400	20
		C70600	20
		C72200	20
HR50	drawn, stress relieved	C71500	20
		C71640	20
...	hard-drawn, end annealed	C10100, C10200, C10300, C10800, C12000, C12200, C14200	30

shall be interpreted as follows: a micrometer caliper set at three times the wall thickness shall pass over the tube freely throughout the flattened part except at the points where the change in element of flattening takes place. The flattened elements shall not show cracking or rupture clearly visible to the unaided eye (Note 3). When tubes are specified in a temper other than annealed this test is required but shall be made on annealed specimens.

11.2 Tubes for ferrule stock are not subject to flattening test.

## 12. Mercurous Nitrate Test

12.1 **Warning**—Mercury is a definite health hazard and therefore equipment for the detection and removal of mercury vapor produced in volatilization is recommended. The use of rubber gloves in testing is advisable.

12.2 The test specimens, cut 6 in. in length, shall withstand without cracking, an immersion in the standard mercurous nitrate solution prescribed in Test Method B 154. The test



specimen shall include the finished tube end. The mercurous nitrate test is required only for Copper Alloy UNS Nos. C23000, C28000, C44300, C44400, C44500, C60800, C61300, C61400, and C68700.

### 13. Nondestructive Testing

13.1 Each tube shall be subjected to the eddy-current test in 13.1.1. Tubes may be tested in the final drawn, annealed, or heat-treated temper or in the drawn temper before the final anneal or heat treatment unless otherwise agreed upon by the supplier and the purchaser. The purchaser may specify either of the tests in 13.1.2 or 13.1.3 as an alternative to the eddy-current test.

13.1.1 *Eddy-Current Test*—Each tube shall be passed through an eddy-current testing unit adjusted to provide information on the suitability of the tube for the intended application. Testing shall follow the procedures of Practice E 243.

13.1.1.1 The depth of the round-bottom transverse notches and the diameters of the drilled holes in the calibrating tube used to adjust the sensitivity of the test unit are shown in Tables 4 and 5, respectively.

13.1.1.2 Tubes that do not actuate the signaling device of the eddy-current tester shall be considered to conform to the requirements of this test. Tubes causing irrelevant signals because of moisture, soil, and like effects may be reconditioned and retested. Such tubes, when retested to the original test parameters, shall be considered to conform if they do not cause output signals beyond the acceptable limits. Tubes causing irrelevant signals because of visible and identifiable handling marks may be retested by the hydrostatic test prescribed in 13.1.2, or the pneumatic test prescribed in 13.1.3. Tubes meeting requirements of either test shall be considered to conform if the tube dimensions are within the prescribed limits, unless otherwise agreed upon between the manufacturer and the purchaser.

13.1.2 *Hydrostatic Test*—Each tube shall stand, without showing evidence of leakage, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 7000 psi, determined by the following equation for thin hollow cylinders under tension. The tube need not be tested at a hydrostatic pressure of over 1000 psi unless so specified.

$$P \leq 2St / \sim D \geq 0.8t!$$

**TABLE 4 Notch Depth**

Tube Wall Thickness, in.	Tube Outside Diameter, in.		
	Over ¼ to ¾ , incl	Over ¾ to 1¼ , incl	Over 1¼ to 3½ , incl
Over 0.017–0.032	0.005	0.006	0.007
Incl 0.032–0.049	0.006	0.006	0.0075
Incl 0.049–0.083	0.007	0.0075	0.008
Incl 0.083–0.109	0.0075	0.0085	0.0095
Incl 0.109–0.120	0.009	0.009	0.011

**TABLE 5 Diameter of Drilled Holes**

Tube Outside Diameter, in.	Diameter of Drilled Holes, in.	Drill No.
¼ –¾ , incl	0.025	72
Over ¾ –1, incl	0.031	68
Over 1–1¼ , incl	0.036	64
Over 1¼ –1½ , incl	0.042	58
Over 1½ –1¾ , incl	0.046	56
Over 1¾ –2, incl	0.052	55

where:

$P$  = hydrostatic pressure, psig;

$t$  = thickness of tube wall, in.;

$D$  = outside diameter of the tube, in.; and

$S$  = allowable stress of the material, psi.

