

ASTM B543 / ASME SB543

Standard Specification for Welded Copper and Copper-Alloy Heat Exchanger Tube

This specification established the requirements for welded tube of copper and various copper alloys up to 3(1/8) in., inclusive, in diameter, for use in surface condensers, evaporators, heat exchangers, and general engineering applications.

A. Chemical Composition :-

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

Table 1

UNS No.	C ^A	Ni incl, Co	Pb, max	Fe	Zn	Mn	Al	P	Sn	Sb	As	Other Elements
C10800	99.95 ^B min	...	...	...	...	...	...	0.005–0.012	...	...	...	...
C12200	99.9min	...	...	...	...	...	...	0.015–0.040	...	...	...	...
C19400	97.0 ^C min	...	0.03	2.1–2.6	0.05–0.20	...	...	0.015–0.15	...	...	...	...
C23000	84.0–86.0	...	0.05	0.05max	remainder	...	...	...	...	...	...	...
C44300	70.0–73.0 ^D	...	0.07	0.06max	remainder	...	...	...	0.8–1.2	...	0.02–0.06	...
C44400	70.0–73.0 ^D	...	0.07	0.06max	remainder	...	...	...	0.8–1.2	0.02–0.10	...	...
C44500	70.0–73.0 ^D	...	0.07	0.06max	remainder	...	...	0.02–0.10	0.8–1.2	...	...	...
C68700	76.0–79.0 ^{AE}	...	0.07	0.06max	remainder	...	1.8–2.5	...	...	...	0.02–0.06	...
C70400	remainder ^{AE}	4.8–6.2	0.05	1.3–1.7	1.0max	0.30–0.8	...	...	...	...	...	...
C70600	remainder ^{AE}	9.0–11.0	0.05	1.0–1.8	1.0max	1.0max	...	...	...	...	...	...
C70620	86.5min ^{AE}	9.0–11.0	0.02	1.0–1.8	0.50max	1.0	...	0.02max	...	...	...	C 0.05max S 0.02max
C71000	remainder ^{AEF}	19.0–23.0	0.05	0.50–1.0	1.0max ^F	1.0max	...	F	...	...	...	F
C71500	remainder ^{AE}	29.0–33.0	0.05	0.40–1.0	1.0max	1.0max	...	...	...	...	...	...

C71520	65.0min ^{AE}	29.0–33.0	0.02	0.40–1.0	0.50max	1.0max	...	0.02max	...	...	...	C 0.05max S 0.02max
C71640	remainder ^F	29.0–32.0	0.05 ^F	1.7–2.3	1.0max ^F	1.5–2.5	...	^F	...	...	...	C.06 ^F max, S.03max
C72200	remainder ^{AFCG}	15.0–18.0	0.05 ^F	0.50–1.0	1.0max ^F	1.0max	...	^F	...	...	...	^F Si.03 max, Ti.03 max ^G

^A Silver counting as copper.

^B Copper + silver + phosphorus.

^C Cu + Sum of Named Elements, 99.8 % min.

^D For tubular products, the minimum Sn content may be 0.9 %

^E Cu + Sum of Named Elements, 99.5 % min.

^F 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, sulphur 0.02 % max, and carbon 0.05 % max.

^G Chromium 0.30 to 0.7

B. Temper :-

1. Tube tempers shall be designated as follows:
 - i. Welded and annealed WO61.
 - ii. Welded and light cold worked WC55.
2. Tubes of Copper Alloy UNS Nos. C23000, C44300, C44400, C44500, and C68700 shall be furnished in the annealed temper or the stress relieved condition as specified in the purchase order unless otherwise agreed upon between the purchaser and the manufacturer or supplier.
3. Tubes of Copper Alloy UNS Nos. C12200, C19400, C70400, C70600, C70620, C71 000, C71 500, C71 520, C71640, and C72200 are normally supplied in the temper specified in the purchase order without stress relief treatment.

C. Grain Size for Annealed Tempers :-

1. Samples of annealed temper tubes shall be examined at a magnification of 75 diameters.

D. Mechanical Property Requirements :-

1. Tensile Strength and Yield Strength Requirements :- Product furnished under this specification shall conform to the tensile and yield strength requirements prescribed in Table 2 when tested in accordance with Test Method E8.

