Designation: B 33 – 94

Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes[1]

This standard is issued under the fixed designation B 33; 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 specification has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by 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.

2. Referenced Documents

2.1 *ASTM Standards:*

B 49 Specification for Copper Redraw Rod for Electrical Purposes[2]

B 193 Test Method for Resistivity of Electrical Conductor Materials[3]

B 258 Specification for Standard Nominal Diameters and Cross-Sectional Areas of AWG Sizes of Solid Round Wires Used as Electrical Conductors[3]

3. Ordering Information

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

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).

3.2 In addition, Supplementary Requirements shall apply only when specified by the purchaser in the inquiry, contract, or purchase order for direct procurement by agencies of the U. S. Government (S1, S2, and S3).

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 B 49 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 Notes 2 and 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 Notes 1 and 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. (0.1 mil) (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 contin-

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[1] This specification is under the jurisdiction of ASTM Committee B-1 on Electrical Conductors and is the direct responsibility of Subcommittee B01.04 on Conductors of Copper and Copper Alloys.

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

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

TABLE 1 Tensile Requirements

Diameter, in.	Area at 20°C		Elongation in 10 in., min, %	Diameter, in.	Area at 20°C		Elongation in 10 in., min, %
	cmil	in.²			cmil	in.²	
0.4600	211 600	0.1662	30	0.0359	1 290	0.00101	20
0.4096	167 800	0.1318	30	0.0320	1 020	0.000804	20
0.3648	133 100	0.1045	30				
0.3249	105 600	0.08291	30	0.0285	812	0.000638	20
				0.0253	640	0.000503	20
0.2893	83 690	0.06573	25	0.0226	511	0.000401	20
0.2576	66 360	0.05212	25	0.0201	404	0.000317	15
0.2294	52 620	0.04133	25				
0.2043	41 740	0.03278	25	0.0179	320	0.000252	15
				0.0159	253	0.000199	15
0.1819	33 090	0.2599	25	0.0142	202	0.000158	15
0.1620	26 240	0.02061	25	0.0126	159	0.000125	15
0.1443	20 820	0.01635	25				
0.1285	16 510	0.01297	25	0.0113	128	0.000100	15
				0.0100	100	0.0000785	10
0.1144	13 090	0.01028	25	0.0089	79.2	0.0000622	10
0.1019	10 380	0.008155	20	0.0080	64.0	0.0000503	10
0.0907	8 230	0.00646	20				10
0.0808	6 530	0.00513	20	0.0071	50.4	0.0000396	
				0.0063	39.7	0.0000312	10
0.0720	5 180	0.00407	20	0.0056	31.4	0.0000246	10
0.0641	4 110	0.00323	20	0.0050	25.0	0.0000196	10
0.0571	3 260	0.00256	20	0.0045	20.2	0.0000159	10
0.0508	2 580	0.00203	20				
				0.0040	16.0	0.0000126	10
0.0453	2 050	0.00161	20	0.0035	12.2	0.00000962	10
0.0403	1 620	0.00128	20	0.0031	9.61	0.00000755	10

TABLE 2 Electrical Resistivity Requirements

Nominal Diameter, in.	Resistivity at 20°C Ω·lb/mile²
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

TABLE 3 Permissible Variations in Diamter

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 %[A]	1 %[A]

[A] Expressed to the nearest 0.0001 in. (0.1 mil).

uous 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* (Expanatory Note 4)—The electrical resistivity of the material shall be determined in accordance with Test Method B 193. 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. (0.0025 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.

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,** 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.

TABLE 4 Sampling for Dimensional Measurements

Number of Units in Lot	First Sample		Second Sample		
	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 plus n_2	Allowable Number of Defects in Both Samples, c_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

TABLE 5 Sampling for Surface Finish and Packaging Inspection

Number of Units in Lot	Number of Units in Sample, n	Allowable Number of Defective Units, c
1 to 30, incl	all	0
31 to 50, incl	30	0
51 to 100, incl	37	0
101 to 200, incl	40	0
201 to 300, incl	70	2
301 to 500, incl	100	2
501 to 800, incl	130	3
Over 800	155	4

TABLE 6 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

6.4.2 *Special Solutions Required:*

6.4.2.1 *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 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 6 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,** 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

TABLE 7 Resistivity Values

Conductivity at 20°C, %	100.00	97.66	97.16	96.16	94.16	93.15
Ω·lb/mile²	875.20	896.15	900.77	910.15	929.52	939.51
Ω·g/m²	0.15328	0.15694	0.15775	0.15940	0.16279	0.16454
Ω·cmil/ft	10.371	10.619	10.674	10.785	11.015	11.133
Ω·mm²/m	0.017241	0.017654	0.017745	0.017930	0.018312	0.018508
μΩ·in.	0.67879	0.69504	0.69863	0.70590	0.72092	0.78267
μΩ·cm	1.7241	1.7654	1.7754	1.7930	1.8312	1.8508

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

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

7. Inspection

7.1 *General* (Explanatory Notes 8 and 9)—Unless otherwise specified in the contract or purchaser 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 especially agreed upon between the manufacturer and the purchaser at the time of 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 upon between 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 Applicable to Inspection:*

7.2.1 *lot* (Explanatory Note 8)—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, etc.) 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 9)—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 and adherence 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 4 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 5.

