



Designation: B33 – 04

# Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes<sup>1</sup>

This standard is issued under the fixed designation B33; 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 Department of Defense.*

## 1. Scope

1.1 This specification covers tinned, round, soft, or annealed copper wire for electrical purposes.

1.2 The SI values for density and resistivity are to be regarded as standard. For all other properties the inch-pound values are to be regarded as the standard and the SI units may be approximate.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

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

**B49** Specification for Copper Rod Drawing Stock for Electrical Purposes

**B193** Test Method for Resistivity of Electrical Conductor Materials

**B258** Specification for Nominal Diameters and Cross-Sectional Areas of AWG Sizes of Solid Round Wires Used as Electrical Conductors

2.2 *Other Document:*<sup>3</sup>

NBS Handbook 100 Copper Wire Tables

## 3. Ordering Information

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

<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.

<sup>3</sup> Available from National Technical Information Service (NTIS), U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.

3.1.1 Quantity of each size,

3.1.2 Wire size-diameter in inches (see 5.3 and Table 1),

3.1.3 Type of copper, if special (see 4.2),

3.1.4 Package size (see 10.1),

3.1.5 Special packaging marking, if required, and

3.1.6 Place of inspection (see 7.1).

## 4. Material

4.1 *Tin for Coating*—The tin used for coating shall be commercially pure (Explanatory Note 1). For purposes of this specification, the tin shall be considered commercially pure if the total of other elements, exclusive of copper, does not exceed 1%. Notwithstanding the previous sentence, chemical analysis of the tin coating or of the tin used for coating shall not be required under this specification. Adequacy of the tin coating is assured by the continuity of coating and adherence of coating requirements (see 5.4 and 5.5, respectively).

4.2 *Copper-Base Metal*—The base metal shall be copper of such quality and purity that the finished product shall have properties and characteristics prescribed in this specification.

NOTE 1—Specification B49 defines copper suitable for use.

4.3 Copper bars of special qualities, forms, or types, as may be agreed upon between the manufacturer and the purchaser, and which will conform to the requirements prescribed in this specification, may also be used.

## 5. General Requirements (See Section 8)

5.1 *Tensile Strength and Elongation (Explanatory Note 2 and Note 3)*—The tinned wire shall conform to the requirements for elongation prescribed in Table 1. No requirements for tensile strength are specified. For wire whose nominal diameter is more than 0.001 in. (1 mil) (0.025 mm) greater than a size listed in Table 1, but less than that of the next larger size, the requirements of the next larger size shall apply.

5.2 *Resistivity (Explanatory Note 1 and Note 4)*—The electrical resistivity of tinned wire at a temperature of 20°C shall not exceed the values prescribed in Table 2.

**TABLE 1 Tensile Requirements**

Diameter		Area at 20°C			Elongation in 10 in. (250 mm), % min
in.	mm	cmil	in. <sup>2</sup>	mm <sup>2</sup>	
0.4600	11.6840	211600.00	0.166190	107.2193	30
0.4096	10.4038	167772.16	0.131768	85.0114	30
0.3648	9.2659	133079.04	0.104520	67.4321	30
0.3249	8.2525	105560.01	0.082907	53.4880	30
0.2893	7.3482	83694.49	0.065733	42.4086	25
0.2576	6.5430	66357.76	0.052117	33.6240	25
0.2294	5.8268	52624.36	0.041331	26.6652	25
0.2043	5.1892	41738.49	0.032781	21.1492	25
0.1819	4.6203	33087.61	0.025987	16.7657	25
0.1620	4.1148	26244.00	0.020612	13.2980	25
0.1443	3.6652	20822.49	0.016354	10.5509	25
0.1285	3.2639	16512.25	0.012969	8.3669	25
0.1144	2.9058	13087.36	0.01027879	6.6315	25
0.1019	2.5883	10383.61	0.00815527	5.2615	20
0.0907	2.3038	8226.49	0.00646107	4.1684	20
0.0808	2.0523	6528.64	0.00512758	3.3081	20
0.0720	1.8288	5184.00	0.00407150	2.6268	20
0.0641	1.6281	4108.81	0.00322705	2.0820	20
0.0571	1.4503	3260.41	0.00256072	1.6521	20
0.0508	1.2903	2580.64	0.00202683	1.3076	20
0.0453	1.1506	2052.09	0.00161171	1.0398	20
0.0403	1.0236	1624.09	0.00127556	0.8229	20
0.0359	0.9119	1288.81	0.00101223	0.6530	20
0.0320	0.8128	1024.00	0.00080425	0.5189	20
0.0285	0.7239	812.25	0.00063794	0.4116	20
0.0253	0.6426	640.09	0.00050273	0.3243	20
0.0226	0.5740	510.76	0.00040115	0.2588	20
0.0201	0.5105	404.01	0.00031731	0.2047	15
0.0179	0.4547	320.41	0.00025165	0.1624	15
0.0159	0.4039	252.81	0.00019856	0.1281	15
0.0142	0.3607	201.64	0.00015837	0.1022	15
0.0126	0.3200	158.76	0.00012469	0.0804	15
0.0113	0.2870	127.69	0.00010029	0.0647	15
0.0100	0.2540	100.00	0.00007854	0.0507	10
0.0089	0.2261	79.21	0.00006221	0.0401	10
0.0080	0.2032	64.00	0.00005027	0.0324	10
0.0071	0.1803	50.41	0.00003959	0.0255	10
0.0063	0.1600	39.69	0.00003117	0.0201	10
0.0056	0.1422	31.36	0.00002463	0.0159	10
0.0050	0.1270	25.00	0.00001963	0.0127	10
0.0045	0.1143	20.25	0.00001590	0.0103	10
0.0040	0.1016	16.00	0.00001257	0.0081	10
0.0035	0.0889	12.25	0.00000962	0.0062	10
0.0031	0.0787	9.61	0.00000755	0.0049	10

