



Designation: ~~B372-11~~ Designation: B372 - 12

# Standard Specification for Seamless Copper and Copper-Alloy Rectangular Waveguide Tube<sup>1</sup>

This standard is issued under the fixed designation B372; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

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

## 1. Scope\*

1.1 This specification establishes the requirements for seamless copper and copper-alloy rectangular tube intended for use as transmission lines in electronic equipment. Five types of material are specified having the following nominal compositions:<sup>2</sup>

Copper or Copper Alloy UNS <sup>2</sup> No.	Previously Used Designation	Nominal Composition, %		
		Copper	Zinc	Phosphorus
C10100	Copper, Type OFE <sup>A</sup>	99.99	—	...
C10100	Copper, Type OFE <sup>A</sup>	99.99 <sup>B</sup>	...	...
<del>C10200</del>	<del>Copper, Type OF<sup>A</sup></del>	<del>99.95</del>	<del>...</del>	<del>...</del>
C10200	Copper, Type OF <sup>A</sup>	99.95 <sup>B</sup>	...	...
<del>C10300</del>	<del>Copper, Type OFXLP<sup>A</sup></del>	<del>99.95</del>	<del>...</del>	<del>0.003</del>
C10300	Copper, Type OFXLP <sup>A</sup>	99.95 <sup>B</sup>	...	0.003
<del>C12000</del>	<del>Copper, Type DLP<sup>A</sup></del>	<del>99.90</del>	<del>...</del>	<del>0.008</del>
C12000	Copper, Type DLP <sup>A</sup>	99.90 <sup>B</sup>	...	0.008
C22000	Commercial bronze, 90 %	90	10	...

<sup>A</sup> Types OF, OFE, OFXLP, and DLP are described in Classification B224.

<sup>B</sup> Minimum copper percentage.

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

## 2. Referenced Documents

2.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards*:<sup>3</sup> <https://standards.iteh.ai/catalog/standards/sist/5c70a28c-3709-4705-9c5d-63530e85baf1/astm-b372-12>

- B170 [Specification for Oxygen-Free Electrolytic Copper Refinery Shapes](#)
- B193 [Test Method for Resistivity of Electrical Conductor Materials](#)
- B224 [Classification of Coppers](#)
- 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](#)
- B846 [Terminology for Copper and Copper Alloys](#)
- 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 \(Photometric Methods\)](#)
- E255 [Practice for Sampling Copper and Copper Alloys for the Determination of Chemical Composition](#)
- E478 [Test Methods for Chemical Analysis of Copper Alloys](#)

<sup>1</sup> 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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<sup>2</sup> The UNS system for copper and copper alloys 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.

<sup>3</sup> 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.

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

2.3 *Other Standard:*

ANSI B46.1 Surface Roughness, Waviness, and Lay<sup>4</sup>

**3. Terminology**

3.1 For definitions of terms related to copper and copper alloys, refer to Terminology B846.

**4. Ordering Information**

4.1 Orders for material under this specification shall include the following information:

4.1.1 Material (Sections 1 and 6)

4.1 Include the following specified choices when placing orders for products under this specification, as applicable:

4.1.1 ASTM designation and year of issue,

4.1.2 Copper or copper alloy UNS No. designation,

4.1.3 Outer and inner rectangular dimensions, dimensional tolerances (Section 10),

4.1.2 Outer and inner rectangular dimensions (Section 11)

4.1.4 Length (10.6),

4.1.5 Total length of each size,

4.1.6 Special packaging, if required (Section 20),

4.1.3 Length (see 11.6)

4.1.7 Embrittlement test, if required (Section 9.2),

4.1.4 Total length of each size,

4.1.5 Special packaging, if required (Section 19);

4.1.6 Embrittlement test, if required (Section 9);

4.1.7 Electrical resistivity test, if required (Section 10), and

4.1.8 Special finish, if required (see 12.2)

4.1.8 Electrical resistivity test, if required (Section 7), and

4.1.9 Special finish, if required (see 11.2).

**5. Materials and Manufacture**

5.1 The material shall be of such quality and purity that the finished product shall have the properties and characteristics prescribed in this specification, and shall be cold drawn to size.

