



Designation: B48 – 00 (Reapproved 2021)<sup>ε1</sup>

# Standard Specification for Soft Rectangular and Square Bare Copper Wire for Electrical Conductors<sup>1</sup>

This standard is issued under the fixed designation B48; 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.

<sup>ε1</sup> NOTE—Table 1 was corrected editorially in October 2021.

## 1. Scope

1.1 This specification covers soft or annealed bare copper wire, rectangular or square in shape with rounded corners (Explanatory Note 1).

1.2 For the purpose of this specification, the wire is classified as follows:

1.2.1 *Type A*—For all applications except those involving edgewise bending.

1.2.2 *Type B*—For applications involving edgewise bending. Type B wire of thickness less than 0.020 in. (0.51 mm) or with a ratio of width to thickness greater than 30 to 1 is not contemplated in this specification.

1.3 Unless otherwise specified by the purchaser, Type A material shall be furnished.

1.4 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 are provided for information only and are not considered standard; except for Sections 12 and 13.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

2.1 *ASTM Standards*:<sup>2</sup>

B49 Specification for Copper Rod for Electrical Purposes

B193 Test Method for Resistivity of Electrical Conductor Materials

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee B01 on Electrical Conductors and is the direct responsibility of Subcommittee B01.04 on Conductors of Copper and Copper Alloys.

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<sup>2</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.

B279 Test Method for Stiffness of Bare Soft Square and Rectangular Copper and Aluminum Wire for Magnet Wire Fabrication

E8/E8M Test Methods for Tension Testing of Metallic Materials

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.2 *Other Documents*:

NBS Handbook 100 Copper Wire Tables<sup>3</sup>

## 3. Ordering Information

3.1 Orders for material to this specification shall include the following information:

3.1.1 Quantity of each size;

3.1.2 Type of wire (see 1.1, 1.2, and 1.3);

3.1.3 Wire size: thickness and width, in inches or millimetres (see 6.1);

3.1.4 Type of copper, if special (see Section 4);

3.1.5 Package size (see 16.1);

3.1.6 Special package marking, if required; and

3.1.7 Place of inspection (see Section 15).

## 4. Material

4.1 The material shall be copper of such quality and purity that the finished product shall have the properties and characteristics prescribed in this specification.

4.2 Specification B49 defines the materials suitable for use.

## 5. Manufacture

5.1 The wire shall be annealed after the last drawing or rolling to size and shape, and shall be so processed as to produce a uniformly soft product with a clean surface.

5.2 The finished wire shall not contain joints except such as have passed through drawing dies. Necessary joints in the wire and rods prior to final drawing shall be made in accordance with good commercial practice.

<sup>3</sup> Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, http://www.nist.gov.

**TABLE 1 Variation in Thickness**

Specified Thickness				Width							
				Over 1.000† in. (25.4 mm)		1.000 in. (25.4 mm) to 0.492 in. (12.5 mm)				Under 0.492 in. (12.5 mm)	
in.		mm		Permissible Variation in Thickness, max, plus and minus							
		in.	%	mm	in.	%	mm	in.	%	mm	
0.501 and over		12.73 and over		...	1	...	...	1	...	...	
under	to, incl	under	to, incl	...	1	...	...	0.003	...	0.076	
0.501	0.280	12.73	7.11	...	1	...	...	...	1	...	
0.280	0.201	7.11	5.11	0.003	...	0.08	...	...	...	...	
0.201	0.098	5.11	2.49	0.0025	...	0.064	...	1	...	...	
0.098	0.051	2.49	1.30	0.002	...	0.051	0.001	...	0.03	0.001	
0.051	...	1.30	...	0.0015	...	0.038	0.001	...	0.03	0.001	

† Editorially corrected.

## 6. Dimensions and Permissible Variations

6.1 The dimensions shall be expressed in decimal fractions of an inch or in millimetres. Unless otherwise specified, it will be assumed that the dimensions are in inches. (Explanatory Note 6, Explanatory Note 7, and Explanatory Note 8.)

6.2 The thickness shall not vary from that specified by more than the amounts prescribed in Table 1.

6.3 The width shall not vary from that specified by more than the amounts prescribed in Table 2.

6.4 The wire shall have rounded corners or rounded edges as specified in Table 3 and as shown in Fig. 1. Where rounded corners are required, the corners of the wire shall be rounded within the limits of radii, 25 % under and 25 % over (as determined by a radius gage) those radii values specified in Table 3.

6.5 From each shipping unit, approximately 12 ft (3.66 m) shall be unwound and the wire gaged at six places between points 12 in. (30.5 cm) and 12 ft (3.66 m) from the end. The shipping unit shall be rejected if the average of the measurements obtained is not within the limits specified in 6.2 and 6.3.