Table 2

Copper or Copper Alloy UNS No.	Temper		Tensile Strength, min, ksi (MPA)	Yield Strength at 0.5 % Extension Under Load, min, Designation Name ksi (MPA)
	Designation	Name		
C10800, C12200	W061	annealed	30 (205)	9 (60) ^A
	WC55	light cold-worked	32 (220)	15 (105)
C19400	W061	annealed	45 (310)	15 (105)
	WC55	light cold-worked	45 (310)	22 (150)
C23000	W061	annealed	40 (275)	12 (85)
	WC55	light cold-worked	42 (290)	20 (140)
C44300, C44400, C44500	W061	annealed	45 (310)	15 (105)
	WC55	light cold-worked	50 (345)	35 (240)
C68700	W061	annealed	50 (345)	18 (125)
	WC55	light cold-worked	^B	^B
C70400	W061	annealed	38 (260)	12 (85)
	WC55	light cold-worked	40 (275)	30 (205)
C70600	W061	annealed	40 (275)	15 (105)
	WC55	light cold-worked	45 (310)	35 (240)
C70620	W061	annealed	40 (275)	15 (105)
	WC55	light cold-worked	45 (310)	35 (240)
C71000	W061	annealed	45 (310)	16 (110)
	WC55	light cold-worked	50 (345)	35 (240)
C71500	W061	annealed	52 (360)	18 (125)
	WC55	light cold-worked	54 (370)	35 (240)
C71520	W061	annealed	52 (360)	18 (125)
	WC55	light cold-worked	54 (370)	35 (240)
C71640	W061	annealed	63 (435)	25 (170)
	WC55	light cold-worked	75 (515)	40 (275)
C72200	W061	annealed	45 (310)	16 (110)
	WC55	light cold-worked	50 (345)	30 (205)

^A Light straightening operation is permitted.

^B Where no properties are shown, strength requirements shall be as agreed upon between the purchaser and the manufacturer or supplier.

E. Performance Requirements :-

1. Expansion Test Requirements:

- i. Product in the annealed tempers and the light cold worked temper shall withstand expansion in accordance with Test Method B153 to the degree specified in Table 3.

Table 3

Temper	Copper or Copper Alloy UNS No.	Expansion of Tube Outside Diameter, in Percent of Original Outside Diameter
Annealed	C10800	30
	C12200	30
	C19400	20
	C23000	20
	C44300, C44400, C44500	20
	C68700	20
	C70400	30
	C70600	30
	C70620	30
	C71000	30
	C71500	30
	C71520	30
	C71640	30
	C72200	30
Light cold-worked	C10800	20
	C12200	20
	C19400	20
	C70400	20
	C70600	20

	C70620	20
	C71000	20
	C71500	20
	C71520	20
	C71640	20
	C72200	20
Annealed and light cold-worked, stress relieved	C23000	20
	C44300, C44400, C44500	20
	C68700	20

2. Flattening Test:

- i. The flattening test shall be performed in accordance with Test Method section in B968/B968M.

3. Reverse Bend Test:

- i. When specified in the contract or purchase order, the reverse bend test described in the Test Method section in H.2.iii shall be performed.

F. Other Requirements :-

1. Mercurous Nitrate Test or Ammonia Vapor Test:

- i. The mercurous nitrate or ammonia vapor test is required only for Copper Alloys UNS Nos. C23000; C44300; C44400; C44500; C60800; and C68700; when purchased if not supplied in an annealed temper
- ii. The test specimens, cut 6 in. [152 mm] in length from the enhanced section shall withstand, without cracking, an immersion in the standard mercurous nitrate solution in Test Method B154 or immersion in the ammonia vapour solution as defined in Test Method B858.
- iii. Unless otherwise agreed upon between the manufacturer, or supplier, and the purchaser, the manufacturer shall have the option of using either the mercurous nitrate test or the ammonia vapor test.

G. Nondestructive Testing :-

1. Each tube shall be subjected to an eddy-current test.
2. The purchaser may specify either of the tests in point G.4 or point G.5 as an alternative to the eddy-current test.
3. Eddy Current Test—
- i. Testing shall follow the procedures of Practice E243, except as modified in point G.3.ii.

