Designation: B 111M – 98 (Reapproved 2004)

METRIC

Standard Specification for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock [Metric][1]

This standard is issued under the fixed designation B 111M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

1. Scope*

1.1 This specification[2] covers seamless tube and ferrule stock of copper and various copper alloys up to 79 mm, 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:[3]

Copper or Copper Alloy UNS No.[3]	Previously Used Designation	Type of Metal
C10100	OFE	Oxygen-free electronic
C10200	OF[A]	Oxygen-free without residual deoxidants
C10300	. . .	Oxygen-free, extra low phosphorus
C10800	. . .	Oxygen-free, low phosphorus
C12000	DLP[A]	Phosphorized, low residual phosphorus
C12200	DHP[A]	Phosphorized, high residual phosphorus
C14200	DPA[A]	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	. . .	. . .

[A] Designations listed in Classification B 224.

NOTE 1—This specification is the metric companion to Specification B 111.

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:* [4]

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

B 154 Test Method for Mercurous Nitrate Test for Copper and Copper Alloys

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

B 224 Classification of Coppers

E 8 Test Methods for Tension Testing of Metallic Materials

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

E 53 Test Methods for Determination of Copper in Unalloyed Copper by Gravimetry

E 54 Test Methods for Chemical Analysis of Special Brasses and Bronzes[5]

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

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

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[2] For *ASME Boiler and Pressure Vessel Code* applications, see related Specification SB-111 in Section 11 of the code.

[3] 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.

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

[5] Withdrawn.

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

TABLE 1 Chemical Requirements

Copper or Copper Alloy UNS No.	Composition, %												
	Copper[A]	Tin	Alumi-num	Nickel, incl Cobalt	Lead, max	Iron	Zinc	Man-ganese	Arsenic	Antimony	Phosphorus	Chromium	Other Named Elements
C10100	99.99 min[B]	. . .	. . .	. . .	0.0010	. . .	0.0001 max	. . .	. . .	. . .	0.0003 max	. . .	[C]
C10200[D]	99.95 min	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
C10300	99.95 min[E]	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.001–0.005	. . .	. . .
C10800	99.95 min[E]	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	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[H]	1.0–1.8	1.0 max[H]	1.0 max	. . .	. . .	. . .		[H]
C71000	remainder	. . .	. . .	19.0–23.0	0.05[H]	0.50–1.0	1.0 max[H]	1.0 max	. . .	. . .		. . .	[H]
C71500	remainder	. . .	. . .	29.0–33.0	0.05[H]	0.40–1.0	1.0 max[H]	1.0 max	. . .	. . .		. . .	[H]
C71640	remainder	. . .	. . .	29.0–32.0	0.05[H]	1.7–2.3	1.0 max[H]	1.5–2.5	. . .	. . .		. . .	[H]
C72200	remainder	. . .	. . .	15.0–18.0	0.05[H]	0.50–1.0	1.0 max[H]	1.0 max	. . .	. . .		0.30–0.70	[H]

[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 silver, lead, tin, bismuth, arsenic, antimony, iron, nickel, mercury, zinc, phosphorus, selenium, tellurium, manganese, cadmium, and oxygen present in the sample.

[C] Impurity maximums in ppm for C101000 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.

[D] Oxygen in C10200 shall be 10 ppm max.

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

[F] Silicon shall be 0.10 % max.

[G] 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.

[H] 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.

E 75 Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys

E 112 Test Methods for Determining Average Grain Size

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

E 255 Practice for Sampling Copper and Copper Alloys for the Determination of Chemical Composition

E 478 Test Methods for Chemical Analysis of Copper Alloys

E 527 Practice for Numbering Metals and Alloys (UNS)

3. Terminology

3.1 *Definitions:*

3.1.1 *lengths*—straight pieces of the product.

3.1.1.1 *specific*—straight lengths that are uniform in collars (ferrules) are made for use in installing condenser tubes.

