Designation: B188 – 10

StandardSpecification for Seamless Copper Bus Pipe and Tube[1]

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 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 U.S. Department of Defense.

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*—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 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E62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods) (Withdrawn 2010)[4]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

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 information 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),

[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.

Current edition approved Oct. 1, 2010. Published November 2010. Originally approved in 1944. Last previous edition approved in 2009 as B188 – 09. DOI: 10.1520/B0188-10.

[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**

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.

4.2 The following options are available and should be 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 Mill test report (Section 22), and

4.2.8 Special packaging, if required (Section 23).

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 processing 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.

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			Tensile Strength ksi (MPa)[B]				Electrical Resistivity[B] max at 20°C (68°F), Ω·g/m²				
							Copper UNS No.				
Code	Name	Classification and Size	min	max	Elongation in 2 in. (51 mm), min, %	Bend Test Angle of Bend,°	C10100	C10200, C10400, C10500, C10700, C11000, C11300, C11400, and C11600	C10300	C12000	Rockwell Hardness (F Scale) 60-kg Load 1/16-in. Ball
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 outside 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 thickness	33 (230)	...	15	...	0.15521	0.15673	0.15940	0.17418	65 min
		over 6-in. (152-mm) major outside 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 diameter	38 (260)	...	6	...	0.15585	0.15737	0.15940	0.17418	75 min

[A] See 6.1.
[B] See Appendix X2.

9.1.1 Tension testing for tensile and elongation information need not be performed except when indicated 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 indicated by the purchaser at the time of placing the order (see 4.2.1).

10.2 *Microscopical Examination*

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 Method 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 indicated 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 Method 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 Method 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 ⅛-in. (3.2-mm) up to and including 3⅛-in. (79.4-mm) nominal outside diameter, or 2½-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.

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 ⅛ (3.15) to ⅝ (15.9), incl	Over ⅝ (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.

12.5.3 *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 drawn unannealed tube or pipe in straight lengths, the roundness tolerances shall be as follows:

t/D (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.

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).

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

12.7.2 *Round Tube:*

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

12.7.3 *Rectangular and Square Tube:*

Specified Distance Between Major Outside Parallel Surface	Tolerance
Up to 5⁄8 (15.9), incl	0.016 in. (0.41 mm)
Over 5⁄8 (15.9)	0.025 in./in. (0.025 mm/mm) of distance between outside parallel surfaces

12.8 *Straightness Tolerances:*

12.8.1 *Round Tubes*—For round tubes of any drawn temper, ¼ to 3½ in. (6.35 to 88.9 mm) in outside diameter, inclusive, the straightness tolerances shall be in accordance with Table 12.

12.8.2 *Rectangular and Square Tubes*—For rectangular and square tubes of any drawn temper, the straightness tolerance shall be ½-in. (13-mm) maximum curvature (depth of arc) in any 6-ft (1.8-m) portion of the total length.

12.9 *Unit Weight*—For purpose of calculating weights, cross sections, and so forth, the density of the copper shall be taken as 0.323 lb/in.^{3} (8.94 g/cm^3).

12.10 *Corner Radius: Rectangular and Square Tubes*—The permissible radii for commercially square corners shall be in accordance with Table 13.

12.11 *Twist Tolerances: Rectangular and Square Tubes*—The maximum twist about the longitudinal axis of drawn temper rectangular and square tubes shall not exceed 1°/ft (1°/305 mm) of length, measured to the nearest degree, and the total angle of twist shall not exceed 20° when measured in accordance with Test Method B428. The requirement is not applicable to tubes in the annealed temper or to tubes whose specified major dimension is less than ½ in. (12.7 mm).

13. Workmanship, Finish, and Appearance

13.1 The product shall be free of defects of a nature that would interfere with the intended application. It shall be well cleaned and free from dirt.

14. Sampling

14.1 The lot size, portion size, and sample size of the finished product shall be as follows:

14.1.1 *Lot Size*—An inspection lot shall be 10 000 lb (4540 kg) or portion thereof, subject to inspection at one time.

14.1.2 *Portion Size*—A portion shall be taken to be representative of a lot according to the following schedule:

Number of Pieces in Lot	Number of Pieces to be Taken[A]
1 to 50	1
51 to 200	2
201 to 1500	3
Over 1500	0.2 % of the total number of pieces in the lot, but not to exceed 10 pieces

[A] Each test portion shall be taken from a separate tube.