13.1.3 *Pneumatic Test*—Each tube shall be subjected to an internal air pressure of 60 psig, min, for 5 s without showing evidence of leakage. The test method used shall permit easy visual detection of any leakage, such as by having the tube under water or by the pressure differential method. Any evidence of leakage shall be cause for rejection.

### 14. Dimensions and Permissible Variations

14.1 *Diameter*—The outside of the tubes shall not vary from that specified by more than the amounts shown in Table 6 as measured by “go” and “no-go” ring gages.

14.2 *Wall Thickness Tolerances*:

14.2.1 *Tubes Ordered to Minimum Wall*—No tube wall at its thinnest point shall be less than the specified wall thickness. The maximum plus deviation from the specified wall at any point shall not exceed twice the values shown in Table 7.

14.2.2 *Tubes Ordered to Nominal Wall*—The maximum plus and minus deviation from the nominal wall at any point shall not exceed the values shown in Table 7.

14.3 *Length*—The length of the tubes shall not be less than that specified when measured at a temperature of 20°C, but may exceed the specified value by the amounts given in Table 8.

14.4 *Squareness of Cut*—The departure from squareness of the end of the tube shall not exceed the following:

Tube, Outside Diameter, in.	Tolerance
Up to ¾ , incl	0.010 in.
Over ¾	0.016 in./in. of diameter

14.5 For the purpose of determining conformance with the dimensional requirements prescribed in this specification, any measured value outside the specified limiting values for any dimensions may be cause for rejection.

### 15. Workmanship, Finish and Appearance

15.1 Roundness, straightness, uniformity of the wall thickness, and inner and outer surface 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.

**TABLE 6 Diameter Tolerances**

Outside Diameter, in.	Wall Thickness, in.				
	0.020 <sup>A</sup>	0.022	0.025	0.028	0.032
			0.035	0.042	0.049 and Over
Diameter Tolerance, Plus and Minus, in.					
Up to 0.500, incl	0.003	0.0025	0.0025	0.0025	0.0025
Over 0.500–0.740, incl	0.0040	0.004	0.004	0.0035	0.003
Over 0.740–1.000, incl	0.0060	0.006	0.005	0.0045	0.004
Over 1.000–1.250, incl	...	0.009	0.008	0.006	0.0045
Over 1.250–1.375, incl	...	...	...	0.008	0.005
Over 1.375–2.000, incl	...	...	...	...	0.006
Over 2.000–3.125, incl	...	...	...	...	0.0065

<sup>A</sup>Tolerances in this column are applicable to light drawn and drawn tempers only. Tolerances for annealed tempers shall be as agreed upon between the manufacturer and the purchaser.

**TABLE 7 Wall Thickness Tolerances, Plus and Minus in.**

Wall Thickness, in.	Outside Diameter, in.			
	Over 1/8 to 5/16, incl	Over 5/16 to 1, incl	Over 1 to 2, incl	Over 2 to 3.125, incl
0.020, incl to 0.032	0.003	0.003	...	...
0.032, incl to 0.035	0.003	0.003	0.004	...
0.035, incl to 0.058	0.004	0.0045	0.0045	0.005
0.058, incl to 0.083	0.0045	0.005	0.005	0.0055
0.083, incl to 0.120	0.005	0.0065	0.0065	0.0065
0.120, incl to 0.134	0.007	0.007	0.0075	0.008

**TABLE 8 Length Tolerances**

Specified Length, ft	Tolerance, all Plus, in.
Up to 15	3/32
Over 15–20, incl	1/8
Over 20–30, incl	5/32
Over 30–60, incl	3/8
Over 60–100, incl <sup>A</sup>	1/2

<sup>A</sup>Condenser tubes in lengths over 100 ft are not in present demand. Tolerance values for the lengths will be developed as experience dictates. Tolerance values for lengths in wall thicknesses of 0.020, incl. to 0.032 shall be as agreed upon between the manufacturer or supplier and the purchaser.