8. Conformance Criteria (Explanatory Note 9)

8.1 Any lot of wire, the samples of which comply with the conformance criteria of this section, shall be considered as complying to the requirements of Section 5. Individual production units that fail to meet one or more of the requirements shall be rejected. Failure of a sample group from a lot to meet one or more of the following criteria shall constitute cause for rejection of the lot. The conformance criteria for each of the prescribed properties given in Section 5 are as follows:

8.1.1 *Elongation*—The lot shall be considered conforming if the average elongation of the four specimens is not less than the appropriate elongation value in Table 1 plus 2.8 %; however, any individual production unit, the specimen from which has an elongation less than the appropriate elongation value in Table 1 shall be rejected.

8.1.1.1 The lot shall be considered to have failed to meet the elongation conformance criterion if the average of the four specimens is less than the elongation in Table 1 plus 2.8 % *and* the elongation of any of the individual specimens is less than the value in Table 1.

8.1.1.2 If the average of the four specimens is less than the elongation in Table 1 plus 2.8 % and the elongation of each of the individual specimens is equal to or more than the value in Table 1, six additional specimens from six production units other than the four originally sampled shall be tested. The lot shall be considered conforming if the elongation of each of the ten specimens is not less than the appropriate elongation value in Table 1, and the average of the ten specimens is not less than that value plus 2.8 %. The lot shall be considered to have failed to meet the elongation requirement if any of the ten specimens is less than the appropriate elongation value in Table 1 or if the average of the ten specimens is less than that value plus 2.8 %.

8.1.2 *Resistivity*—The electrical resistivity of each of the four specimens shall conform to the requirements of 5.2.

Failure to meet these requirements shall constitute failure to meet the resistivity conformance criterion.

8.1.3 *Dimensions*—The dimensions of the first sample (Table 4) shall conform to the requirements of 5.3. If there are no failures, the lot conforms to this requirement. If there are failures but the number of these does not exceed the allowable defect number c_2 (Table 4), for the respective number of units in the sample, a second sample equal to n_2 shall be taken and the total defects of the n_1 plus n_2 units shall not exceed the allowable defect number, c_2. Failure to meet this requirement shall constitute failure to meet the dimensional conformance criterion.

8.1.4 *Continuity of Coating*—The continuity of the coating of each of the eight specimens shall conform to the requirements of 5.4. Failure of more than two specimens shall constitute failure to meet the continuity criterion. If not more than two specimens fail to meet the continuity criterion, eight additional specimens from the lot shall be tested, all of which shall conform to the continuity criterion. However, any individual production unit, the specimen from which failed to meet the continuity criterion, shall be rejected.

8.1.5 *Adherence of Coating*—The adherence of the coating of each of the eight specimens shall conform to the requirements of 5.5. Failure of more than two specimens shall constitute failure to meet the adherence criterion. If not more than two specimens fail to meet the adherence criterion, eight additional specimens from the lot shall be tested, all of which shall conform to the adherence criterion. However, any individual production unit, the specimen from which failed to meet the adherence criterion, shall be rejected.

8.1.6 *Surface Finish*—The surface finish of the samples taken in accordance with Table 5 shall conform to the requirements of 5.7. The number of units in the sample showing surface defects not consistent with commercial practice shall not exceed the allowable defect number c, in Table 5. Failure to meet this requirement shall constitute failure to meet the surface-finish conformance criterion.

8.1.7 *Packaging*—Conformance to the packaging requirements specified by the purchaser shall be determined in accordance with Table 5. The number of units in the sample showing nonconformance to the requirement shall not exceed the allowable defect number, c, in Table 5. Failure to meet this requirement shall constitute failure to meet the packaging conformance criterion.

9. Density (Explanatory Note 10)

9.1 For the purpose of calculating linear densities, cross sections, etc., the density of the copper shall be taken as 8.89 g/cm^3 (0.32117 lb/in.^{3}) at 20°C.

10. Packaging and Shipping

10.1 Package sizes shall be agreed upon by the manufacturer and the purchaser in the placing of individual orders.

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

11. Keywords

11.1 tinned annealed copper wire; tinned copper electrical wire; tinned soft copper wire

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order, for agencies of the U.S. Government.

S1. Referenced Documents

S1.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

S1.1.1 *Federal Standards:*[4]

Fed. Std. No. 102 Preservation, Packaging and Packing Levels

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

Fed. Std. No. 185 Identification Marking of Copper and Copper-Base Alloy Mill Products

S1.1.2 *Military Standard:*[4]

MIL-STD-129 Marking for Shipment and Storage

S1.1.3 *Military Specification:*[4]

MIL-C-3993 Packaging of Copper and Copper-Base Alloy Mill Products

S2. Identification Marking

S2.1 All material shall be properly marked for identification in accordance with Fed. Std. No. 185 except that the ASTM specification number shall be shown.

S3. Inspection

S3.1 The purchaser shall have the right to perform any of the inspections and tests set forth in this specification when such inspections and tests are deemed necessary to assure that the material conforms to the prescribed requirements.

S4. Preparation for Delivery

S4.1 *Preservation, Packaging, Packing:*

S4.1.1 *Military Agencies*—The material shall be separated by size, composition, grade, types, temper, and class, as applicable, and shall be preserved and packaged, Level A or C and packed Level A, B, or C as specified in the contract or purchase order, in accordance with the requirements of MIL-C-3993.

S4.1.2 *Civil Agencies*—The requirements of Fed. Std. No. 102 shall be referenced for definitions of the various levels of packaging protection.

S4.2 *Marking:*

S4.2.1 *Military Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with MIL-STD-129.

S4.2.2 *Civil Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with Fed. Std. No. 123.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.