



Designation: B189 – 05 (Reapproved 2021)

# Standard Specification for Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes<sup>1</sup>

This standard is issued under the fixed designation B189; 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.

## 1. Scope

1.1 This specification covers lead-coated and lead-alloy-coated, round, soft or annealed copper wire for electrical purposes.

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 are provided for information only and are not considered standard. The SI values for density and resistivity are to be regarded as the standard.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* The hazard statement applies only to Section 6 of this specification.

1.4 *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 The following documents of the issue in effect at the time of reference form a part of these methods to the extent referenced herein:

2.2 *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.

Current edition approved Oct. 1, 2021. Published October 2021. Originally approved in 1944. Last previous edition approved in 2015 as B189 – 05 (2015). DOI: 10.1520/B0189-05R21.

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[B258 Specification for Standard Nominal Diameters and Cross-Sectional Areas of AWG Sizes of Solid Round Wires Used as Electrical Conductors](#)

2.3 *NIST Standard:*<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:

- 3.1.1 Quantity of each size and type of coating;
- 3.1.2 Wire size: diameter in inches (see 5.3 and Table 1);
- 3.1.3 Type of coating (see Section 1);
- 3.1.4 Type of copper, if special (see 4.2);
- 3.1.5 Package size (see 8.1);
- 3.1.6 Special package marking, if required; and
- 3.1.7 Place of inspection (see 6.1).

## 4. Material

4.1 *Coating Material*—The coating material shall be commercially pure lead or a lead alloy. The lead alloy shall conform to the following requirements as to chemical composition as determined by analysis of samples from the coating bath:

Lead, min, %	25
Tin, max, %	75 <sup>A</sup>
Antimony, max, %	6

<sup>A</sup> It is permissible to use alloying constituents other than those specified above to replace a portion of the tin.

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.

4.2.1 Copper 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.

NOTE 1—Specification B49 defines copper suitable for use.

<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 Tensile Requirements**

Diameter, in.	Area at 20 °C		Elongation in 10 in., min, %
	cmils	in. <sup>2</sup>	
0.4600	211 600	0.1662	30
0.4096	167 800	0.1318	30
0.3648	133 100	0.1045	30
0.3249	105 600	0.08291	30
0.2893	83 690	0.06573	25
0.2576	66 360	0.05212	25
0.2294	52 620	0.04133	25
0.2043	41 740	0.03278	25
0.1819	33 090	0.02599	25
0.1620	26 240	0.02061	25
0.1443	20 820	0.01635	25
0.1285	16 510	0.01297	25
0.1144	13 090	0.01028	25
0.1019	10 380	0.008155	20
0.0907	8 230	0.00646	20
0.0808	6 530	0.00513	20
0.0720	5 180	0.00407	20
0.0641	4 110	0.00323	20
0.0571	3 260	0.00256	20
0.0508	2 580	0.00203	20
0.0453	2 050	0.00161	20
0.0403	1 620	0.00128	20
0.0359	1 290	0.00101	20
0.0320	1 020	0.000804	20
0.0285	812	0.000638	20
0.0253	640	0.000503	20
0.0226	511	0.000401	20
0.0201	404	0.000317	15
0.0179	320	0.000252	15
0.0159	253	0.000199	15
0.0142	202	0.000158	15
0.0126	159	0.000125	15
0.0113	128	0.000100	15
0.0100	100	0.0000785	10
0.0089	79.2	0.0000622	10
0.0080	64.0	0.0000503	10
0.0071	50.4	0.0000396	10
0.0063	39.7	0.0000312	10
0.0056	31.4	0.0000246	10
0.0050	25.0	0.0000196	10
0.0045	20.2	0.0000159	10
0.0040	16.0	0.0000126	10
0.0035	12.2	0.00000962	10
0.0031	9.61	0.00000755	10

**5. General Requirements (See Section 9)**

5.1 *Tensile Strength and Elongation (Explanatory Note 1)*—The coated 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) 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 2)*—The electrical resistivity of the coated wire at a temperature of 20 °C shall not exceed the values prescribed in **Table 2**.

**TABLE 2 Electrical Resistivity Requirements**

Nominal Diameter, in.	Resistivity at 20 °C, Ω-lb/mile <sup>2</sup>
0.460 to 0.290, incl	896.15
Under 0.290 to 0.103, incl	900.77
Under 0.103 to 0.0201, incl	910.15
Under 0.0201 to 0.0111, incl	929.52
Under 0.0111 to 0.0030, incl	939.51

5.3 *Dimensions and Permissible Variations (Explanatory Note 1)*—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). The coated wire shall not vary from the specified diameter by more than the amounts prescribed in **Table 3**.