## 7. Physical Requirements

### 7.1 Elongation:

7.1.1 Type A wire shall conform to the requirements for elongation given in Table 4.

7.1.2 For Type B wire elongation tests shall not be required.

7.1.3 Elongation tests shall be made in accordance with Test Methods E8/E8M on representative samples. The elongation shall be determined as the permanent increase in length, due to the breaking of the wire in tension, measured between gage marks placed originally 10 in. (250 mm) apart upon the test specimen (Explanatory Note 2). The fracture shall be in between gage marks and not closer than 1 in. (25 mm) to either gage mark.

### 7.2 Bending:

7.2.1 Both edges of Type B wire shall withstand bending edgewise through 180° around the mandrel indicated without cracking. The mandrel shall be one of the sizes shown in Table 5 and shall be the size that is equal to or next larger than the figure obtained by multiplying the width of the wire by the factor in Table 6, corresponding to the ratio of the width to the thickness of the wire. In cases where the mandrel diameter desired is less than 0.156 in. (3.96 mm) or the thickness is less than 0.020 in. (0.51 mm) or the ratio of the width to thickness of the wire is greater than 30 to 1, the scope of Type B wire is exceeded and the edgewise bending properties shall be as agreed upon between the purchaser and the manufacturer (Explanatory Note 3 and Explanatory Note 4).

7.2.2 For Type A wire the bend test shall not be required.

### 7.3 Low Stress Elongation (LSE):

7.3.1 Types A and B wire shall have a minimum LSE value of 1 % determined in accordance with Test Method B279. (Explanatory Note 5).

### 7.4 Retests:

7.4.1 If upon testing a sample from any coil or reel of wire, the results do not conform to the respective requirements of 7.1, 7.2, and 7.3, two additional samples shall be tested, each of which shall conform to the prescribed requirements.

## 8. Standard Reference Temperature

8.1 For the purpose of this specification, all wire dimensions and properties shall be considered as occurring at the internationally standardized reference temperature of 20 °C.

## 9. Standard Rules for Rounding Off

9.1 All calculations for the standard nominal dimensions and properties of rectangular and square wires shall be rounded off in the final value only, in accordance with the rounding-off method of Practice E29.

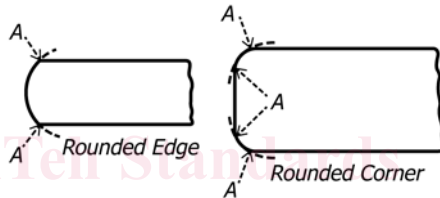
**TABLE 2 Variation in Width**

Specified Width		Permissible Variation in Width, max, plus and minus
in.	mm	
0.492 and over	12.5 and over	1 % but not to exceed 0.016 in. (0.406 mm)
Under 0.492 to 0.315, incl	under 12.5 to 8.00, incl	0.003 in. (0.076 mm)
Under 0.315 to 0.098, incl	under 8.00 to 2.49, incl	1 %
Under 0.098	under 2.49	0.001 in. (0.025 mm)

**TABLE 3 Requirements for Rounded Corners and Rounded Edges**

Specified Thickness				Corner Radius for Specified Width					
in.		mm		in.	mm	in.	mm		
0.689 and over		17.50 and over		0.188	4.78	0.188	4.78	...	...
under	to, incl	under	to, incl	0.748 and over	19.0 and over	under 0.748 to 0.187, incl	under 19.0 to 4.75, incl	under 0.187	under 4.75
0.689	0.439	17.50	11.15	0.125	3.18	0.094	2.39	...	...
0.439	0.280	11.15	7.10	0.094	2.39	0.039	1.00	...	...
0.280	0.177	7.10	4.50	0.063	1.60	0.039	1.00	0.039	1.00
0.177	0.124	4.50	3.15	0.063	1.60	0.03	0.80	0.03	0.80
0.124	0.098	3.15	2.15	rounded edge <sup>A</sup>		0.03 <sup>B</sup>	0.80 <sup>B</sup>	0.026	0.67
0.098 <sup>C</sup>	0.063	2.15 <sup>C</sup>	1.60	rounded edge <sup>A</sup>		0.03 <sup>B</sup>	0.80 <sup>B</sup>	0.020	0.50
0.063 <sup>D</sup>	...	1.60 <sup>D</sup>	...	rounded edge <sup>A</sup>		full rounded edge <sup>E</sup>		full rounded edge <sup>E</sup>	

<sup>A</sup> A rounded edge is an edge produced by (1) rolling wire to the size specified either with or without edging rolls or (2) drawing through a die (see Fig. 1).  
<sup>B</sup> Rectangular wire with a thickness under 0.124 in. (3.15 mm) to 0.063 in. (1.60 mm) and a width under 0.751 in. (19.08 mm) to 0.189 in. (4.80 mm) may be manufactured with the corner radius specified for the same thickness and a width under 0.189 in. (4.80 mm).  
<sup>C</sup> Square wire 0.072 in. (1.83 mm) and under shall have a corner radius of 0.016 in. (0.41 mm) ±25%.  
<sup>D</sup> Rectangular wire with a thickness under 0.063 in. (1.60 mm) to 0.03 in. (0.80 mm) may be manufactured with a corner radius of 0.016 in. (0.41 mm) ±25%.  
<sup>E</sup> Except as permitted by Footnote B, rectangular wire less than 0.751 in. (19.08 mm) wide with full rounded edge shall have a radius half the thickness of the wire, ±25%.