14.2 *Chemical Analysis*—Samples for chemical analysis shall be taken in accordance with Practice E255. Drillings, millings, and so forth shall be taken in approximately equal weight from each of the sample pieces selected in accordance

TABLE 6 Wall Thickness Tolerances for Copper Rectangular and Square Tube

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)	Distance Between Outside Parallel Surface, in.[A] (mm)						
	1/32 (0.794) to 1/8 (3.18), incl	Over 1/8 (3.18) 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	0.002 (0.051)	0.002 (0.051)	0.0025 (0.064)	0.003 (0.076)	...	...	...
Over 0.017 (0.432) to 0.024 (0.610) incl	0.003 (0.076)	0.0025 (0.064)	0.003 (0.076)	0.0035 (0.089)	...	...	...
Over 0.024 (0.610) to 0.034 (0.864) incl	0.0035 (0.089)	0.0035 (0.089)	0.0035 (0.089)	0.004 (0.10)	0.006 (0.15)	...	...
Over 0.034 (0.864) to 0.057 (1.45) incl	0.004 (0.10)	0.004 (0.10)	0.0045 (0.11)	0.005 (0.12)	0.007 (0.18)	0.009 (0.23)	...
Over 0.057 (1.45) to 0.082 (2.08) incl	...	0.005 (0.13)	0.006 (0.15)	0.007 (0.18)	0.008 (0.20)	0.010 (0.25)	0.012 (0.30)
Over 0.082 (2.08) to 0.119 (3.02) incl	...	0.007 (0.18)	0.008 (0.20)	0.009 (0.23)	0.010 (0.25)	0.012 (0.30)	0.014 (0.36)
Over 0.119 (3.02) to 0.164 (4.17) incl	...	0.009 (0.23)	0.010 (0.25)	0.011 (0.28)	0.012 (0.30)	0.014 (0.36)	0.016 (0.41)
Over 0.164 (4.17) to 0.219 (5.56) incl	...	0.011 (0.28)	0.012 (0.30)	0.013 (0.33)	0.015 (0.38)	0.017 (0.43)	0.019 (0.48)
Over 0.219 (5.56) to 0.283 (7.19) incl	...	...	0.015 (0.38)	0.016 (0.41)	0.018 (0.46)	0.020 (0.51)	0.022 (0.56)

[A] In the case of rectangular tube, the major dimension determines the thickness tolerance applicable to all walls.

TABLE 7 Tolerances on Distance Between Parallel Surfaces for Copper Rectangular and Square Tube

NOTE 1—The following tolerances are plus and minus; if tolerances all plus or all minus are desired, double the values given.

Dimensions *a* or *b* (Fig. 1), in. (mm)	Tolerances, in. (mm)
Up to 1/8 (3.18), incl	0.003 (0.076)
Over 1/8 to 5/8 (3.18 to 15.9), incl	0.004 (0.10)
Over 5/8 to 1 (15.9 to 25.4), incl	0.005 (0.13)
Over 1 to 2 (25.4 to 50.8), incl	0.006 (0.15)
Over 2 to 3 (50.8 to 76.2), incl	0.007 (0.18)
Over 3 to 4 (76.2 to 102), incl	0.008 (0.20)
Over 4 to 5 (102 to 127), incl	0.009 (0.23)
Over 5 to 6 (127 to 152), incl	0.010 (0.25)
Over 6 to 8 (152 to 203), incl	0.011 (0.28)
Over 8 to 10 (203 to 254), incl	0.012 (0.30)

Nominal dimension *a* determines tolerance applicable to both *a* and *c*.
Nominal dimension *b* determines tolerance applicable to both *b* and *d*.

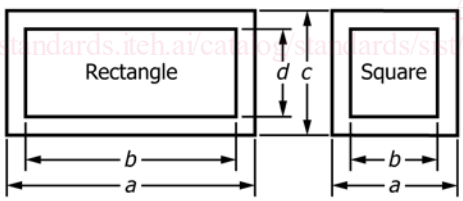

FIG. 1 Tolerances on Distance Between Parallel Surfaces for Copper Rectangular and Square Tube (Table 7)

with 15.1 and combined into one composite sample. The minimum weight of the composite sample shall be 150 g.

14.2.1 Instead of sampling in accordance with Practice E255, 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 semi-finished 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:

14.2.1.1 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.

14.2.1.2 When samples are taken from the semi-finished product, a sample shall be taken to represent each 10 000 lb (4550 kg) or fraction thereof, except that not more than one sample shall be required per piece.

14.2.1.3 Due to 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.

14.2.1.4 In the event that heat identification or traceability is required, the purchaser shall specify the details desired.

15. Number of Tests and Retests

15.1 Specimens taken from each sample piece selected in accordance with Section 14 shall be subjected to the Rockwell hardness test and to the electrical resistivity or conductivity test to determine conformance to the requirements prescribed in Table 3. The values for the Rockwell hardness number of each specimen shall be established by taking the arithmetical average of at least three readings.

15.2 One specimen taken from each sample piece shall be tested for tensile properties and one for bending, if required, to determine conformance to the requirements in Table 3.

15.3 In the case of coppers designated as oxygen-free or deoxidized, a section of each sample piece selected in accordance with Section 14 shall be submitted to microscopical examination as specified in Section 10.2 and also to the embrittlement test, if specified, as prescribed in Section 10.3.

15.4 *Retests:*

15.4.1 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

15.4.2 If the percentage elongation of any tension test specimen is less than that specified and any part of the fracture is outside the middle two thirds of the gage length or in a