15.2 Annealed-temper or stress-relieved tubes shall be clean and smooth but may have a superficial, dull iridescent film on both the inside and the outside surface. Drawn-temper tubes shall be clean and smooth, but may have a superficial film of drawing lubricant on the surfaces.

## 16. Sampling

16.1 *Sampling*—The lot size, portion size, and selection of sample pieces shall be as follows:

16.1.1 *Lot Size*—600 tubes or 10 000 lb or fraction of either, whichever constitutes the greater weight.

16.1.2 *Portion Size*—Sample pieces from two individual lengths of finished product.

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

## 17. Number of Tests and Retests

17.1 *Chemical Analysis*—Samples for chemical analysis shall be taken in accordance with Practice E 255. Drillings,

millings, and so forth shall be taken in approximately equal weight from each of the sample pieces selected in accordance with 16.1.2 and combined into one composite sample. The minimum weight of the composite sample that is to be divided into three equal parts shall be 150 g.

17.1.1 Instead of sampling in accordance with Practice E 255, the manufacturer shall have the option of determining conformance to chemical composition as follows: Conformance shall be determined by the manufacturer by analyzing samples taken at the time the castings are poured or samples taken from the semifinished product. If the manufacturer determines the chemical composition of the material during the course of manufacture, he shall not be required to sample and analyze the finished product. The number of samples taken for determination of chemical composition shall be as follows:

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

17.1.1.2 When samples are taken from the semifinished product, a sample shall be taken to represent each 10 000 lb or fraction thereof, except that not more than one sample shall be required per piece.

17.1.1.3 Because of 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.

17.1.1.4 In the event that heat identification or traceability is required, the purchaser shall specify the details desired.

17.2 *Other Tests*—For tests specified in Sections 8-12 inclusive, specimens shall be taken from each of the pieces selected in accordance with 16.1.2.

17.3 If any test specimen representing a lot fails to conform to the requirements of Sections 6-12, two additional specimens, at the option of the manufacturer, may be taken as before, and submitted for check analysis or subjected to any tests in which the original specimen failed, but each of these specimens shall conform to the requirements specified.

## 18. Test Methods

18.1 The properties and chemical compositions enumerated in this specification shall, in case of disagreement, be determined in accordance with the following ASTM methods:

Test	ASTM Designation
Chemical analysis	B 170, <sup>A</sup> E 53, E 54, E 62, E 75, E 478
Grain size	E 112
Expansion (pin test)	B 153
Mercurous nitrate	B 154
Tension	E 8
Nondestructive test	E 243

<sup>A</sup>Reference to Specification B 170 is to the suggested chemical methods in the annex thereof. When E-1 Committee has tested and published methods for assaying the low-level impurities in copper, the Specification B 170 annex will be eliminated.

18.2 The surface of the test specimen for microscopical examination shall approximate a radial longitudinal section of the tube.

18.3 Tubes selected for test shall be subjected to the tension test which shall, in case of disagreement, be made in accordance with Test Methods E 8. Tension test specimen shall be of the full section of the tube and shall conform to the requirements of the section, Specimens for Pipe and Tube, of Test Methods E 8, unless the limitations of the testing machine preclude the use of such a specimen. Test specimens conforming to Type No. 1 of Fig. 13, Tension Test Specimens for Large-Diameter Tubular Products, of Test Methods E 8, may be used when a full section specimen cannot be tested.

18.4 Whenever tension test results are obtained from both full-size and machined specimens and they differ, the results obtained from full-size test specimens shall be used to determine conformance to the specification requirements.

18.5 Tension test results on material covered by this specification are not seriously affected by variations in speed of testing. A considerable range of testing speed is permissible; however, the range of stressing to the yield strength should not exceed 100 ksi/min. Above the yield strength the movement per minute of the testing machine head under load should not exceed 0.5 in./in. of gage length (or distance between grips for full-section specimens).