5.2 The copper will normally be of the types given in Table 1, but may be of such other types as may be agreed upon between

<sup>4</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

<https://standards.iteh.ai/catalog/standards/sist/5c70a28c-3709-4705-9c5d-63530e85baf1/astm-b372-12>

**TABLE 1 Chemical Requirements**

Element	Composition, %				
	Copper UNS Nos.				Copper Alloy UNS No. C22000
	C10100 <sup>A</sup>	C10200 <sup>B</sup>	C10300	C12000	
Copper <sup>C</sup>	99.99 min	99.95 min	...	99.90 min	89.0–91.0
Copper	99.99 min	99.95 <sup>C</sup> min	...	99.90 <sup>C</sup> min	89.0–91.0
Copper, C + phos-	...	...	99.95	...	...
Copper, + phos-	...	...	99.95 <sup>C</sup> min	...	...
—phorus; min	...	...	...	...	...
—phorus	...	...	...	...	...
Phosphorus	0.0003 max	...	0.001– 0.005	0.004– 0.012	...
Zinc	0.0001 max	...	...	...	remainder
Lead, max	0.0005	...	...	...	0.05
Iron, max	0.0010	...	...	...	0.05

<sup>A</sup> The following additional impurity maximum limits shall apply: As 0.0005%, Sb 0.0004%, Te 0.0002%, O 0.0005%, Bi 0.0001%, Cd 0.0001%, Mn 0.00005%, Ni 0.0010%, Se 0.0003%, Ag 0.0025%, S 0.0015% and Sn 0.0002%.

<sup>B</sup> Oxygen in C10200 shall be 0.0010 ppm % max.

<sup>C</sup> Silver counting as copper.

the manufacturer or supplier, and the purchaser.

5.3 The copper and copper-alloy tubes shall be finished by such cold-working and annealing operations as are necessary to meet the required properties.

5.1 Materials:

5.1.1 The material of manufacture shall be of such quality and purity to be suitable for processing into the products prescribed herein.

5.2 Manufacture:

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

5.2.2 The product shall be hot or cold worked to the finished size, and subsequently annealed when required, to meet the temper properties.

**6. Chemical Composition**

6.1 The material shall conform to the chemical requirements specified composition requirements in Table 1:

6.2 These specification limits do not preclude the presence of other elements. Limits for unnamed elements may be established by agreement between manufacturer or supplier and purchaser.

6.3 For copper alloys in which zinc is specified as the remainder, either copper or zinc may be taken as the difference between the sum of all the elements analyzed and 100%.

6.3.1 Alloy C22000—When all the elements in Table 1 are analyzed, their sum shall be 99.8% minimum for the copper or copper alloy 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 and purchaser, limits may be established and analysis required for unnamed elements.

6.3 For alloys in which zinc is listed as “remainder,” either copper or zinc may be taken as the difference between the sum of results of all other elements determined and 100 %. When all elements for C22000 in Table 1 are determined, the sum of the results shall be 99.8 % minimum.

**7. Rockwell Hardness**

7.1 The material shall conform to the Rockwell hardness requirements prescribed in Table 2.

**8. Microscopical Examination**

8.1 The test specimens of Copper UNS Nos. C10100, C10200, C10300, 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 employed.

**9. Embrittlement Test**

9.1 It is to be expected that samples of Copper UNS Nos. C10100, C10200, C10300, and C12000 covered by this specification shall be capable of passing 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 definitely specified in the ordering information. In case of a dispute, a referee method in accordance with Procedure C shall be employed.

**10. Electrical Resistivity**

10.1 It is to be expected that samples of Copper UNS Nos. C10100, C10200, C10300, and C12000 covered by this specification will conform to the following electrical resistivity requirements, although actual determination of this property is not mandatory under the terms of this specification unless definitely specified. The electrical resistivity of representative samples of Copper UNS No. C10100, shall not exceed 0.15585  $\Omega \cdot g/m$  <sup>Physical Property Requirements</sup>

7.1 Electrical Resistivity Requirement:

7.1.1 When specified in the contract or purchase order, the product furnished from Copper UNS Nos. C10100, C10200, C10300, and C12000 shall be capable of conforming to the following electrical mass resistivity requirements, when tested in accordance with Test Method B193. The electrical resistivity of representative samples of Copper UNS No. C10100, shall not exceed 0.15585

**TABLE 2 Hardness Requirements**

Copper or Copper Alloy UNS No.	Rockwell Hardness, 30T Scale <sup>A</sup>
C10100	30 min
C10200	30 min
C10300	30 min
C12000	30 min
C22000	43 to 66

<sup>A</sup> The tube shall be split along the center line of its narrow side, and Rockwell hardness readings then taken on its inner surface.

