



Designation: **B188—15 B188 – 15^{ε1}**

Standard Specification for Seamless Copper Bus Pipe and Tube¹

This standard is issued under the fixed designation B188; 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 reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

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

^{ε1} NOTE—Table 10 was editorially corrected in April 2016.

1. Scope*

1.1 This specification establishes the requirements for seamless copper bus pipe and tube intended for use as electrical conductors.

1.1.1 The product shall be made from one of the following coppers, as denoted in the ordering information:²

Copper UNS No. ²	Previously Used Designation	Type of Copper
C10100	OFE	Oxygen-free, electronic
C10200	OF	Oxygen-free without residual deoxidants
C10300	—	Oxygen-free, extra low phosphorus
C10400, C10500, C10700	OFS	Oxygen-free, silver bearing
C11000	ETP	Electrolytic tough pitch
C11300, C11400, C11600	STP	Silver-bearing tough pitch
C12000	DLP	Phosphorized, low residual phosphorus

1.2 Unless otherwise specified, any one of the above coppers may be furnished.

1.3 *Units*—The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units, which are provided for information only and are not considered standard.

2. Referenced Documents

2.1 *ASTM Standards*:³

- [B193 Test Method for Resistivity of Electrical Conductor Materials](#)
- [B428 Test Method for Angle of Twist in Rectangular and Square Copper and Copper Alloy Tube](#)
- [B577 Test Methods for Detection of Cuprous Oxide \(Hydrogen Embrittlement Susceptibility\) in Copper](#)
- [B601 Classification for Temper Designations for Copper and Copper Alloys—Wrought and Cast](#)
- [B846 Terminology for Copper and Copper Alloys](#)
- [E8/E8M Test Methods for Tension Testing of Metallic Materials](#)
- [E18 Test Methods for Rockwell Hardness of Metallic Materials](#)
- [E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications](#)
- [E53 Test Method for Determination of Copper in Unalloyed Copper by Gravimetry](#)
- [E62 Test Methods for Chemical Analysis of Copper and Copper Alloys \(Photometric Methods\) \(Withdrawn 2010\)⁴](#)
- [E243 Practice for Electromagnetic \(Eddy Current\) Examination of Copper and Copper-Alloy Tubes](#)
- [E255 Practice for Sampling Copper and Copper Alloys for the Determination of Chemical Composition](#)

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 The UNS system for copper and copper alloys (see Practice E527) 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.

³ 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.

⁴ The last approved version of this historical standard is referenced on www.astm.org.

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

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

3. Terminology

- 3.1 For definitions of terms related to copper and copper alloys, refer to Terminology **B846**.
- 3.2 *Definitions of Terms Specific to This Standard:*
 - 3.2.1 *bus pipe or tube*—a high conductivity copper tubular product used as an electrical conductor.

4. Ordering Information

- 4.1 Include the following specified choices when placing orders for product under this specification, as applicable:
 - 4.1.1 ASTM designation and year of issue,
 - 4.1.2 Copper UNS designation (**1.1.1** and **1.2**),
 - 4.1.3 Temper (Section **7**),
 - 4.1.4 Dimensions and form (Section **12**),
 - 4.1.5 Length (Section **12**),
 - 4.1.6 Quantity—total weight or total length or number of pieces of each size (**Table 1**),
- 4.2 The following options are available but may not be included unless specified at the time of placing the order when required:
 - 4.2.1 Bend test (Section **10**),
 - 4.2.2 Hydrogen embrittlement susceptibility test (Section **10**),
 - 4.2.3 Microscopical examination (Section **10**),
 - 4.2.4 Tension testing (Section **9**),
 - 4.2.5 Eddy-current test (Section **11**),
 - 4.2.6 Certification (Section **21**),
 - 4.2.7 Test report (Section **22**), and
 - 4.2.8 If the specification number is required to be shown on the packaging (Section **23.2**).