NOTE 1—The arc is not necessarily tangent to the flats at points A. However, the wire shall be commercially free of sharp, rough, or projecting edges.

**FIG. 1 Sections of Wire with Rounded Edges and Rounded Corners**

**TABLE 4 Requirements for Elongation**

Specified Thickness		Elongation in 10 in. (250 mm); min, %
in.	mm	
0.290 and over	7.37 and over	35
Under 0.290 to 0.051, incl	under 7.37 to 1.30, incl	32
Under 0.051 to 0.021, incl	under 1.30 to 0.53, incl	32
Under 0.021 to 0.011, incl	under 0.53 to 0.28, incl	25
Under 0.011	under 0.28	20

**TABLE 5 Standard Mandrel Sizes for Edgewise Bend Test**

Mandrel Diameters			
in.	mm	in.	mm
0.156	3.96	0.625	15.9
0.188	4.78	0.750	19.0
0.220	5.59	0.875	22.2
0.250	6.35	1.000	25.4
0.312	7.98	1.250	31.8
0.375	9.52	1.500	38.1
0.438	11.1	1.750	44.4
0.500	12.7	2.000 <sup>A</sup>	50.8

<sup>A</sup> The maximum mandrel diameter of 2 in. (50.8 mm) is based on the suggested maximum width of strap, made from round copper wire, of 1.250 in. (31.8 mm), established by the Copper Development Association.

**TABLE 6 Factor for Determining Mandrel Size for Edgewise Bend Test**

Width to Thickness Ratio	Multiplying Factor to Determine Mandrel Size
30 to 20, incl	1.50
Under 20 to 10, incl	1.25
Under 10 to 5, incl	1.00
Under 5 to 2.5, incl	0.75
Under 2.5	0.50

and width dimensions in mils (0.001 in.) or millimetres as applicable. Values so derived shall be rounded off in accordance with Section 9 to the same number of significant figures as used in expressing the nominal dimensions, but in no case to less than three significant figures.

**11. Nominal Mass/Unit Length and Length**

11.1 Nominal mass/unit length and lengths shall be calculated from the nominal wire dimensions in accordance with the

**10. Nominal Cross-Sectional Areas**

10.1 Nominal cross-sectional areas in square mils or square millimetres shall be calculated by subtracting the area reductions due to rounded corners or rounded edges (see Table 7 and Table 8) from the product of the specified nominal thickness

TABLE 7 Areas of Square Copper Wire

Nominal Size		Calculated Area of Perfect Square		Nominal Corner Radius		Calculated Departure <sup>A</sup>		Nominal Area		Nominal Area Working Value	
in.	mm	mil <sup>2</sup>	mm <sup>2</sup>	in.	mm	mils <sup>2</sup>	mm <sup>2</sup>	mils <sup>2</sup>	mm <sup>2</sup>	mils <sup>2</sup>	mm <sup>2</sup>
1	2	3	4	5	6	7	8	9	10	11	12
0.0508	1.290	2580.64	1.66493	0.016	0.41	219.75	0.14177	2360.89	1.52315	2.36 × 10 <sup>-3</sup>	1.52
0.0571	1.450	3260.41	2.10349	0.016	0.41	219.75	0.14177	3040.66	1.96171	3.04	1.96
0.0641	1.628	4108.81	2.65038	0.016	0.41	219.75	0.14177	3889.06	2.50907	3.89	2.51
0.0720	1.829	5184.00	3.34451	0.016	0.41	219.75	0.14177	4964.25	3.20274	4.96	3.20
0.0808	2.052	6528.64	4.21202	0.020	0.51	343.36	0.22151	6185.28	3.99050	6.19	3.99
0.0907	2.304	8226.49	5.30740	0.020	0.51	343.36	0.22151	7883.13	5.08588	7.88	5.09
0.1019	2.588	10383.61	6.69909	0.026	0.66	580.28	0.37437	9803.33	6.32472	9.80	6.32
0.1144	2.906	13087.36	8.44344	0.026	0.66	580.28	0.37437	12507.08	8.06907	12.51	8.07
0.1285	3.264	16512.25	10.65304	0.032	0.81	879.00	0.56710	15633.25	10.08595	15.63	10.09
0.1443	3.665	20822.49	13.43384	0.032	0.81	879.00	0.56710	19943.49	12.86674	19.94	12.87
0.1620	4.115	26244.00	16.93158	0.032	0.81	879.00	0.56710	25365.00	16.36448	25.36†	16.36
0.1819	4.620	33087.61	21.34680	0.040	1.02	1373.44	0.88609	31714.17	20.46071	31.71	20.46
0.2043	5.189	41738.49	26.92800	0.040	1.02	1373.44	0.88609	40365.05	26.04192	40.37	26.04
0.2294	5.827	52624.36	33.95113	0.040	1.02	1373.44	0.88609	51250.92	33.06504	51.25	33.07
0.2576	6.543	66357.76	42.81137	0.040	1.02	1373.44	0.88609	64984.32	41.92528	64.98	41.93
0.2893	7.348	83694.49	53.99634	0.040	1.02	1373.44	0.88609	82321.05	53.11025	82.32	53.11
0.3249	8.252	105560.01	68.10310	0.040	1.02	1373.44	0.88609	104186.57	67.21701	104.2	67.22
0.3648	9.266	133097.04	85.86889	0.040	1.02	1373.44	0.88609	131723.60	84.98280	131.7	84.98
0.4096	10.404	167772.16	108.23989	0.040	1.02	1373.44	0.88609	166398.72	107.35380	166.4	107.4
0.4600	11.684	211600.00	136.51586	0.094	2.39	7584.82	4.89342	204015.18	131.62243	204.0	131.6