$\Omega \cdot \text{g}/\text{m}^2$ , C10200 shall not exceed 0.15737  $\Omega \cdot \text{g}/\text{m}^2$  and Copper UNS No. C10300 shall not exceed 0.15940  $\Omega \cdot \text{g}/\text{m}^2$  and Copper UNS No. C12000 shall not exceed 0.17418  $\Omega \cdot \text{g}/\text{m}^2$  when tested at 68°F (20°C).

NOTE 1—The International Annealed Copper Standard electrical conductivity equivalents are as follows:

Electrical Resistivity, $\Omega \cdot \text{g}/\text{m}^2$	Conductivity, %
0.15176	101.00
0.15328	100.00
0.15585	<u>98.35</u>
<del>0.15614–98.16</del>	<u>98.16</u>
0.15737–97.40	<u>97.40</u>
0.15940–96.16	<u>96.16</u>
0.1703190–	90
<del>0.1741888–</del>	<u>88</u>
0.17418	<u>88</u>

H:

## 8. Mechanical Property Requirements

### 8.1 Rockwell Hardness Requirements :

8.1.1 When specified in the contract or purchase order, the product shall conform to the Rockwell hardness requirement prescribed in Table 2, when tested in accordance with Test Method E18.

## 9. Performance Requirements

### 9.1 Microscopical Examination:

9.1.1 Samples of Copper UNS Nos. C10100, C10200, C10300, 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 of Test Method B577 shall be used.

### 9.2 Hydrogen Embrittlement Test :

9.2.1 Samples of Copper UNS Nos. C10100, C10200, C10300, and C12000 shall be capable of passing 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 definitely specified in the ordering information. In case of a dispute, a referee method in accordance with Procedure C shall be employed.

## 10. Dimensions and Permissible Variations

H:1

### 10.1 General:

10.1.1 The standard method of specifying, ordering, and measuring rectangular waveguide tube shall be major by minor outer dimension and major by minor inner dimension.

10.1.2 All cross-sectional measurements shall be made at the corners at a point at least ½ in. (12.7 mm) from the ends.

10.1.3 For the purpose of determining conformance with the dimensional requirements prescribed in this specification, any measured value outside the specified limiting values for any dimension may be cause for rejection.

### 10.2 Dimensional Tolerances:

10.2.1 Standard dimensions and tolerances of waveguide tube shall be as specified in Table 3.

H:2.2

10.2.2 Other dimensions and tolerances shall be subject to agreement between the manufacturer or supplier and the purchaser.

H:3

10.3 Corner Radii—Outer corner radii shall be 0.015 in. (0.381 mm) min and 0.032 in. (0.813 mm) max. Maximum inner corner radii shall be as specified in Table 4.

H:4

10.4 Eccentricity—The maximum allowable eccentricity, defined as one-half the difference between the maximum and minimum opposite wall thicknesses as measured at any cross section perpendicular to the longitudinal axis, shall be in accordance with Table 5.

H:5

10.5 Rectangularity—The adjoining faces of the tube shall be as square in relation to each other as the best mill practice will permit.