**TABLE 2 Electrical Resistivity Requirements**

Nominal Diameter		Resistivity at 20°C	
in.	mm	Ω-lb/mile <sup>2</sup>	Ω-g/m <sup>2</sup>
0.460 to 0.290, incl	11.7 to 7.4, incl	896.15	0.15695
Under 0.290 to 0.103, incl	Under 7.4 to 2.6, incl	900.77	0.15776
Under 0.103 to 0.0201, incl	Under 2.6 to 0.51, incl	910.15	0.15940
Under 0.0201 to 0.0111 incl	Under 0.51 to 0.28, incl	929.52	0.16279
Under 0.0111 to 0.0030, incl	Under 0.28 to 0.076, incl	939.51	0.16454

**5.3 Dimensions and Permissible Variations (Explanatory Note 2)**—The wire sizes shall be expressed as the diameter of

the wire in decimal fractions of an inch to the nearest 0.0001 in. (0.1 mil) or in millimetres to the nearest 0.0025 mm. The tinned wire shall not vary from the specified diameter by more than the amounts prescribed in **Table 3**.

**5.4 Continuity of Coating**—The tin coating shall be continuous. The continuity of coating on the wire shall be determined on representative samples taken before stranding or insulating. The continuity of tinning shall be determined by the hydrochloric acid-sodium polysulfide test in accordance with **6.4**.

**5.5 Adherence of Coating**—The tin coating shall be firmly adherent to the surface of the copper. The adherence of coating on the wire shall be determined on representative samples taken before stranding or insulating. The adherence of coating shall be determined by the wrapping and immersion test in accordance with **6.5**.

**5.6 Joints**—Necessary joints in the completed wire and in the wire and rods prior to final drawing shall be made in accordance with the best commercial practice.

**5.7 Finish**—The coating shall consist of a smooth continuous layer, firmly adherent to the surface of the copper. The wire shall be free of all imperfections not consistent with the best commercial practice.

## 6. Test Methods

**6.1 Tensile Strength and Elongation (Explanatory Note 5)**—No test for tensile strength shall be required. The elongation of wire whose nominal diameter is larger than 0.0808 in. (2.052 mm) in diameter shall be determined as the permanent increase in length, expressed in percent of the original length, due to the breaking of the wire in tension, measured between gage marks placed originally 10 in. (254 mm) apart upon the test specimen. The elongation of wire whose nominal diameter is 0.0808 in. and under may be determined as described above or by measurements made between the jaws of the testing machine. When the latter method is used, the zero length shall be the distance between the jaws at the start of the tension test and be as near 10 in. as practicable and the final length shall be the distance between the jaws at the time of rupture. The fracture shall be between gage marks in the case of specimens so marked or between the jaws of the testing machine and not closer than 1 in. (25.4 mm) to either gage mark or either jaw.

**6.2 Resistivity (Explanatory Note 4)**—The electrical resistivity of the material shall be determined in accordance with Test Method **B193**. The purchaser may accept certification that the wire was drawn from rod stock meeting the international standard for annealed copper instead of resistivity tests on the finished wire.

**6.3 Dimensional Measurements**—Dimensional measurements shall be made with a micrometre caliper equipped with a vernier graduated in 0.0001 in. (0.0025 mm). Measurements

**TABLE 3 Permissible Variations in Diameter**

Nominal Diameter of Wire		Permissible Variations in Diameter			
		in.		mm	
in.	mm	plus	minus	plus	minus
Under 0.0100	Under 0.25	0.0003	0.00010	0.0076	0.0025
0.0100 and over	0.25 and over	3 %	1 %	3 %	1 %

shall be made on at least three places on each unit selected for this test. If accessible, one measurement shall be taken on each end and one near the middle. The average of the three measurements shall determine compliance with the requirements.

#### 6.4 Continuity of Coating:

##### 6.4.1 Specimens:

6.4.1.1 *Length of Specimens*—Test specimens shall have a length of about 6 in. (152 mm). They shall be tagged or marked to correspond with the coil, spool, or reel from which they were cut.

6.4.1.2 *Treatment of Specimens*—The specimens shall be thoroughly cleaned by immersion in a suitable organic solvent such as benzene, ether, or trichloroethylene for at least 3 min; then removed and wiped dry with a clean, soft cloth (**Caution**—see Explanatory **Note 6**). The specimens thus cleaned shall be kept wrapped in a clean, dry cloth until tested. That part of the specimen to be immersed in the test solution shall not be handled. Care shall be taken to avoid abrasion by the cut ends.