TABLE 1 Dimensions and Weights of Copper Pipe, Nominal or Standard Pipe Sizes^A

Nominal or Standard Pipe Size, in.	Dimensions, in. (mm)			Cross-Sectional Area of Wall, in. ² (mm ²)	Theoretical Weight, lb/ft (kg/m)
	Outside Diameter	Inside Diameter	Wall Thickness		
Regular					
¼	0.540(13.7)	0.376(9.55)	0.082(2.08)	0.118(0.761)	0.457(0.680)
⅜	0.675(17.1)	0.495(12.6)	0.090(2.29)	0.165(1.06)	0.641(0.954)
½	0.840(21.3)	0.626(15.9)	0.107(2.72)	0.246(1.59)	0.955(1.42)
¾	1.050(26.7)	0.822(20.9)	0.114(2.90)	0.335(2.16)	1.30(1.93)
1	1.315(33.4)	1.063(27.0)	0.126(3.20)	0.471(3.04)	1.82(2.71)
1¼	1.660(42.2)	1.368(34.7)	0.146(3.71)	0.694(4.48)	2.69(4.00)
1½	1.900(48.3)	1.600(40.6)	0.150(3.81)	0.825(5.32)	3.20(4.76)
2	2.375(60.3)	2.063(52.4)	0.156(3.96)	1.09(7.03)	4.22(6.28)
2½	2.875(73.0)	2.501(63.5)	0.187(4.75)	1.58(10.2)	6.12(9.11)
3	3.500(88.9)	3.062(77.8)	0.219(5.56)	2.26(14.6)	8.75(13.0)
3½	4.000(102)	3.500(88.9)	0.250(6.35)	2.95(19.0)	11.4(17.0)
4	4.500(114)	4.000(102)	0.250(6.35)	3.34(21.5)	12.9(19.2)
5	5.562(141)	5.062(129)	0.250(6.35)	4.17(26.9)	16.2(24.1)
6	6.625(168)	6.125(156)	0.250(6.35)	5.01(32.3)	19.4(28.9)
8	8.625(219)	8.001(203)	0.312(7.92)	8.15(52.6)	31.6(47.0)
10	10.750(273)	10.020(255)	0.365(9.27)	11.9(76.8)	46.2(68.7)
12	12.750(324)	12.000(305)	0.375(9.52)	14.6(94.2)	56.5(84.1)
Extra Strong					
¼	0.540(13.7)	0.294(7.47)	0.123(3.12)	0.161(1.04)	0.625(0.930)
⅜	0.675(17.1)	0.421(10.7)	0.127(3.23)	0.219(1.41)	0.847(1.26)
½	0.840(21.3)	0.542(13.8)	0.149(3.78)	0.323(2.08)	1.25(1.86)
¾	1.050(26.7)	0.736(18.7)	0.157(3.99)	0.440(2.84)	1.71(2.54)
1	1.315(33.4)	0.951(24.2)	0.182(4.62)	0.648(4.18)	2.51(3.73)
1¼	1.660(42.2)	1.272(32.3)	0.194(4.93)	0.893(5.76)	3.46(5.15)
1½	1.900(48.3)	1.494(37.9)	0.203(5.16)	1.08(6.97)	4.19(6.23)
2	2.375(60.3)	1.933(49.1)	0.221(5.61)	1.50(9.68)	5.80(8.63)
2½	2.875(73.0)	2.315(58.8)	0.280(7.11)	2.28(14.7)	8.85(13.2)
3	3.500(88.9)	2.892(73.6)	0.304(7.72)	3.05(19.7)	11.8(17.6)
3½	4.000(102)	3.358(85.3)	0.321(8.15)	3.71(23.9)	14.4(21.4)
4	4.500(114)	3.818(97.0)	0.341(8.66)	4.46(28.8)	17.3(25.7)
5	5.562(141)	4.812(122)	0.375(9.52)	6.11(39.4)	23.7(35.3)
6	6.625(168)	5.751(146)	0.437(11.1)	8.50(54.8)	32.9(49.0)
8	8.625(219)	7.625(194)	0.500(12.7)	12.8(82.6)	49.5(73.7)
10	10.750(273)	9.750(248)	0.500(12.7)	16.1(104)	62.4(92.9)

^A 1 in.² = 1 270 000 cmil.

5. Materials and Manufacture

5.1 Material:

5.1.1 The material of manufacture shall be cast billet of one of the UNS copper alloy numbers included in the scope, and as so specified in the contract or purchase order, and shall be of such purity and soundness as to be suitable for processing into lengths of pipe or tube for the intended application.

5.2 Manufacture:

5.2.1 The product shall be manufactured by such hot-working, cold-working, and annealing processes as to produce a uniform, wrought, seamless structure in the finished product.

5.2.2 The method of manufacture shall be hot or cold working to the finished size, and subsequent annealing when required to meet the temper properties specified (see 7.1).

6. Chemical Composition

6.1 The material shall conform to the chemical composition requirements in Table 2 for the copper UNS No. designation specified in the ordering information.

6.2 These composition limits do not preclude the presence of other elements. By agreement between the manufacturer or supplier and purchaser, limits may be established and analysis required for unnamed elements.

7. Temper

7.1 The standard tempers for products described in this specification are given in Table 3 as defined in Classification B601.

7.1.1 *Soft Anneal*—O60.