H:6

10.6 Length—Unless otherwise specified, waveguide tube shall be furnished in 12-ft (3.66-m) standard (stock) straight lengths with ends. The shortest permissible length of the ends shall not be less than 60 % of the nominal length (specific and stock), and

**TABLE 3 Dimensional Tolerances**

Outer Dimensions, in. (mm)			Inner Dimensions, in. (mm)			Nominal Wall Thickness, in. (mm)
Major Dimensions	Minor Dimensions	Tolerance, plus and minus	Major Dimensions	Minor Dimensions	Tolerance, plus and minus	
0.420 (10.7)	0.250 (6.35)	0.003 (0.076)	0.340 (8.64)	0.170 (4.32)	0.002 (0.051)	0.040 (1.02)
0.500 (12.7)	0.250 (6.35)	0.003 (0.076)	0.420 (10.7)	0.170 (4.32)	0.002 (0.051)	0.040 (1.02)
0.590 (15.0)	0.335 (8.51)	0.003 (0.076)	0.510 (13.0)	0.255 (6.48)	0.002 (0.051)	0.040 (1.02)
0.702 (17.8)	0.391 (9.93)	0.003 (0.076)	0.622 (15.8)	0.311 (7.90)	0.002 (0.051)	0.040 (1.02)
0.850 (21.6)	0.475 (12.1)	0.003 (0.076)	0.750 (19.0)	0.375 (9.52)	0.003 (0.076)	0.050 (1.27)
1.000 (25.4)	0.500 (12.7)	0.004 (0.10)	0.900 (22.9)	0.400 (10.2)	0.004 (0.10)	0.050 (1.27)
1.250 (31.8)	0.625 (15.9)	0.004 (0.10)	1.122 (28.5)	0.497 (12.6)	0.004 (0.10)	0.064 (1.63)
1.500 (38.1)	0.750 (19.0)	0.004 (0.10)	1.372 (34.8)	0.622 (15.8)	0.004 (0.10)	0.064 (1.63)
1.718 (43.6)	0.923 (23.4)	0.005 (0.13)	1.590 (40.4)	0.795 (20.2)	0.005 (0.13)	0.064 (1.63)
2.000 (50.8)	1.000 (25.4)	0.005 (0.13)	1.872 (47.5)	0.872 (22.1)	0.005 (0.13)	0.064 (1.63)
2.418 (61.4)	1.273 (32.3)	0.006 (0.15)	2.290 (58.2)	1.145 (29.1)	0.006 (0.15)	0.064 (1.63)
3.000 (76.2)	1.500 (38.1)	0.006 (0.15)	2.840 (72.1)	1.340 (34.0)	0.006 (0.15)	0.080 (2.03)
3.560 (90.4)	1.860 (47.2)	0.006 (0.15)	3.400 (86.4)	1.700 (43.2)	0.006 (0.15)	0.080 (2.03)
4.460 (113)	2.310 (58.7)	0.008 (0.20)	4.300 (109)	2.150 (54.6)	0.008 (0.20)	0.080 (2.03)
5.260 (134)	2.710 (68.8)	0.008 (0.20)	5.100 (130)	2.550 (64.8)	0.008 (0.20)	0.080 (2.03)
6.660 (169)	3.410 (86.6)	0.008 (0.20)	6.500 (165)	3.250 (82.6)	0.008 (0.20)	0.080 (2.03)

**TABLE 4 Permissible Inner Corner Radii**

Nominal Wall Thickness, in. (mm)	Permissible Inner Corner Radii, max, in. (mm)
0.040 (1.02)	0.016 (0.41)
0.050 (1.27)	0.032 (0.81)
0.064 (1.63)	0.032 (0.81)
0.080 (2.03)	0.047 (1.2)

**TABLE 5 Eccentricity Tolerances**

Specified Major Outer Dimension, in. (mm)	Allowable Eccentricity, <sup>A</sup> max, in. (mm)
0.420 to 0.850 (10.7 to 21.6), excl	0.003 (0.08)
0.850 to 2.418 (21.6 to 61.4), excl	0.004 (0.10)
2.418 to 3.000 (61.4 to 76.2), excl	0.005 (0.13)
3.000 to 3.560 (76.2 to 90.4), excl	0.006 (0.15)
3.560 to 4.460 (90.4 to 113), excl	0.007 (0.18)
4.460 to 6.660 (113 to 169), incl	0.008 (0.20)

<sup>A</sup> Applicable only to those sizes of tubes shown in Table 3. See 14.0.2.2.

the maximum permissible weight of ends shall not exceed 25 % of the lot weight. Waveguide tube, ordered to specific or stock lengths, with or without ends, shall conform to the tolerances prescribed in Table 6.

