

# ASTM B111 / ASME SB111

## Standard Specification for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock

This specification establishes the requirements for seamless tube and ferrule stock of copper and various copper alloys up to 31/8 in. [80 mm] inclusive, in diameter, for use in surface condensers, evaporators, and heat exchangers.

### A. Chemical Composition :-

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

Table 1

Copper or Copper Alloy UNS No.	Copper <sup>A</sup>	Tin	Aluminum	Nickel, incl. Cobalt	Lead, max	Iron	Zinc	Manganese	Arsenic	Phosphorus	Other Elements
C10100	99.99 min <sup>B</sup>	0.002 max	...	0.0010 max	0.0005 max	0.0010 max	0.0001 max	0.00005 max	0.0005 max	0.0003 max	Sb 0.0004 max; Cr 0.0001 max; <sup>C</sup>
C10200 <sup>D</sup>	99.95 min	...	...	...	...	...	...	...	...	...	<sup>D</sup>
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	98.5 min	...	...	...	...	0.8–12	0.20 max	...	...	0.01–0.04	...
C23000	84.0–86.0	...	...	...	0.05	0.05 max	remainder	...	...	...	...
C28000	59.0–63.0	...	...	...	0.09	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	...	...	...	Sb 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	...	0.015 max	...
C68700	76.0–79.0	...	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	...	...	...
C70600	remainder	...	...	9.0–11.0	0.05	1.0–1.8	1.0 max	1.0 max	...	...	...
C70620	86.5 min	...	...	9.0–11.0	0.02	1.0–1.8	0.50 max	1.0 max	...	0.02max	C 0.05 max; S 0.02max
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	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	C 0.05 max; S 0.02max
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	C 0.06 max; S 0.03 max <sup>H</sup>
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	Si 0.03 max; Ti 0.03 max <sup>H</sup> ; Cr 0.30–0.70

<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.

**B. Mechanical Properties :-**

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

**Table 2**

Copper or Copper Alloy UNS No.	Temper Designation		Tensile Strength, min ksi <sup>A</sup> [Mpa]	Yield Strength, <sup>B</sup> min ksi <sup>A</sup> [Mpa]	Elongation in 2 in. [50 mm], min %
	Standard	Former			
C10100, C10200, C10300, C10800, C12000, C12200, C14200	H55	light-drawn	36 [250]	30 [205]	...
C10100, C10200, C10300, C10800, C12000, C12200, C14200	H80	hard-drawn	45 [310]	40 [275]	...
C19200	H55	light-drawn	40 [275]	35 [240]	...
C19200	H80	hard-drawn	48 [330]	43 [295]	...
C19200	O61	annealed	38 [260]	12 [85]	...
C23000	O61	annealed	40 [275]	12 [85]	...
C28000	O61	annealed	50 [345]	20 [140]	...
C44300, C44400, C44500.	O61	annealed	45 [310]	15 [105]	...
C60800	O61	annealed	50 [345]	19 [130]	...
C61300, C61400	O61	annealed	70 [480]	30 [205]	...
C68700	O61	annealed	50 [345]	18 [125]	...
C70400	O61	annealed	38 [260]	12 [85]	...
C70400	H55	light-drawn	40 [275]	30 [205]	...
C70600, C70620	O61	annealed	40 [275]	15 [105]	...
C70600, C70620	H55	light-drawn	45 [310]	35 [240]	...
C71000	O61	annealed	45 [310]	16 [110]	...
C71500, C71520	O61	annealed	52 [360]	18 [125]	...
C71500, C71520					
Wall thicknesses up to 0.048 in. [1.2 mm] , incl	HR50	drawn and stress-relieved	72 [495]	50 [345]	12
Wall thicknesses over 0.048 in. [1.2 mm]	HR50	drawn and stress-relieved	72 [495]	50 [345]	15
C71640	O61	annealed	63 [435]	25 [170]	...
C71640	HR50	drawn and stress-relieved	81 [560]	58 [400]	...
C72200	O61	annealed	45 [310]	16 [110]	...
C72200	H55	light-drawn	50 [345]	45 [310]	...

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

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

**C. Grain Size for Annealed Tempers :-**

1. Grain size shall be a standard requirement for all product in the annealed (O61) temper.
2. Samples of annealed-temper tubes selected for test shall be subjected to microscopical examination per Test Methods E112 at a magnification of 75 diameters and shall show uniform and complete recrystallization.
3. Products other than of Copper Alloy UNS Nos. C19200 and C28000 shall have an average grain size within the limits of 0.010 to 0.045 mm.

**D. Expansion Test :-**

1. Tube specimens selected for test shall withstand the expansion shown in Table 3 when expanded in accordance with Test Method B153.