- ii. The test unit sensitivity required to detect the resultant discontinuities shall be equivalent to or greater than that required to detect the notches or drilled holes of Table 4 or Table 5 and Table 6 or Table 7 respectively, or other calibration discontinuities that may be used by mutual agreement between the manufacturer or supplier and the purchaser.

Table 4: Notch Depth — Inch-Pound Values

Tube Wall Thickness, in.	Tube Outside Diameter, in.		
	Over 1/4 to 3/4, incl	Over 3/4 to 1(1/4), incl	Over 1(1/4) to 3(1/8), 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: Notch Depth — SI Values

Tube Wall Thickness, in.	Tube Outside Diameter, in.		
	Over 6 to 19, incl	Over 19 to 32, incl	Over 32 to 80, incl
Over 0.4–0.8	0.13	0.15	0.18
Incl 0.8–1.3	0.15	0.15	0.19
Incl 1.3–2.1	0.18	0.19	0.2
Incl 2.1–2.8	0.19	0.22	0.24
Incl 2.8–3.0	0.23	0.23	0.28

Table 6: Diameter of Drilled Holes — Inch-Pound Values

Tube Outside Diameter	Diameter of Drilled Holes	Drill No.
in.	in.	
1/4–3/4, incl	0.025	72
Over 3/4–1, incl	0.031	68
Over 1–1(1/4), incl	0.036	64
Over 1(1/4)–1(1/2), incl	0.042	58
Over 1(1/2)–1(3/4), incl	0.046	56
Over 1(3/4)–2, incl	0.052	55

Table 7: Diameter of Drilled Holes — SI Values

Tube Outside Diameter	Diameter of Drilled Holes	Drill No.
mm.	mm.	
6.0–19.0, incl	0.65	72
Over 19.0–25.4, incl	0.8	68
Over 25.4–31.8, incl	0.92	64
Over 31.8–38.1, incl	1.1	58
Over 38.1–44.4, incl	1.2	56
Over 44.4–50.8, incl	1.3	55

4. Hydrostatic Test—

- i. When specified, each tube shall withstand, without showing evidence of leakage, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 7000 psi [48 MPa], determined by the following equation for thin hollow cylinders under tension. The tube need not be tested at a hydrostatic pressure of over 1000 psig [7.0 MPa] unless so specified.

$$P = 2St / (D - 0.8t) \quad \dots\dots\dots(1)$$

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].

5. Pneumatic Test—

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

H. Test Methods :-

1. Composition shall be determined, in case of disagreement, as follows:

<u>Element</u>	<u>Method</u>
Copper 99.75 to 99.99	E53 Electrolytic
Copper 60 to 99.74	E478 Electrolytic
Tin 0.9 to 1.2	E478 Titrimetric
Aluminum 1.8 to 6.5	E478 Titrimetric
Nickel, inc. Cobalt	E478 Gravimetric
Lead 0.05 to 0.10	E478 Atomic Absorption
Iron 0.05 to 1.8	E54
Zinc to 1.0	E478 Atomic Absorption
Zinc 1.4 to 30.0	E478 Titrimetric
Manganese to 1.0	E62
Arsenic 0.02 to 0.5	E62
Antimony 0.02 to 0.1	E62
Phosphorus 0.001 to 0.04	E62
Chromium 0.30 to 0.70	E118

2. Other Tests:

- i. The product furnished shall conform to all other requirements when subjected to tests in accordance with the following table.

<u>Requirement</u>	<u>ASTM Designation</u>
Grain Size	E112
Tensile strength	E8
Expansion test	B153
Flattening test	Section H.2.ii
Reverse bend test	Section H.2.iii
Electromagnetic (eddy-current) test	E243

- ii. Flattening Test— Each test specimen shall be flattened in a press in accordance with B968/B968M.
 iii. Reverse Bend Test— The test specimen shall be flattened and bent around a mandrel with a diameter four times the wall thickness, with the mandrel parallel to the length and in contact with the outside surface of the tube. The weld shall be placed at the point of maximum bend.

Densities

Copper or Copper Alloy UNS No.	Density, lb/in.3	Density, g/cm3
C10800, C12200	0.323	8.94
C19400	0.322	8.91
C23000	0.31 6	8.75
C44300, C44400, C44500	0.308	8.53
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

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