ASTM B111

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

98(1998) e2 Edition · Technical Summary

Item	Description
Designation	ASTM B111-98e2 (fixed designation B 111; 98 = 1998 edition, e2 = second editorial revision)
Title	Standard Specification for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock
Publisher	ASTM International — Subcommittee B05.04, Book of Standards Vol. 02.01
Status	Historical edition (current combined standard B111/B111M-18a); approved for use by the U.S. Department of Defense
Tube type	Seamless tube and ferrule stock up to 3-1/8 in. [80 mm] OD inclusive, for surface condensers, evaporators, and heat exchangers
Materials	25 UNS designations — coppers, brasses, aluminum bronzes, and copper-nickel alloys (see Section 3)
Tempers	O61 annealed / H55 light-drawn / H80 hard-drawn / HR50 drawn and stress-relieved / HE80 hard-drawn and end-annealed
Key tests	Tensile, grain size, expansion, flattening, residual stress (mercurous nitrate or ammonia vapor), eddy-current, hydrostatic or pneumatic

Note: The referenced Scribd pages (document/859190373 and /155739304) are viewer shells without the standard text. This document is not a verbatim reproduction of the official standard; it is a technical summary compiled from multiple public sources. For the authoritative full text, purchase the official edition from ASTM International (www.astm.org).

1. Scope

This specification establishes the requirements for **seamless tube and ferrule stock** of copper and various copper alloys up to **3-1/8 in. [80 mm] inclusive in outside diameter**, for use in **surface condensers, evaporators, and heat exchangers**. A metric companion, Specification B111M, is available; no metric equivalents are presented in B111 itself. The standard does not purport to address all safety concerns associated with its use — the user is responsible for establishing appropriate safety and health practices. (Warning: mercury, used in one of the test methods, is a definite health hazard in use and disposal.)

2. Materials and Manufacture

Manufacturing process — The product shall be manufactured by such processes as casting, extrusion, drawing, annealing, straightening, trimming, or other processes that produce a seamless tube in the specified condition.

Tempers — Tube and ferrule stock shall be furnished in any one of the following tempers: **annealed (O61)**, **light-drawn (H55)**, **hard-drawn (H80)**, or **hard-drawn and end-annealed (HE80)**; drawn and stress-relieved (HR50) is also furnished. Tube for ferrule stock shall be annealed sufficiently to be fully recrystallized.

Stress-relief — It is suggested that tubes of Copper Alloy UNS Nos. C60800, C61300, C61400, and C68700 be subjected to a stress-relieving thermal treatment subsequent to straightening when required by the purchase order. Roundness, straightness, and length tolerances for such tube are by agreement between manufacturer and purchaser.

3. Specified Materials (UNS Alloys)

UNS No.	Former Designation	Type of Metal	Cu + Named Elements, min %
C10100	OFE	Oxygen-free electronic	99.99
C10200	OF	Oxygen-free without residual deoxidants	99.95
C10300	—	Oxygen-free, extra low phosphorus	99.95
C10800	—	Oxygen-free, low phosphorus	99.95
C12000	DLP	Phosphorized, low residual phosphorus	99.90
C12200	DHP	Phosphorized, high residual phosphorus	99.90
C14200	DPA	Phosphorized, arsenical	99.40
C19200	—	Phosphorized, 1 % iron	99.0*
C23000	—	Red Brass	99.8
C28000	—	Muntz Metal	99.7
C44300 / C44400 / C44500	—	Admiralty Metals, B, C, and D (inhibited)	99.6
C60800	—	Aluminum Bronze	99.0*
C61300	—	Aluminum Bronze (Cu + named elements)	99.0*
C61400	—	Aluminum Bronze, D	99.0*
C68700	—	Aluminum Brass, B (arsenical)	99.5
C70400	—	95-5 Copper-Nickel	99.5*
C70600 / C70620	—	90-10 Copper-Nickel (welding grade)	99.5*
C71000	—	80-20 Copper-Nickel	99.5*
C71500 / C71520	—	70-30 Copper-Nickel (welding grade)	99.5*
C71640	—	Copper-nickel-iron-manganese	99.5*
C72200	—	Copper-nickel (with chromium, iron)	99.5*

*Values marked * are minimum copper plus named elements; alloying-element ranges (Ni, Fe, Mn, Zn, Sn, Al, As, P, Pb, Cr) are defined in the standard's chemical-composition tables and verified by analysis per ASTM E478 or equivalent. Ordering requires: designation, UNS alloy, temper, dimensions (OD × wall × length), quantity, end finish, and any certification requirements.*

4. Tensile Requirements (min)

Copper / Copper Alloy UNS No.	Temper (Std.)	Tensile Strength ksi (MPa)	Yield Strength ksi (MPa)	Elongation in 2 in., min %
C10100…C14200 (coppers)	H55 light-drawn	36 (250)	30 (205)	—
C10100…C14200 (coppers)	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)	—

Copper / Copper Alloy UNS No.	Temper (Std.)	Tensile Strength ksi (MPa)	Yield Strength ksi (MPa)	Elongation in 2 in., min %
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 ≤ 0.048 in. incl.)	HR50 drawn, stress-relieved	72 (495)	50 (345)	12
C71500 / C71520 (wall > 0.048 in.)	HR50 drawn, stress-relieved	72 (495)	50 (345)	15
C71640	O61 annealed	63 (435)	25 (170)	—
C71640	HR50 drawn, stress-relieved	81 (560)	58 (400)	—
C72200	O61 annealed	45 (310)	16 (110)	—
C72200	H55 light-drawn	50 (345)	45 (310)	—

Yield strength taken at 0.5 % extension under load. Material specified to meet ASME Boiler and Pressure Vessel Code requirements shall have tensile properties as prescribed above.