5.4 *Continuity of Coating*—The lead or lead-alloy 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 coating shall be determined by the ammonium persulfate test in accordance with 6.4 or by the sodium polysulfide-hydrochloric acid test in accordance with 6.5. In case the results obtained in the sodium polysulfide-hydrochloric acid test are not conclusive, the ammonium persulfate test shall be employed and the results obtained by this latter test shall be final.

5.5 *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.

5.6 *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 3)*—No test for tensile strength shall be required.

6.1.1 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 the wire whose nominal diameter is 0.0808 in. (2.052 mm) and under may be determined as just described 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. (254 mm) as practical, 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

**TABLE 3 Permissible Variations in Diameter**

Nominal Diameter of Wire, in.	Permissible Variations in Diameter	
	plus	minus
Under 0.0100	0.0003 in. (0.3 mil)	0.0001 in. (0.1 mil)
0.0100 and over	3 % <sup>A</sup>	1 % <sup>A</sup>

<sup>A</sup> Expressed to the nearest 0.0001 in. (0.1 mil).

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 2)*—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 in lieu of resistivity tests on the finished wire.

6.3 *Dimensional Measurements*—Dimensional measurements shall be made with a micrometer caliper equipped with a vernier graduated in 0.0001 in. (0.1 mil). Measurements 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 (Ammonium Persulfate Test)*:

6.4.1 *Specimens*:

6.4.1.1 *Length of Specimens*—The length of test specimens shall be determined by substituting the appropriate value of  $K$ , as given in Table 4, in the following equation:

$$L = K/D$$

where:

$L$  = length of test specimen, in. (or mm), and

$D$  = diameter of the coated wire, in. (or mm).

In cases where the length of a specimen, determined by the above equation, is such that it cannot be immersed as a single length in the specified manner, it may be divided into shorter sections which will permit complete immersion.

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. (**Warning**—Explanatory Note 4.) The ends of each specimen shall be completely coated with wax to protect the exposed copper. The wax-coated length shall not be included in determining the length of the specimen.

6.4.2 *Special Solutions*:

6.4.2.1 *Test Solution (Ammonium Persulfate)*—Dissolve 10 g of ammonium persulfate (cp crystals containing not less than 95 % of ammonium persulfate) in 500 mL of distilled water. Add 75 mL of cp  $\text{NH}_4\text{OH}$  (sp gr 0.90) and dilute to 1 L with distilled water. The ammonium persulfate solution shall be freshly prepared each day. Tests are to be conducted and shall not be subjected to temperatures above 100 °F (38 °C).

6.4.2.2 *Reference Color Standard (Copper Sulfate-Ammonium Hydroxide)*—Dissolve 0.100 g of anhydrous cop-

per sulfate in distilled water, add 75 mL of cp  $\text{NH}_4\text{OH}$  (sp gr 0.90), and dilute to 1 L.

6.4.3 *Procedure*—Immerse a specimen of the required length (see 6.4.1.1) in the quantity of test solution prescribed in Table 4, using as the container a test tube of appropriate dimensions. Immerse the specimen in the test solution at a temperature between 83 and 87 °F (28 and 31 °C) for a period of 15 min. Then remove the specimen and compare the test solution with an equal depth of the reference color standard contained in a similar test tube. Make the color comparison by viewing the solutions lengthwise of the test tubes. The color of the test solution after immersion of the test specimen shall not be darker than that of the reference color-standard solution.

6.5 *Continuity of Coating (Sodium Polysulfide-Hydrochloric Acid Test)*:

6.5.1 *Specimens*:

6.5.1.1 *Length of Specimens*—The test specimens shall each 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.

6.5.1.2 *Treatment of Specimens*—The test 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. (**Warning**—Explanatory Note 4.) The specimens thus cleaned shall be kept wrapped in a clean, dry cloth until tested. (**Warning**—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.)

6.5.2 *Special Solutions (Explanatory Note 5)*:

6.5.2.1 *Sodium Polysulfide Solution (sp gr 1.142)*—A concentrated solution shall be made by dissolving sodium sulfide cp crystals in distilled water until the solution is saturated at about 21 °C 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 16 °C. 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 specimens shall not be considered to be exhausted until it fails to blacken a piece of clean copper as described above.

6.5.2.2 *Hydrochloric Acid Solution (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 16 °C. 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 5 have been immersed in it for two cycles.

6.5.3 *Procedure*—Immerse a length of at least 4.5 in. (114 mm) from each of the cleaned specimens in accordance with the following cycles, in test solutions maintained at a temperature between 16 and 21 °C:

6.5.3.1 Immerse the specimen for 30 s in the sodium polysulfide solution, wash, and then shake lightly to remove excess water.

