Designation: B 372 – 97

Standard Specification for Seamless Copper and Copper-Alloy Rectangular Waveguide Tube[1]

This standard is issued under the fixed designation B 372; 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.

1. Scope

1.1 This specification covers seamless copper and copper-alloy rectangular tube intended for use as transmission lines in electronic equipment. Four types of material are specified having the following nominal compositions:[2]

Copper or Copper Alloy UNS[2] No.	Previously Used Designation	Nominal Composition, % Copper	Zinc	Phosphorus
C10200	Copper, Type OF[A]	100	...	...
C10300	...	99.99	...	0.003
C12000	Copper, Type DLP[A]	100	...	...
C22000	Commercial bronze, 90 %	90	10	...

[A] Types OF and DLP are described in Classification B 224.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

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:*

B 170 Specification for Oxygen-Free Electrolytic Copper—Refinery Shapes[3]

B 193 Test Method for Resistivity of Electrical Conductor Materials[4]

B 224 Classification of Coppers[3]

B 428 Test Method for Angle of Twist in Rectangular and Square Copper and Copper Alloy Tube[3]

B 577 Test Method for Hydrogen Embrittlement of Copper[3]

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials[5]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[6]

E 53 Test Methods for Chemical Analysis of Copper[7]

E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition[7]

E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)[7]

E 478 Test Methods for Chemical Analysis of Copper Alloys[8]

2.3 *Other Standard:*

ANSI B46.1 Surface Roughness, Waviness, and Lay[9]

3. Terminology

3.1 *Definitions:*

3.1.1 *lengths*—straight pieces of the product.

3.1.1.1 *ends*—straight pieces, shorter than the nominal length, left over after cutting the product into mill lengths, stock lengths or specific lengths. They are subject to minimum length and maximum weight requirements.

3.1.1.2 *specific*—straight lengths that are uniform in length, as specified, and subject to established length tolerances.

3.1.1.3 *specific with ends*—specific lengths, including ends.

3.1.1.4 *stock*—straight lengths that are mill cut and stored in advance of orders. They are usually 12 ft (3.66 m) and subject to established length tolerances.

3.1.1.5 *stock with ends*—stock lengths, including ends.

3.1.2 *tube*—a hollow product of round or any other cross section having a continuous periphery.

3.1.2.1 *tube, waveguide*—a tube used as transmission line to electronic equipment.

4. Ordering Information

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

4.1.1 Material (Sections 1 and 6),

4.1.2 Outer and inner rectangular dimensions (Section 11),

4.1.3 Length (see 11.6),

[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 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] *Annual Book of ASTM Standards*, Vol 02.01.

[4] *Annual Book of ASTM Standards*, Vol 02.03.

[5] *Annual Book of ASTM Standards*, Vol 03.01.

[6] *Annual Book of ASTM Standards*, Vol 14.02.

[7] *Annual Book of ASTM Standards*, Vol 03.05.

[8] *Annual Book of ASTM Standards*, Vol 03.06.

[9] Available from the American National Standards Institute, 11 W. 42 St., 13th Floor, New York, NY 10036.

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).

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 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.

6. Chemical Composition

6.1 The material shall conform to the chemical requirements specified 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.

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. C10200, C10300, and C12000 shall be free of cuprous oxide as determined by Procedure A of Test Method B 577. 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. C10200, C10300, and C12000 covered by this specification shall be capable of passing the embrittlement test of Procedure B of Test Method B 577. 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.

TABLE 1 Chemical Requirements

Element	Composition, %			
	Copper UNS Nos.			Copper Alloy UNS No. C22000
	C10200[A]	C10300	C12000	
Copper[B]	99.95 min	...	99.90 min	89.0–91.0
Copper,[B] + phosphorus, min	...	99.95	...	...
Phosphorus	...	0.001–0.005	0.004–0.012	...
Zinc	...	...	...	remainder
Lead, max	...	...	...	0.05
Iron, max	...	...	...	0.05

[A] Oxygen in C10200 shall be 10 ppm max.
[B] Silver counting as copper.