5. Grain Size for Annealed Tempers

Grain size is a **standard requirement for all product in the annealed (O61) temper**. Samples shall be examined microscopically per Test Methods E112 at a magnification of 75 diameters and shall show uniform and complete recrystallization. Products other than C19200 and C28000 shall have an **average grain size of 0.010 to 0.045 mm**. These requirements do not apply to light-drawn (H55), hard-drawn (H80), hard-drawn and end-annealed (HE80), or drawn and stress-relieved (HR50) tempers.

6. Expansion Requirements

Temper Designation	Copper / Alloy UNS No.	Expansion of Tube OD, % of Original OD
O61 annealed	C19200	30
O61 annealed	C23000	20
O61 annealed	C28000	15
O61 annealed	C44300 / C44400 / C44500	20
O61 annealed	C60800	20
O61 annealed	C61300 / C61400	20
O61 annealed	C68700	20
O61 annealed	C70400	30

Temper Designation	Copper / Alloy UNS No.	Expansion of Tube OD, % of Original OD
O61 annealed	C70600	30
O61 annealed	C71000	30
O61 annealed	C71500	30
O61 annealed	C71640	30
O61 annealed	C72200	30
H55 light-drawn	C10200 / C12000 / C12200	20
H55 light-drawn	C14200	20
H55 light-drawn	C70400	20
H55 light-drawn	C70600	20
H55 light-drawn	C72200	20
HR50 drawn, stress-relieved	C71500	20
Hard-drawn, end-annealed	C10200 / C12000 / C14200	30

Tube specimens shall withstand the expansion shown when expanded in accordance with Test Method B153; the expanded tube shall show no cracking or rupture visible to the unaided eye. Hard-drawn tubes not end-annealed are not subject to this test. Tubes for ferrule stock are not subject to the expansion test.

7. Other Required Tests

7.1 Flattening test — Each specimen shall be flattened in a press at three places along its length, each rotated about one-third turn from the previous area; each flattened area shall be at least 2 in. long. A micrometer caliper set at three times the wall thickness shall pass freely over the flattened area, and the flattened areas shall be free of defects (minor blemishes that do not interfere with the intended application are acceptable). Ferrule-stock tube is not subject to the flattening test.

7.2 Residual stress test — When specified in the purchase order, required only for C23000, C28000, C44300/C44400/C44500, C60800, C61300/C61400, and C68700 not supplied in annealed temper. The producer may optionally use the mercurous nitrate test (B154) or the ammonia vapor test (B858).

7.3 Eddy-current test — Each tube shall be eddy-current tested per Practice E243 (notch depths per Table 4, e.g., 0.005–0.009 in. depending on wall thickness and OD). The purchaser may specify the hydrostatic or pneumatic test as an alternative.

7.4 Hydrostatic test — Each tube shall withstand, without leakage, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of **7000 psi [48 MPa]** per the thin-hollow-cylinder formula (P = 2St/D); need not exceed 1000 psi [7 MPa] unless otherwise specified.

8. Referenced Documents

Standard	Title	Role in B111
ASTM B153	Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing	Expansion test method
ASTM B154	Mercurous Nitrate Test for Copper and Copper Alloys	Residual-stress (crack) test
ASTM B601	Temper Designations for Copper and Copper Alloys (Wrought and Cast)	Temper codes (O61, H55, H80, HR50, HE80)
ASTM B858	Ammonia Vapor Test for Copper and Copper Alloys	Alternative residual-stress test

Standard	Title	Role in B111
ASTM E8/E8M	Tension Testing of Metallic Materials	Tensile test method
ASTM E112	Determining Average Grain Size	Grain-size measurement (annealed tempers)
ASTM E243	Eddy-Current Examination of Copper and Copper-Alloy Tubing	Non-destructive examination
ASTM E478	Chemical Analysis of Copper Alloys	Chemical-composition verification

9. Typical Applications and Selection Notes

Requirement	Recommended Alloy	Rationale
Power-plant surface condensers (fresh water)	C12200 (DHP copper)	Best thermal conductivity; low cost
Power-plant surface condensers (seawater)	C70600 (90-10 Cu-Ni)	Corrosion/erosion and biofouling resistance; iron content 1.0–1.8 % protects against impingement attack
Aggressive seawater / high-velocity service	C71500 (70-30 Cu-Ni)	Higher strength; better sulfide resistance
Refinery / petrochemical exchangers	C44300 (Admiralty) or C68700 (Aluminum Brass)	Resistance to sulfur compounds and impingement
High-pressure / thick-wall duty	C71500 HR50 drawn, stress-relieved	72 ksi min tensile; stress corrosion controlled
Ferrule stock (tube sheets)	Copper alloys, fully recrystallized O61	Easy cold forming into ferrules

Chinese equivalent grades (GB/T 8890): BFe10-1-1 ≈ C70600; BFe30-1-1 ≈ C71500; HSn70-1 ≈ C44300; HAl77-2 ≈ C68700.

— End of Summary —