<sup>A</sup> The reduction in area due to rounding the corners.

TABLE 8 Calculated Reduction in Area Due to Rounding of Corners of Rectangular Wire

Specified Thickness		Specified Width											
		in.		mm		in.		mm					
		0.751 and over		19.08 and over		under 0.751 to 0.189, incl		under 19.08 to 4.80, incl		under 0.189 to 4.80			
		mils <sup>2</sup>		mm <sup>2</sup>		mils <sup>2</sup>		mm <sup>2</sup>		mils <sup>2</sup>		mm <sup>2</sup>	
in.		mm		30339.29		19.5732		30339.29		19.5737		...	
0.689 and over		17.50 and over		...		...		...		...		...	
under	to, incl	under	to, incl	30339.29	19.5732	30339.29	19.5737	...	...	...	...	...	...
0.689	0.439	17.50	11.15	13412.50	8.65321	7584.82	4.89342	4.89342	...	...	...	...	...
0.439	0.226	11.15	5.74	7584.82	4.89342	1373.44	0.88609	0.88609	...	...	...	...	...
0.226	0.166	5.24	4.22	3406.90	2.19805	1373.44	0.88609	1373.44	0.88609	1373.44	0.88609	...	...
0.166	0.126	4.22	3.20	3406.00	2.19805	879.00	0.56710	879.00	0.56710	879.00	0.56710	879.00	0.56710
0.126	0.096	3.20	2.44	A	A	879.00	0.56710	580.28	0.56710	580.28	0.56710	580.28	0.56710
0.096	0.061	2.44	1.55	A	A	879.00	0.56710	343.36	0.56710	343.36	0.56710	343.36	0.56710
0.061	...	1.55	...	A	A	A	A	A	A	A	A	A	A

<sup>A</sup> For wire with rounded edges, the calculated reduction in area in square mils is equivalent to  $214\,600\,T^2$ , where  $T$  is the thickness of the wire in inches, and the calculated reduction in area in square mm is equivalent to  $0.2146\,T_1^2$ , where  $T_1$  is the thickness of the wire in millimetres. For square wire, see Table 7.

following equations and shall be rounded off in the final value only, in accordance with Section 9, to the same number of significant figures as used in expressing the nominal dimensions, but in no case to less than three significant figures:

$$\text{Mass/Unit Length, lb/1000 ft} = 3.8540 \times A \times 10^{-3}$$

$$\text{kg/km} = 8.89 \times A_1$$

$$\text{Length, ft/lb} = (2.5947 \times 10^5)/A$$

$$\text{m/kg} = 112.486/A_1$$

where:

$A$  = nominal cross-sectional area in square mils, obtained in accordance with Section 10, and

$A_1$  = nominal cross-sectional area in square millimetres obtained in accordance with Section 10.

## 12. Resistivity

12.1 Electrical resistivity shall be determined on representative samples by resistance measurements (Explanatory Note 9). At a temperature of 20 °C, the resistivity shall not exceed  $0.017241\,\Omega \cdot \text{mm}^2/\text{m}$ .

12.2 Tests to determine conformance to electrical resistance requirements shall be made on the uninsulated conductor in accordance with Test Method B193.