3.1.2 *lengths*—straight pieces of the product.

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

3.2 *Definition 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 metres),

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).

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 2 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 450 mm 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” 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

TABLE 2 Tensile Requirements

Copper or Copper Alloy UNS No.	Temper Designation		Tensile Strength, min	Yield Strength,[A] min	Elongation in 50 mm, min, %
	Standard	Former	MPa	MPa	
C10100, C10200, C10300, C10800, C12000, C12200, C14200	H55	light-drawn	250	205	. . .
C10100, C10200, C10300, C10800, C12000, C12200, C14200	H80	hard-drawn	310	275	. . .
C19200	H55	light-drawn	275	240	. . .
C19200	H80	hard-drawn	330	295	. . .
C19200	O61	annealed	260	85	. . .
C23000	O61	annealed	275	85	. . .
C28000	O61	annealed	345	140	. . .
C44300, C44400, C44500	O61	annealed	310	105	. . .
C60800	O61	annealed	345	130	. . .
C61300, C61400	O61	annealed	480	205	. . .
C68700	O61	annealed	345	125	. . .
C70400	O61	annealed	260	85	. . .
C70400	H55	light-drawn	275	205	. . .
C70600	O61	annealed	275	105	. . .
C70600	H55	light-drawn	310	240	. . .
C71000	O61	annealed	310	110	. . .
C71500	O61	annealed	360	125	. . .
C71500:					
Wall thicknesses up to 1.21 mm, incl	HR50	drawn, stress-relieved	495	345	12
Wall thicknesses over 1.21 mm	HR50	drawn, stress-relieved	495	345	15
C71640	O61	annealed	435	170	. . .
C71640	HR50	drawn, stress-relieved	560	400	. . .
C72200	O61	annealed	310	110	. . .
C72200	H55	light-drawn	345	310	. . .

[A] At 0.5 % extension under load.

visible to the unaided eye (Note 4). 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 150 mm 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 6 and 7, respectively. The notch depth shall not vary from the prescribed by more than ±0.015 mm when measured at the center of the notch, and the diameter of the drilled hole shall not vary by more than +0.025, −0.005 mm of the hole diameter specified.

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 48 MPa,

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	20
		C10800, C12000, C12200	20
		C14200	20
		C19200	20
		C70400	20
		C70600	20
		C72200	
HR50	drawn, stress-relieved	C71500	20
		C71640	20
. . .	hard-drawn, end-annealed	C10100, C10200, C10300, C10800, C12000, C12200, C14200	30

TABLE 4 Notch Depth

Tube Wall Thickness, mm	Tube Outside Diameter, mm		
	Over 6 to 19, incl	Over 19 to 32, incl	Over 32 to 79, incl
Over 0.43–0.81	0.13	0.15	0.18
Incl 0.81–1.3[A]	0.15	0.15	0.19
Incl 1.3–2.1	0.18	0.19	0.20
Incl 2.1–2.8	0.19	0.22	0.24
Incl 2.8–3.0	0.23	0.23	0.28

[A] Editorially corrected.

determined by the following equation for thin hollow cylinders under tension. The tube need not be tested at a hydrostatic pressure of over 6.9 MPa unless so specified.

$$P = 2St/(D - 0.8t)$$

where:

P = hydrostatic pressure, MPa;
t = thickness of tube wall, mm;
D = outside diameter of the tube, mm; and
S = allowable stress of the material, MPa.

13.1.3 *Pneumatic Test*—Each tube shall be subjected to an internal air pressure of 400 kPa, 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.