7.1.2 *Hard Drawn*—H80.

8. Electrical Resistivity Requirements

8.1 The product furnished shall conform to the maximum electrical resistivity requirements prescribed in Table 3 when tested in accordance with Test Method B193.

9. Mechanical Property Requirements

9.1 Product furnished under this specification shall conform to the tensile and hardness property requirements prescribed in Table 3.

9.1.1 Tension testing for tensile and elongation information need not be performed except when specified by the purchaser at the time of placing the order (see 4.2.4).

9.1.2 The tension test shall be used to resolve cases of dispute.

10. Performance Requirements

10.1 Bend Test Requirements:

10.1.1 The product shall conform to the bend testing requirements prescribed in Table 3.

10.1.2 Bend testing need not be performed except when specified by the purchaser at the time of placing the order (see 4.2.1).

10.2 Microscopical Examination:

TABLE 2 Chemical Requirements

NOTE 1—If the type of silver-bearing copper is not specified (that is, whether tough-pitch, phosphorized, or oxygen-free) any one of the three types may be supplied at the option of the manufacturer.

Element	Composition, %										
	Copper UNS No.										
	C10100 ^A	C10200	C10300	C10400 ^B	C10500 ^B	C10700 ^B	C11000	C11300 ^C	C11400 ^C	C11600 ^C	C12000
Copper (incl silver), min	99.99 ^D	99.95	99.95 ^E	99.95	99.95	99.95	99.90	99.90	99.90	99.90	99.90
Phosphorus	^A	...	0.001–0.005	...	...	...	...	...	...	...	0.004–0.012
Oxygen, max.	0.0005	0.0010	...	0.0010	0.0010	0.0010	...	...	...	...	...
Silver	^A	...	...	8 ^F	10 ^F	25 ^F	...	8 ^F	10 ^F	25 ^F	...

^A Impurity maximums in ppm of C10100 shall be: antimony 4, arsenic 5, bismuth 1.0, cadmium 1, iron 10, lead 5, manganese 0.5, nickel 10, phosphorus 3, selenium 3, silver 25, sulfur 15, tellurium 2, tin 2, and zinc 1.

^B C10400, C01500, and C10700 are oxygen-free coppers with the addition of a specified amount of silver. The compositions of these alloys are equivalent to C10200 plus the intentional addition of silver.

^C C11300, C11400, C11500, and C11600 are electrolytic tough-pitch copper with silver additions. The compositions of these alloys are equivalent to C11000 plus the intentional addition of silver.

^D Copper shall be determined by difference between “impurity total” and 100 %.

^E Copper (includes silver) + phosphorus, min.

^F Values are minimum silver in troy ounces per avoirdupois ton (1 oz/ton is equivalent to 0.0034 %).

TABLE 3 Mechanical and Electrical Properties^A

Temper Designation		Classification and Size	Tensile Strength ksi (MPa) ^B		Elongation in 2 in. (51 mm), min, %	Bend Test Angle of Bend, °	Electrical Resistivity ^B max at 20°C (68°F), Ω·g/m ²				Rockwell Hardness (F Scale) 60-kg Load 1/16-in. Ball
Code	Name		min	max			Copper UNS No.				
O60	Soft Anneal	All types, all sizes	...	37 (255)	25	180	0.15176	0.15328	0.15614	0.17031	50 max
H80	Hard Drawn	Rectangular or square:									
		up to 6-in. (152-mm) major out- side dimension, incl up to 3/16- in. (4.8-mm) wall thickness, incl	35 (240)	...	8	...	0.15585	0.15737	0.15940	0.17418	75 min
		over 3/16-in. (4.8-mm) wall thick- ness	33 (230)	...	15	...	0.15521	0.15673	0.15940	0.17418	65 min
		over 6-in. (152-mm) major out- side dimension	32 (220)	...	20	...	0.15425	0.15577	0.15940	0.17418	65 min
		Round (pipe and tube):									
		up to 4-in. (102-mm) outside diameter, incl	40 (275)	...	3	90	0.15713	0.15865	0.15940	0.17418	80 min
		over 4-in. (102-mm) outside diam- eter	38 (260)	...	6	...	0.15585	0.15737	0.15940	0.17418	75 min

^A See 6.1.

^B See Appendix X2.

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10.2.1 The test specimens of material designated as Copper UNS Nos. C10100, C10200, C10300, C10400, C10500, C10700, and C12000 shall be free of cuprous oxide as determined by Procedure A of Test Methods B577. In case of a dispute, a referee method in accordance with Procedure C shall be used.

