



Designation: B33 – 10

Standard Specification for Tin-Coated Soft or Annealed Copper Wire for Electrical Purposes¹

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 tin-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.

1.2.1 *Exceptions*—The SI values for density, resistivity, and volume are to be regarded as 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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*²

[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:*³

[NBS Handbook 100 Copper Wire Tables](#)

3. Ordering Information

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

¹ 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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² 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.

³ 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. (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.

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.

TABLE 1 Tensile Requirements

| Diameter | | Area at 20°C | | | Elongation in 10 in. (250 mm), % min |
|----------|--------|--------------|------------------|-----------------|---|
| in. | mm | cmil | in. ² | mm ² | |
| 0.4600 | 11.684 | 211600 | 0.1662 | 107.0 | 30 |
| 0.4096 | 10.404 | 167800 | 0.1318 | 85.0 | 30 |
| 0.3648 | 9.266 | 133100 | 0.1045 | 67.4 | 30 |
| 0.3249 | 8.252 | 105600 | 0.08291 | 53.5 | 30 |
| 0.2893 | 7.348 | 83690 | 0.06573 | 42.4 | 25 |
| 0.2576 | 6.543 | 66360 | 0.05212 | 33.6 | 25 |
| 0.2294 | 5.827 | 52620 | 0.04133 | 26.7 | 25 |
| 0.2043 | 5.189 | 41740 | 0.03278 | 21.2 | 25 |
| 0.1819 | 4.620 | 33090 | 0.02599 | 16.8 | 25 |
| 0.1620 | 4.115 | 26240 | 0.02061 | 13.3 | 25 |
| 0.1443 | 3.665 | 20820 | 0.01635 | 10.6 | 25 |
| 0.1285 | 3.264 | 16510 | 0.01297 | 8.37 | 25 |
| 0.1144 | 2.906 | 13090 | 0.01028 | 6.63 | 25 |
| 0.1019 | 2.588 | 10380 | 0.008155 | 5.26 | 20 |
| 0.0907 | 2.304 | 8230 | 0.00646 | 4.17 | 20 |
| 0.0808 | 2.052 | 6530 | 0.00513 | 3.31 | 20 |
| 0.0720 | 1.829 | 5180 | 0.00407 | 2.63 | 20 |
| 0.0641 | 1.628 | 4110 | 0.00323 | 2.08 | 20 |
| 0.0571 | 1.450 | 3260 | 0.00256 | 1.65 | 20 |
| 0.0508 | 1.290 | 2580 | 0.00203 | 1.31 | 20 |
| 0.0453 | 1.151 | 2050 | 0.00161 | 1.04 | 20 |
| 0.0403 | 1.024 | 1620 | 0.00128 | 0.823 | 20 |
| 0.0359 | 0.912 | 1290 | 0.00101 | 0.653 | 20 |
| 0.0320 | 0.813 | 1020 | 0.000804 | 0.519 | 20 |
| 0.0285 | 0.724 | 812 | 0.000638 | 0.412 | 20 |
| 0.0253 | 0.643 | 640 | 0.000503 | 0.324 | 20 |
| 0.0226 | 0.574 | 511 | 0.000401 | 0.259 | 20 |
| 0.0201 | 0.511 | 404 | 0.000317 | 0.205 | 15 |
| 0.0179 | 0.455 | 320 | 0.000252 | 0.162 | 15 |
| 0.0159 | 0.404 | 253 | 0.000199 | 0.128 | 15 |
| 0.0142 | 0.361 | 202 | 0.000158 | 0.102 | 15 |
| 0.0126 | 0.320 | 159 | 0.000125 | 0.080 | 15 |
| 0.0113 | 0.287 | 128 | 0.000100 | 0.065 | 15 |
| 0.0100 | 0.254 | 100 | 0.0000785 | 0.051 | 10 |
| 0.0089 | 0.226 | 79.2 | 0.0000622 | 0.040 | 10 |
| 0.0080 | 0.203 | 64.0 | 0.0000503 | 0.032 | 10 |
| 0.0071 | 0.180 | 50.4 | 0.0000396 | 0.026 | 10 |
| 0.0063 | 0.160 | 39.7 | 0.0000312 | 0.020 | 10 |
| 0.0056 | 0.142 | 31.4 | 0.0000246 | 0.016 | 10 |
| 0.0050 | 0.127 | 25.0 | 0.0000196 | 0.013 | 10 |
| 0.0045 | 0.114 | 20.3 | 0.0000159 | 0.010 | 10 |
| 0.0040 | 0.102 | 16.0 | 0.0000126 | 0.0081 | 10 |
| 0.0035 | 0.089 | 12.3 | 0.00000962 | 0.0062 | 10 |
| 0.0031 | 0.079 | 9.61 | 0.00000755 | 0.0049 | 10 |

TABLE 2 Electrical Resistivity Requirements

| Nominal Diameter | | Resistivity at 20°C | |
|------------------------------|---------------------------|------------------------|--------------------|
| in. | mm | Ω-lb/mile ² | Ω-g/m ² |
| 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 |

(0.0025 mm). The tin-coated 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 **6.3**.

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 **6.4** for 0.0320 in. (0.813 mm) and larger sizes.

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):

6.1.1 No test for tensile strength shall be required.

6.1.2 The elongation of wire with a nominal diameter greater than 0.0808 in. (2.052 mm) shall be determined as the permanent increase in length due to the breaking of the wire in tension. The elongation shall be measured between gage marks placed originally 10 in. (254 mm) apart upon the test specimen and expressed in percent of the original length.

6.1.3 The elongation of wire with a nominal diameter equal to or less than 0.0808 in. (2.053 mm) may be determined as described above or by measurements made between the jaws of the testing machine. When measurements are made between the jaws, 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 practicable. The final length shall be the distance between the jaws at the time of rupture. The fracture shall be between gage marks or jaws of the testing machine, depending on method used, and not closer than 1 in. (25.4 mm) to either gage mark or jaw.

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

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 % |

6.3 Continuity of Coating:

6.3.1 Specimens:

6.3.1.1 *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.

6.3.1.2 *Treatment of Specimens*—The specimens shall be thoroughly cleaned by immersion in a suitable organic solvent 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.

6.3.2 Special Solutions Required:

6.3.2.1 *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 **6.3.3** have been immersed in it for two cycles.

6.3.2.2 *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 1.135 to 1.145 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. The test solution used for testing samples shall be considered exhausted if it fails to blacken a piece of clean copper as described above.

6.3.3 Procedure:

6.3.3.1 *Immersion of Specimens*—Immerse a length of at least 4-½ 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 **6.3.2**, wash, and wipe dry; (2) immerse the specimen for 30 s in the sodium polysulfide solution described in **6.3.2**, 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.

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

6.3.3.3 *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.

6.4 Adherence of Coating:

6.4.1 Specimens:

6.4.1.1 *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.

6.4.1.2 *Treatment of Specimens*—The specimens shall be thoroughly cleaned, if required, by immersion in a suitable organic solvent 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.

6.4.2 Procedure:

6.4.2.1 *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.

6.4.2.2 *Immersion Test*—Remove the helically wrapped portion of the test specimen from the mandrel and immerse completely in the sodium polysulfide solution (see **6.3.2**) for 30 s at the temperature prescribed in **6.3.3**. On removal from the sodium polysulfide solution, immediately rinse the specimen in clean water and remove the excess by shaking.

6.4.2.3 *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 blackening of the copper shall be cause for rejection. A grayish brown appearance of the coating after immersion shall not constitute failure.

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

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 |