TABLE 5 Diameter of Drilled Holes

Tube Outside Diameter	Diameter of Drilled Holes	Drill No.
mm	mm	
6.0–19.0, incl	0.635	72
Over 19.0–25.4, incl	0.785	68
Over 25.4–31.8, incl	0.915	64
Over 31.8–38.1, incl	1.07	58
Over 38.1–44.4, incl	1.17	56
Over 44.4–50.8, incl	1.32	55

TABLE 6 Wall Thickness Tolerances, Plus and Minus, mm

Wall Thickness, mm	Outside Diameter, mm		
	Over 12 to 25, incl	Over 25 to 50, incl	Over 50 to 79, incl
0.506, incl to 0.813[A]	0.076	. . .	. . .
0.813, incl to 0.889	0.076	0.10	. . .
0.889, incl to 1.47	0.11	0.11	0.13
1.47, incl to 2.11	0.13	0.13	0.14
2.11, incl to 3.05	0.17	0.17	0.17
3.05, incl to 3.40	0.18	0.19	0.20

[A] Editorially corrected.

TABLE 7 Length Tolerances

Specified Length, mm	Tolerance, all Plus, mm
Up to 4500	2.4
Over 4500–6000, incl	3.2
Over 6000–10 000, incl	4.0
Over 10 000–18 000, incl	9.5
Over 18 000–30 000, incl[A]	13

[A] Condenser tubes in lengths over 30 000 mm are not in present demand. Tolerance values for the lengths will be developed as experience dictates. Tolerance values for lengths in wall thicknesses of 0.508, inclusive to 0.813 shall be as agreed upon between the manufacturer or supplier and the purchaser.

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 8 as measured by "go" and "no-go" ring gages.

14.2 *Wall Thickness Tolerances*:

TABLE 8 Diameter Tolerances

Outside Diameter, mm	Wall Thickness, mm				
	0.508[A] 0.559 0.635 0.711	0.813	0.889	1.07	1.24 and Over
	Diameter Tolerance, Plus and Minus, mm				
Up to 12, incl	0.076	0.064	0.064	0.064	0.064
Over 12–18, incl	0.10	0.10	0.10	0.089	0.076
Over 18–25, incl	0.15	0.15	0.13	0.11	0.10
Over 25–35, incl	. . .	. . .	. . .	0.20	0.13
Over 35–50, incl	. . .	. . .	. . .	. . .	0.15
Over 50–79, incl	. . .	. . .	. . .	. . .	0.17

[A] 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.

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 6.

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 6.

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 7.

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

Tube, Outside Diameter, mm	Tolerance
Up to 15.9, incl	0.25 mm
Over 15.9	0.016 mm/mm 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 dimension 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.

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 4550 kg 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, etc., 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 semi-finished product, a sample shall be taken to represent each 4550 kg 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	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

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. The 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 from 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 690 MPa/min. Above the yield strength, the movement per minute of the testing machine head under load should not exceed 0.5 mm/mm 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 5 MPa
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 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 se parated 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.

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:*

Fed. Std. No. 102 Preservation, Packaging and Packing Levels[6]

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[6]

Fed. Std. No. 185 Identification Marking of Copper and Copper-Base Alloy Mill Products[6]

S1.1.2 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[6]

S1.1.3 *Military Specification:*[6]

MIL-C-3993 Packaging of Copper and Copper-Base Alloy Mill Products[6]

S2. Quality Assurance

S2.1 *Responsibility for Inspection:*

S2.1.1 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

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

inspections or tests set forth when such inspections and tests are deemed necessary to ensure 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.

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, g/cm^3
C10100, C10200, C10300, C10800, C12000, C12200, C14200	8.94
C19200	8.86
C23000	8.75
C28000	8.39
C44300, C44400, C44500	8.53
C60800	8.17
C61300, C61400	7.89
C68700	8.33
C70400	8.94
C70600	8.94
C71000	8.94
C71500	8.94
C71640	8.94
C72200	8.94

SUMMARY OF CHANGES

Committee B05 has identified the location of selected changes to this standard since the last issue B 111M – 93 that may impact the use of this standard.

(*1*) Tables 6 and 8 were modified to include tolerances for diameters over 50 mm up to and including 79 mm.