TABLE 2 Hardness Requirements

Copper or Copper Alloy UNS No.	Rockwell Hardness, 30T Scale[A]
C10200	30 min
C10300	30 min
C12000	30 min
C22000	43 to 66

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

10. Electrical Resistivity

10.1 It is to be expected that samples of Copper UNS Nos. 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. C10200 shall not exceed 0.15737 $\Omega \cdot g/m^2$ and Copper UNS No. C10300 shall not exceed 0.15940 $\Omega \cdot g/m^2$ and Copper UNS No. C12000 shall not exceed 0.17418 $\Omega \cdot g/m^2$ when tested at 68°F (20°C).

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

Electrical Resisitivity, $\Omega \cdot g/m^2$	Conductivity, %
0.15176	101.00
0.15328	100.00
0.15614	98.16
0.15737	97.40
0.15940	96.16
0.17031	90
0.17418	88

11. Dimensions and Permissible Variations

11.1 *General*:

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

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

11.1.3 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.

11.2 *Dimensional Tolerances*:

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

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

11.3 *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.

11.4 *Eccentricity*—The maximum allowable eccentricity, defined as one-half the difference between the maximum 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 (0.010)	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 6 Length Tolerances

Length, ft (m)	Tolerance,[A] plus in. (mm)
Standard (stock)	1 (25)
Specific:	
Up to 14 (4.27), incl	¼(6.4)
Over 14 (4.27)	½(13)

[A] Applicable only to full-length pieces.

minimum opposite wall thicknesses as measured at any cross section perpendicular to the longitudinal axis, shall be in accordance with Table 5.

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

11.6 *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 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.

TABLE 5 Eccentricity Tolerances

Specified Major Outer Dimension, in. (mm)	Allowable Eccentricity,[A] 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)

[A] Applicable only to those sizes of tubes shown in Table 3. See 11.2.2.

11.7 *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 ⅝-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 ⅝-in. dimension across the measured section.

11.8 *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 *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 B 428.

11.10 *Surface Roughness*—The average interior surface roughness of the finished tube, in accordance with ANSI B46.1, shall not exceed 32 µin. A.A.[10] for tube up to 4 in. (102 mm) major ID and 64 µin. A.A.[10] for tube whose major ID is 4 in. or over.

[10] The symbol "A.A." stands for arithmetic average.

12. Workmanship, Finish, and Appearance

12.1 The material shall be free of defects of a nature that interfere with normal commercial applications. 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 Unless otherwise specified, the interior and exterior surfaces of the finished tube shall be bright, dry, and free of scale or oxides.

13. Sampling

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

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

13.1.2 *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. Number of Tests and Retests

14.1 *Chemical Analysis*—Samples for chemical analysis shall be taken in accordance with Practice E 55. Drillings, millings, etc., shall be taken in approximately equal weight from each of the sample pieces selected in accordance with 13.1.2 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.

14.1.1 Instead of sampling in accordance with Practice E 55, 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:

14.1.1.1 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.

14.1.1.2 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.

14.1.1.3 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.

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

14.2 *Number of Tests*—Sample pieces selected for purpose of tests in accordance with 13.1 shall be subjected to the following tests.

14.2.1 A specimen from each sample piece shall be subjected to the Rockwell hardness test (see 15.1). The value for the Rockwell hardness number of each specimen shall be established by taking the arithmetical average of at least three readings.

14.2.2 In the case of Copper UNS Nos. C10200, C10300, and C12000, a specimen from each sample piece shall be submitted to microscopical examination as specified in Section 8, to the embrittlement test, if specified, as prescribed in Section 9; and also for determination of electrical resistivity, if specified, as prescribed in Section 10.

14.3 *Retests*:

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

14.3.2 If the results of the test on one of the specimens fail to meet the specified requirements, two additional specimens shall be taken from different sample pieces and tested. The results of the tests on both of these specimens shall meet the specified requirements. Failure of more than one specimen to meet the specified requirements for a particular property shall be cause for rejection of the entire lot.