10.2.2 The test need not be performed except when specified at the time of placing the order (see 4.2.3).

10.3 Hydrogen Embrittlement Susceptibility Test:

10.3.1 When tested, material designated as Copper UNS Nos. C10100, C10200, C10300, C10400, C10500, C10700, and C12000 shall pass the embrittlement test of Procedure B of Test Methods B577. The actual performance of this test is not mandatory under the terms of this specification unless specified in the ordering information (see 4.2.2). In case of dispute, a referee method in accordance with Procedure C of Test Methods B577 shall be employed.

11. Other Requirements

11.1 Nondestructive Testing:

11.1.1 When specified (see 4.2.5), the product shall be tested in the final size but may be tested before the final anneal or heat treatment, when these thermal treatments are required, unless otherwise agreed upon by the manufacturer or supplier and purchaser.

11.1.2 *Eddy-Current Test*—When specified, each piece of product from 1/8-in. (3.2-mm) up to and including 3 1/8-in. (79.4-mm) nominal outside diameter, or 2 1/2-in. (63.5-mm) distance between outside parallel surfaces, shall be subjected to an eddy-current test. Testing shall follow the procedures of Practice E243 except for determination of “end effect.” The product shall be passed through an eddy-current testing unit adjusted to provide information on the suitability of the product for the intended application.

11.1.3 Notch-depth standards rounded to the nearest 0.001 in. (0.025 mm) shall be 22 % of the nominal wall thickness. The notch depth tolerance shall be ±0.0005 in. (0.013 mm). Alternatively, when the test is performed using speed-insensitive equipment that can select a maximum imbalance signal, a maximum imbalance signal of 0.3 % shall be used.

11.1.4 Product that does not actuate the signaling device of the eddy-current test shall be considered as conforming to the requirements of this test. Product with discontinuities indicated by the testing unit may be reexamined or retested, at the option of the manufacturer, to determine whether the discontinuity is cause for rejection. Signals that are found to have been caused by minor mechanical damage, soil, or moisture shall not be cause for rejection of the product provided the dimensions of the product are still within prescribed limits and the product is suitable for its intended application.

12. Dimensions, Weights, and Permissible Variations

12.1 *General*—For the purpose of determining conformance with the dimensional requirements given in this specification, any measured value outside the specified limiting values for any dimension may be cause for rejection.

12.2 *Dimensions and Weights*—The dimensions and weights for nominal or standard copper pipe of various outside diameters shall be as prescribed in **Table 1**.

12.3 *Weight Tolerances*—The weight of the nominal or standard pipe shall not vary from the theoretical weight per foot prescribed in **Table 1** by more than the following:

Nominal or Standard Pipe Size, in.	Weight Tolerance, %
6 and under	5
Over 6 to 8, incl	7
Over 8	8

12.4 *Thickness Tolerances*—The wall thickness of nominal or standard pipe at any point shall not be less than that prescribed in **Table 1** by more than the following:

Nominal or Standard Pipe Size, in.	Thickness Tolerance, % ^A
6 and under	5
Over 6 to 8, incl.	7
Over 8	8

^A Expressed to the nearest 0.001 in. (0.025 mm).

12.5 *Copper Tube (Other than Pipe):*

12.5.1 *Round Tube*—Wall thickness tolerances shall be in accordance with **Table 4**. Diameter tolerances shall be in accordance with **Table 5**.

12.5.2 *Rectangular Including Square Tube*—Wall thickness tolerances shall be in accordance with **Table 6**. The tolerances on distance between parallel surfaces for rectangular and square tube in straight lengths only shall be in accordance with **Table 7** and **Fig. 1**.

12.5.3 *Length and Length Tolerances*—Tube ordered to specific or stock lengths with or without ends shall conform to the tolerances prescribed in **Table 8** and **Table 9**.

12.5.3.1 Pipe ordered to specific stock lengths with or without ends shall conform to tolerances prescribed in **Table 10** and **Table 11**.

12.6 *Roundness*—For tube or pipe of H (drawn) tempers in straight lengths, the roundness tolerances shall be as follows:

<i>t/D</i> (Ratio of Wall Thickness to Outside Diameter)	Roundness Tolerance, % of Outside Diameter (Expressed to the Nearest 0.001 in. (0.025 mm))
0.01 to 0.03 incl	1.5
Over 0.03 to 0.05, incl	1.0
Over 0.05 to 0.10, incl	0.8 or 0.002 in. (0.51 mm), whichever is greater
Over 0.10	0.7 or 0.002 in. (0.51 mm), whichever is greater

12.6.1 Compliance with the roundness tolerance shall be determined by taking measurements on the outside diameter only, irrespective of the manner in which the tube dimensions are specified.