## 19. Significance of Numerical Limits

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

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, for over 10 to 100 ksi, incl
Elongation	nearest 1 %
Grain size	nearest multiple of 0.005 mm

## 20. Inspection

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

20.2 If in addition the purchaser elects to perform his own inspection, the manufacturer shall afford the inspector all reasonable facilities to satisfy him that the tubes are being furnished in accordance with this specification. All tests (except check analysis) and inspection shall be made at the place of manufacture before shipment, unless otherwise specified, and shall be so conducted as not to interfere with the operation of the works. When automated finishing and inspection equipment is available at a facility, purchaser and supplier may by mutual agreement accomplish the final inspection simultaneously.

## 21. Rejection and Rehearing

21.1 Material that fails to conform to the requirements of this specification when inspected or tested by the purchaser or his agent may be rejected. Rejection should be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the manufacturer or supplier may make claim for a rehearing.

## 22. Certification

22.1 When specified on the purchase order, the manufacturer shall furnish to the purchaser a certificate stating that each lot has been sampled, tested, and inspected in accordance with this specification and has met the requirements. When material is specified to meet the requirements of *ASME Boiler and Pressure Vessel Code*, the certification requirements are mandatory.

## 23. Packaging and Package Marking

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

23.2 Each shipping unit shall be legibly marked with the purchase order number, metal or alloy designation, temper, size, shape, total length or piece count, or both, and name of supplier. The specification number shall be shown, when specified.

## 24. Mill Test Report

24.1 When specified on the purchase order, the manufacturer shall furnish to the purchaser a test report showing results of tests required by the specification.

## 25. Keywords

25.1 condenser tube; copper; copper alloys; evaporator; ferrule stock; heat exchanger; seamless tube



## 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. 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 *Federal Standards*:<sup>10</sup>

Fed. Std. No. 102 Preservation, Packaging and Packing Levels

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

Fed. Std. No. 185 Identification Marking of Copper and Copper-Base Alloy Mill Products

S1.1.2 *Military Standard*:<sup>10</sup>

MIL-STD-129 Marking for Shipment and Storage

S1.1.3 *Military Specification*:<sup>10</sup>

MIL-C-3993 Packaging of Copper and Copper-Base Alloy Mill Products

### S2. Quality Assurance

S2.1 *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the

purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections or tests set forth when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.

### S3. Identification Marking

S3.1 All material shall be properly marked for identification in accordance with Fed. Std. No. 185 except that the ASTM specification number and the alloy number shall be used.

### S4. Preparation for Delivery

S4.1 *Preservation, Packaging, Packing:*

S4.1.1 *Military Agencies*—The material shall be separated by size, composition, grade or class and shall be preserved and packaged, Level A or C, packed Level A, B, or C as specified in the contract or purchase order, in accordance with the requirements of MIL-C-3993.

S4.1.2 *Civil Agencies*—The requirements of Fed. Std. No. 102 shall be referenced for definitions of the various levels of packaging protection.

S4.2 *Marking:*

S4.2.1 *Military Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with MIL-STD-129.

S4.2.2 *Civil Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with Fed. Std. No. 123.

<sup>10</sup> Available from Standardization Documents Order Desk, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094. Attn: NPODS.

## APPENDIX

(Nonmandatory Information)

### X1. DENSITY OF COPPER AND COPPER ALLOYS

X1.1 The densities of the alloys covered by this specification are given in Table X1.1.

**TABLE X1.1 Densities**

Copper or Copper Alloy UNS No.	Density, lb/in. <sup>3</sup>
C10100, C10200, C10300, C10800, C12000, C12200, C14200	0.323
C19200	0.320
C23000	0.316
C28000	0.303
C44300, C44400, C44500	0.308
C60800	0.295
C61300, C61400	0.285
C68700	0.301
C70400	0.323
C70600	0.323
C71000	0.323
C71500	0.323
C71640	0.323
C72200	0.323

## SUMMARY OF CHANGES

Committee B05 has identified the location of selected changes to this standard since the last issue of B 111 – 95 that may impact the use of this standard.

(I) Tables 6 and 7 were modified to include tolerances for diameters over 2 in. up to and including 3.125 in.

*ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.*

*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.*

*This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org).*