**TABLE 4 Data for Ammonium Persulfate Test**

Wire Diameter, in.	$K$	Quantity of Test Solutions, mL
0.460 to 0.321, incl	1.2	150
Under 0.321 to 0.161, incl	0.8	100
Under 0.161 to 0.0810, incl	0.4	50
Under 0.0810 to 0.0400, incl	0.2	25
Under 0.0400 to 0.0030, incl	0.1	12.5

**TABLE 5 Limiting Number of Test Specimens for Hydrochloric Acid Test**

Diameter, in.	Maximum Number of Specimens to be Tested for Two 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

6.5.3.2 Immerse the specimen for 1 min in the HCl solution, wash, and then shake lightly to remove excess water.

6.5.3.3 Immerse the specimen for 30 s in the sodium polysulfide solution, wash, and then shake lightly to remove excess water.

6.5.3.4 Immerse the specimen for 1 min in the HCl solution, wash, and then shake lightly to remove excess water. After the operations described, examine the specimens to ascertain whether blackened areas resulting from the action of the sodium polysulfide are present. (Blackening of the coated surface that occurs when the specimen is immersed in the sodium polysulfide solution should disappear during immersion in the HCl solution, leaving blackened areas only where copper is exposed.) In examining specimens, disregard blackening present within 0.5 in. of the cut ends.

6.5.3.5 *Washing Specimens*—After each immersion, thoroughly wash the specimens in clean water and then shake lightly to remove excess water.

6.6 *Finish*—Surface-finish inspection shall be made with the unaided eye (normal spectacles excepted).

**7. Inspection**

7.1 *General (Explanatory Notes 3 and 6)*—Unless otherwise specified in the contract or purchase order, the manufacturer shall be responsible for the performance of all inspection and test requirements specified.

7.1.1 All inspections and tests shall be made at the place of manufacture unless otherwise agreed to by the manufacturer and the purchaser at the time of the purchase.

7.1.2 The manufacturer shall afford the inspector representing the purchaser all reasonable manufacturer’s facilities to satisfy him that the material is being furnished in accordance with this specification.

7.1.3 Unless otherwise agreed by the purchaser and the manufacturer, conformance of the wire to the various requirements listed in Section 5 shall be determined on samples taken from each lot of wire presented for acceptance.

7.1.4 The manufacturer shall, if requested prior to inspection, certify that all wire in the lot was made under such conditions that the product as a whole conforms to the requirements of this specification as determined by regularly made and recorded tests.

*7.2 Definitions for Inspection Purposes:*

7.2.1 *lot (Explanatory Note 7)*—any amount of wire of one type and size presented for acceptance at one time, such amount, however, not to exceed 25 000 lb (11 350 kg).

7.2.2 *sample*—a quantity of production units (coils, reels, and so forth.) selected at random from the lot for the purpose of determining conformance of the lot to the requirements of this specification.

7.2.3 *specimen*—a length of wire removed for test purposes from any individual production unit of the sample.

7.3 *Sample Size (Explanatory Note 6)*—The number of production units in a sample shall be as follows:

7.3.1 For elongation and resistivity determinations, the sample shall consist of four production units. For continuity of coating tests, the sample shall consist of eight production units. From each unit, one test specimen of sufficient length shall be removed for the performance of the required tests.

7.3.2 For dimensional measurements, the sample shall consist of a quantity of production units shown in Table 6 under the heading “First Sample.”

7.3.3 For surface-finish inspection and for packaging inspection (when specified by the purchaser at the time of placing the order) the sample shall consist of a quantity of production units shown in Table 7.

**8. Packaging and Package Marking**

8.1 Package sizes shall be agreed upon by the manufacturer and the purchaser when placing individual orders.

8.2 The wire shall be protected against damage in ordinary handling and shipping.

**9. Conformance Criteria (Explanatory Notes 3 and 6)**

9.1 Any lot of wire, the samples of which comply with the conformance criteria of this section, shall be considered as

**TABLE 6 Sampling for Dimensional Measurements**

Number of Units in Lot	First Sample		Second Sample		Allowable Number of Defects in Both Samples, $c_2$
	Number of Units in Sample, $n_1$	Allowable Number of Defects in First Sample, $c_1$	Number of units in Sample, $n_2$	$n_1 + n_2$	
1 to 14, incl	all	0	...	...	...
15 to 50, incl	14	0	...	...	...
51 to 100, incl	19	0	23	42	1
101 to 200, incl	24	0	46	70	2
201 to 400, incl	29	0	76	105	3
401 to 800, incl	33	0	112	145	4
Over 800	34	0	116	150	4