12.6.2 The deviation from roundness is measured as the difference between major and minor diameters as determined at any one cross section of the tube.

TABLE 4 Wall Thickness Tolerances for Copper Tube (Not Applicable to Pipe)

NOTE 1—*Maximum Deviation at Any Point:* The following tolerances are plus and minus; if tolerances all plus or all minus are desired, double the values given.

Wall Thickness, in. (mm)	Outside Diameter, in. (mm)					
	Over 1/8 (3.15) to 5/8 (15.9), incl	Over 5/8 (15.9) to 1 (25.4), incl	Over 1 (25.4) to 2 (50.8), incl	Over 2 (50.8) to 4 (102), incl	Over 4 (102) to 7 (178), incl	Over 7 (178) to 10 (254), incl
Up to 0.017 (0.432) incl	0.001 (0.025)	0.0015 (0.038)	0.002 (0.051)	...	...	...
Over 0.017 (0.432) to 0.024 (0.610) incl	0.002 (0.051)	0.002 (0.051)	0.0025 (0.064)	...	...	...
Over 0.024 (0.610) to 0.034 (0.864) incl	0.0025 (0.064)	0.0025 (0.064)	0.003 (0.076)	0.004 (0.10)	...	...
Over 0.034 (0.864) to 0.057 (1.45) incl	0.003 (0.076)	0.0035 (0.089)	0.0035 (0.089)	0.005 (0.13)	0.007 (0.18)	...
Over 0.057 (1.45) to 0.082 (2.08) incl	0.0035 (0.089)	0.004 (0.10)	0.004 (0.10)	0.006 (0.15)	0.008 (0.20)	0.010 (0.25)
Over 0.082 (2.08) to 0.119 (3.02) incl	0.004 (0.10)	0.005 (0.13)	0.005 (0.13)	0.007 (0.18)	0.009 (0.23)	0.011 (0.28)
Over 0.119 (3.02) to 0.164 (4.17) incl	0.005 (0.13)	0.006 (0.15)	0.006 (0.15)	0.008 (0.20)	0.010 (0.25)	0.012 (0.30)
Over 0.164 (4.17) to 0.219 (5.56) incl	0.007 (0.18)	0.0075 (0.19)	0.008 (0.20)	0.010 (0.25)	0.012 (0.30)	0.014 (0.36)
Over 0.219 (5.56) to 0.283 (7.19) incl	...	0.009 (0.23)	0.010 (0.25)	0.012 (0.30)	0.014 (0.36)	0.016 (0.41)
Over 0.283 (7.19) to 0.379 (9.63) incl	...	0.012 (0.30)	5 ^A	5 ^A	6 ^A	6 ^A
Over 0.379 (9.62)	...	...	5 ^A	5 ^A	6 ^A	6 ^A

^A Percent of the specified wall expressed to nearest 0.001 in. (0.025 mm).

TABLE 5 Average Diameter Tolerances for Copper Tube

Specified Diameter, in. (mm)	Diameter to Which Tolerance Applies ^A	Tolerance, plus and minus, in. (mm)
Up to 5/8 (15.9), incl	inside or outside	0.002 (0.051)
Over 5/8 (15.9) to 1 (25.4), incl	inside or outside	0.0025 (0.064)
Over 1 (25.4) to 2 (50.8), incl	inside or outside	0.003 (0.076)
Over 2 (50.8) to 3 (76.2), incl	inside or outside	0.004 (0.10)
Over 3 (76.2) to 4 (102), incl	inside or outside	0.005 (0.13)
Over 4 (102) to 5 (127), incl	inside or outside	0.006 (0.15)
Over 5 (127) to 6 (152), incl	inside or outside	0.007 (0.18)
Over 6 (152) to 8 (203), incl	inside or outside	0.008 (0.20)
Over 8 (203) to 10 (254), incl	inside or outside	0.010 (0.25)

^A The average outside diameter of a tube is the average of the maximum and minimum outside diameters, as determined at any one cross-section of the tube.

12.6.3 No tolerances have been established for as-extruded tube, redrawn tube, annealed tube, any tube furnished in coils, or drawn tube whose wall thickness is under 0.016 in. (~~0.406 mm~~)(0.406 mm).

12.7 *Squareness of Cut*—For pipe and tube in straight lengths, the departure from squareness of the end of any pipe or tube shall not exceed the following:

12.7.1 *Pipe:*

Specified Outside Diameter, in. (mm)	Tolerance
Up to 5/8 (15.9), incl	0.010 in. (0.25 mm)
Over 5/8 (15.9)	0.016 in./in. (0.016 mm/mm) of diameter

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