11.7

**10.7 Squareness of Cut**—The departure from the squareness of the end of any tube shall not exceed 0.010 in. (0.25 mm) for tube up to 5/8-in. (15.9-mm) dimension, inclusive, across the measured section, and 0.016 in./in. (0.41 mm/mm) of distance between parallel surfaces for tube over 5/8-in. dimension across the measured section.

11.8

**TABLE 6 Length Tolerances**

Length, ft (m)	Tolerance, <sup>A</sup> plus in. (mm)
Standard (stock)	1 (25)
Specific:	
Up to 14 (4.27), incl	1/4 (6.4)
Over 14 (4.27)	1/2 (13)

<sup>A</sup> Applicable only to full-length pieces.

**10.8 Straightness**—The maximum curvature (depth of arc) measured along any 2-ft (0.610-m) portion of the total length shall not exceed 0.010 in. (0.25 mm) edgewise and 0.020 in. (0.51 mm) flatwise on the concave external surfaces. The tube shall be so positioned during measurement that gravity will not tend to increase the amount of bow. The edgewise and flatwise bow shall be determined by using a suitable straightedge.

~~11.9~~

**10.9 Twist**—The maximum twist about the longitudinal axis of the finished tube shall not exceed 1°/ft of length on the face of any surface, inside or outside. Determination of twist shall be in accordance with Test Method B428.

~~11.10~~

**10.10 Surface Roughness**—The average interior surface roughness of the finished tube, in accordance with ANSI B46.1, shall not exceed 32 µin. A.A.<sup>5</sup> for tube up to 4 in. (102 mm) major ID and 64 µin. A.A.<sup>5</sup> for tube whose major ID is 4 in. or over.

~~12.~~

## **11. Workmanship, Finish, and Appearance**

~~12.1~~**11.1** The product shall be free of defects, but blemishes of a nature that do not interfere with ~~normal commercial applications~~, the intended application are acceptable. The finished tube shall be uniform in composition and wall thickness, straight and smooth from end to end, and shall be free of internal or external mechanical imperfections in accordance with good commercial practice. In addition, the interior surface of the tube shall be free of burrs, plug marks, chatter marks, dirt, grease, scale, and splinters. Scratches not more than 0.001-in. (0.025-mm) deep, as measured metallographically, will be permitted in the longitudinal direction of the interior surfaces for tubes 0.622 in. (15.8 mm) by 0.311 in. (7.90 mm) and larger. For tubes smaller than 0.622 by 0.311 in., the depth of scratches on interior surfaces shall not exceed 0.12 % of the width.

~~12.2~~**11.2** Unless otherwise specified, the interior and exterior surfaces of the finished tube shall be bright, dry, and free of scale or oxides.

~~13.~~

## **12. Sampling**

~~13.1~~

**12.1 Sampling**—The lot size, portion size, and selection of sample pieces shall be as follows:

~~13.1.1~~**12.1.1 Lot Size**—The lot size shall be 5000 lb (2270 kg) or fraction thereof.

~~13.1.2~~**12.1.2** An inspection lot shall be 5000 lb (2270 kg) or less, of the same mill form, alloy, rockwell hardness range, and nominal dimensions, subject to inspection at one time.

**12.1.2 Portion Size**—Sample pieces for purpose of tests shall be taken from each lot according to the following schedule:

Number of Pieces in Lot	Number of Sample Pieces to be Taken
1 to 50	1
51 to 200	2
201 to 1500	3
Over 1500	0.2 % of total number of pieces in the lot, but not over 10 samples.

~~14.~~

## **13. Number of Tests and Retests**

~~14.1~~

**13.1 Chemical Analysis**—Samples for chemical analysis shall be taken in accordance with Practice E255. Drillings, millings, and so forth, etc., shall be taken in approximately equal weight from each of the sample pieces selected in accordance with ~~13.1.2~~**12.1.2** and combined into one composite sample. The minimum weight of the composite sample that is to be divided into three equal parts shall be 150 g.

**13.1.1** 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:

**13.1.1.1** 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.

**13.1.1.2** 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.

<sup>5</sup> The symbol "A.A." stands for arithmetic average.