14.3.3 If the chemical analysis fails to conform to the specified limits, analysis shall be made on a new composite sample prepared from additional pieces selected in accordance with 13.1. The results of this retest shall comply with the specified requirements.

15. Test Methods

15.1 The properties enumerated in this specification shall, in the case of disagreement, be determined in accordance with the following applicable methods:

Test	ASTM Designation
Chemical analysis	B 170,[A] E 53, E 62, E 478
Rockwell hardness	E 18
Electrical resistivity	B 193

[A] Reference to Specification B 170 is to the suggested chemical methods in the annex thereof. When Committee E-1 has tested and published methods for assaying the low-level impurities in copper, the Specification B 170 annex will be eliminated.

16. Significance of Numerical Limits

16.1 For purposes of determining compliance with the specified limits for requirements of chemical composition, hardness, and electrical resistivity, an observed value or a calculated value shall be rounded to the nearest unit in the last right-hand place of the figures of the specified limit in accordance with the rounding method of Practice E 29.

17. Inspection

17.1 The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy him that the material is being furnished in accordance with the specified requirements.

18. Rejection and Rehearing

18.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the manufacturer or supplier may make claim for a rehearing.

19. Packaging and Package Marking

19.1 The material shall be separated by size, composition,and temper, and prepared for shipment in such a manner as to ensure acceptance by common carrier for transportation and to afford protection from the normal hazards of transportation.

19.2 Each shipping unit shall be legibly marked with the purchase order number, metal or alloy designation, temper, size, shape, gross and net weight, and name of supplier. The specification number shall be shown, when specified.

APPENDIXES

(Nonmandatory Information)

X1. CROSS INDEX OF WAVEGUIDE DESIGNATIONS

X1.1 This Appendix gives the ASESA[B] and EIA[A] designations for those sizes of waveguide tube covered herein.These data are given in Table X1.1 for information purposes only.

X2. METRIC EQUIVALENTS

X2.1 The SI unit for strength properties now shown is in accordance with the International System of Units (SI). The derived SI unit for force is the newton (N), which is defined as that force which when applied to a body having a mass of one kilogram gives it an acceleration of one metre per second squared ($N = kg \cdot m/s^2$). The derived SI unit for pressure or stress is the newton per square metre (N/m^2), which has been named the pascal (Pa) by the General Conference of Weights and Measures. Since 1 ksi = 6 894 757 Pa the metric equivalents are expressed as megapascal (MPa), which is the same as MN/m^2 and N/mm^2.

TABLE X1.1 Waveguide Designations

Outer Dimensions, in.		Inner Dimensions, in.		Reference Designations	
Major	Minor	Major	Minor	EIA[A]	ASESA[B]
0.420	0.250	0.340	0.170	WR34	RG-354/U
0.500	0.250	0.420	0.170	WR42	RG-53/U
0.590	0.335	0.510	0.255	WR51	RG-352/U
0.702	0.391	0.622	0.311	WR62	RG-91/U
0.850	0.475	0.750	0.375	WR75	RG-346/U
1.000	0.500	0.900	0.400	WR90	RG-52/U
1.250	0.625	1.122	0.497	WR112	RG-51/U
1.500	0.750	1.372	0.622	WR137	RG-50/U
1.718	0.923	1.590	0.795	WR159	RG-343/U
2.000	1.000	1.872	0.872	WR187	RG-49/U
2.418	1.273	2.290	1.145	WR229	RG-340/U
3.000	1.500	2.840	1.340	WR284	RG-48/U
3.560	1.860	3.400	1.700	WR340	RG-112/U
4.460	2.310	4.300	2.150	WR430	RG-104/U
5.260	2.710	5.100	2.550	WR510	RG-337/U
6.660	3.410	6.500	3.250	WR650	RG-69/U

[A] Electronic Industries Association.
[B] Armed Services Electro-Standards Agency.