**Table 3**

Temper Designation		Copper or Copper Alloy UNS No.	Expansion of Tube Outside Diameter, in Percent of Original Standard Former 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, C70620	30		
		C71000	30		
		C71500, C71520	30		
		C71640	30		
		C72200	30		
		H55	light-drawn	C10100, C10200, C10300, C10800, C12000, C12200	20
				C14200	20
C19200	20				
C70400	20				
C70600, C70620	20				
C72200	20				
HR50	drawn and stress relieved	C71500, C71520	20		
		C71640	20		
...	hard-drawn and end annealed	C10100, C10200, C10300, C10800, C12000, C12200, C14200	30		

**E. Flattening Test :-**

**F. Residual Stress Test :-**

1. A residual stress test, when specified in the purchase order, is required only for Copper Alloy UNS Nos. C23000, C28000, C44300, C44400, C44500, C60800, C61 300, C61400, and C68700 and when not supplied in an annealed temper.
2. Unless otherwise specified, the producer shall have the option of testing the product to either the mercurous nitrate test, Test Method B154, or the ammonia vapor test, Test Method B858.

**G. Non-destructive Testing :-**

1. Eddy-Current Test:-
  - i. Testing shall follow the procedures of Practice E243.
  - ii. 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 Table 4, and Table 5, respectively.
  - iii. Tubes causing irrelevant signals because of visible and identifiable handling marks may be retested by the hydrostatic test or the pneumatic test.

**Table 4: Notch Depth**

Tube Wall Thickness, in [mm]	Tube Outside Diameter, in.[mm]		
	Over 1/4 to 3/4 [6 to 19], incl	Over 3/4 to 1(1/4) [19 to 32], incl	Over 1(1/4) to 3(1/8) [32 to 80], incl
Over 0.017–0.032 [0.4–0.8]	0.005 [0.13]	0.006 [0.15]	0.007 [0.18]
Incl 0.032–0.049 [0.8–1.3]	0.006 [0.15]	0.006 [0.15]	0.0075 [0.19]
Incl 0.049–0.083 [1.3–2.1]	0.007 [0.18]	0.0075 [0.19]	0.008 [0.20]
Incl 0.083–0.109 [2.1–2.8]	0.0075 [0.19]	0.0085 [0.22]	0.0095 [0.24]
Incl 0.109–0.120 [2.8–3.0]	0.009 [0.23]	0.009 [0.23]	0.011 [0.28]

**Table 5: Diameter of Drilled Holes**

Tube Outside Diameter, in. [mm]	Diameter of Drilled Holes, in. [mm]	Drill No.
1/4–3/4 [6.0–19.0], incl	0.025 [0.65]	72
Over 3/4–1 [19.0–25.4], incl	0.031 [0.8]	68
Over 1–1(1/4) [25.4–31.8], incl	0.036 [0.92]	64
Over 1(1/4)–1(1/2) [31.8–38.1], incl	0.042 [1.1]	58
Over 1(1/2)–1(3/4) [38.1–44.4], incl	0.046 [1.2]	56
Over 1(3/4)–2 [44.4–50.8], incl	0.052 [1.3]	55

2. Hydrostatic Test:-

- i. 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 [48 MPa] as 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 [7.0 MPa] unless so specified.

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

where: P = hydrostatic pressure, psig [MPa] ;  
t = thickness of tube wall, in. [mm] ;  
D = outside diameter of the tube, in. [mm] ; and  
S = allowable stress of the material, psi [MPa] .

3. Pneumatic Test :-

- i. Each tube shall be subjected to an internal air pressure of 60 psig [400 kPa] , min, for 5 s without showing evidence of leakage.

**H. Test Methods :-**

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

<u>Test</u>	<u>ASTM Designation</u>
Chemical analysis	B170, AE53, E54, E62, E75, E76, E478
Grain size	E112
Expansion (pin test)	B153
Mercurous nitrate	B154
Tension	E8
Non-destructive test	E243

*A Reference to Specification B170 is to the suggested chemical methods in the annex thereof. When E01 Committee has tested and published methods for assaying the low-level impurities in copper, the Specification B170 annex will be eliminated.*

<b>Densities</b>		
<b>Copper or Copper Alloy UNS No.</b>	<b>Density, lb/in.3</b>	<b>Density, g/cm3</b>
C10100, C10200, C10300, C10800, C12000, C12200, C14200	0.323	8.94
C19200	0.32	8.86
C23000	0.316	8.75
C28000	0.303	8.39
C44300, C44400, C44500	0.308	8.53
C60800	0.295	8.17
C61300, C61400	0.285	7.89
C68700	0.301	8.33
C70400	0.323	8.94
C70600, C70620	0.323	8.94
C71000	0.323	8.94
C71500, C71520	0.323	8.94
C71640	0.323	8.94
C72200	0.323	8.94

### Related Keywords

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