##### 6.4.2 Special Solutions Required:

6.4.2.1 *Hydrochloric Acid Solution (HCl) (sp gr 1.088)*—Commercial HCl (sp gr 1.12) shall be diluted with distilled water to a specific gravity of 1.088 measured at 15.6°C (60°F). A portion of HCl solution having a volume of 180 mL shall be considered to be exhausted when the number of test specimens prescribed in **Table 4** of a size as indicated in **6.4.3** have been immersed in it for two cycles.

6.4.2.2 *Sodium Polysulfide Solution (sp gr 1.142) (Explanatory Note 7)*—A concentrated solution shall be made by dissolving sodium sulfide cp crystals in distilled water until the solution is saturated at about 21°C (70°F), and adding sufficient flowers of sulfur (in excess of 250 g/L of solution) to provide complete saturation, as shown by the presence in the solution of an excess of sulfur after the solution has been allowed to stand for at least 24 h. The test solution shall be made by diluting a portion of the concentrated solution with distilled water to a specific gravity of 1.142 at 15.6°C (60°F). The sodium polysulfide test solution should have sufficient strength to blacken thoroughly a piece of clean untinned copper wire in 5 s. A portion of the test solution used for testing samples shall not be considered to be exhausted until it fails to blacken a piece of clean copper as described above.

##### 6.4.3 Procedure:

6.4.3.1 *Immersion of Specimens*—Immerse a length of at least 4½ in. (114 mm) from each of the clean specimens, in accordance with the following cycles, in test solutions maintained at a temperature between 15.6 and 21°C (60 and 70°F):

(1) Immerse the specimen for 1 min in the HCl solution described in **6.4.2**, wash, and wipe dry; (2) immerse the specimen for 30 s in the sodium polysulfide solution described in **6.4.2**, wash, and wipe dry; (3) immerse the specimen for 1 min in the HCl solution, wash, and dry; (4) immerse the specimen for 30 s in the sodium polysulfide solution, wash, and wipe dry.

6.4.3.2 *Washing Specimens*—After each immersion, immediately wash the specimens thoroughly in clean water and wipe dry with a clean, soft cloth.

6.4.3.3 *Examination of Specimens*—After immersion and washing, examine the specimens to ascertain if copper exposed through openings in the tin coating has been blackened by action of the sodium polysulfide. The specimens shall be considered to have failed if, by such blackening, exposed copper is revealed. No attention shall be paid to blackening within 0.5 in. (12.7 mm) of the cut end. A grayish brown appearance of the coating shall not constitute failure.

#### 6.5 Adherence of Coating:

##### 6.5.1 Specimens:

6.5.1.1 *Length of Specimens*—Test specimens shall be approximately 12 in. (305 mm) in length and shall be tagged or marked to correspond with the coil, spool, or reel from which they are cut.

6.5.1.2 *Treatment of Specimens*—The specimens shall be thoroughly cleaned, if required, by immersion in a suitable organic solvent such as benzene, ether, or trichloroethylene for at least 3 min, then removed and dried (**Caution**—see Explanatory **Note 6**). The specimens thus cleaned shall be kept wrapped in a clean dry cloth until tested. That part of the specimens to be immersed in the test solution shall not be handled. Care shall be taken to avoid abrasion of the surface to be subjected to test. Wire of sizes 0.005 in. (0.13 mm) and smaller may be cleaned after wrapping around the mandrel.

##### 6.5.2 Procedure:

6.5.2.1 *Wrapping*—Slowly wrap the test specimen in a suitable manner in an open helix around a polished mandrel having rounded ends and a diameter not to exceed four times the nominal diameter of the specimen. Take care not to stretch the specimen during the wrapping operation. The spacing of the consecutive turns shall be approximately equal to the diameter of the wire. For sizes 0.021 in. (0.53 mm) and smaller, not more than six helical turns shall be used for the test, and for wire larger than 0.021 in., not more than three turns shall be used.

6.5.2.2 *Immersion Test*—Remove the helically wrapped portion of the test specimen from the mandrel and immerse completely in the sodium polysulfide solution (see **6.4.2**) for 30 s at the temperature prescribed in **6.4.3**. On removal from the sodium polysulfide solution, immediately rinse the specimen in clean water and remove the excess by shaking.

6.5.2.3 *Examination of Specimens*—Examine visually the outer peripheral surface of the helically wrapped portion of the specimen. For wires 0.021 in. (0.53 mm) and smaller, a magnification not greater than three times may be used. Any cracking or parting of the coating in this area shown by

**TABLE 4 Limiting Number of Test Specimens for Coating Tests**

Nominal Diameter, in.	Maximum Number of Specimens to be Tested for 2 Cycles in 180 mL of Acid Solution
0.460 to 0.141, incl	2
Under 0.141 to 0.0851, incl	4
Under 0.0851 to 0.0501, incl	6
Under 0.0501 to 0.0381, incl	10
Under 0.0381 to 0.0301, incl	12
Under 0.0301 to 0.0030, incl	14