Designation: B 33 – 00

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 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.

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]

2.2 *Other Document:*

NBS Handbook 100– Copper Wire Tables[4]

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).

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 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.

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

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

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

[4] Available from National Technical Information Service, 5285 Port Royal Rd., Springfield, VA 22161.

TABLE 1 Tensile Requirements

Diameter		Area at 20°C			Elongation in 10 in. (250 mm), % max
in.	mm	cmil	in.^{2}	mm^2	
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

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.

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

TABLE 3 Permissible Variations in Diamter

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 %

6.2 *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 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 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 5). 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 4½in. (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.

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

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 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 Note 8 and Note 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 5 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 6.

TABLE 6 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

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 5) 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 5) 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

TABLE 5 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

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 6 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 6. 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 6. The number of units in the sample showing nonconformance to the requirement shall not exceed the allowable defect number, *c*, in Table 6. 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

EXPLANATORY NOTES

NOTE 1—It is necessary that the coating of tin on the wire be continuous. The test in the sodium polysulfide is for the purpose of determining whether or not the wire carries a continuous envelope of pure tin. The thickness of the tin coating is necessarily varied. Under the same conditions of tinning, the coating on all sizes of wire, excepting on fine wire, is approximately the same. The coating on fine wire is in general relatively heavier than that on coarse wire. It is not, therefore, correct to apply a larger number of cycles in the test on coarse wire than is applied to fine wire. It is probable that one cycle of the dip test would be sufficient to discover defects in tinned wire, but in order to make certain that no partially covered spots may escape attention, provision has been made for two cycles. It has been found that the tin coating on copper wire consists of two parts, an envelope of pure tin on the outside, with an intermediate layer of copper-tin alloy. This tin alloy, as well as the amount of tin present, has an effect on the resistivity of the wire. Since the relative amount of tin coating and alloy is greater on the small wire than it is on the coarser wire, the resistivity of the wire increases as the size decreases. This also accounts for the decrease in elongation due to tinning soft wire.

NOTE 2—The values of the wire diameters in Table 1 are given to the nearest 0.0001 in. and correspond to the standard sizes given in Specification B 258. The use of gage numbers to specify wire sizes is not recognized in this specification because of the possibility of confusion. An excellent discussion of wire gages and related subjects is contained in *NBS Handbook 100* of the National Bureau of Standards.

NOTE 3—Other tests than those provided in this specification have been considered at various times, such as twist tests, wrap tests, etc. It is the opinion of the committee that twist tests on soft wire serve no useful purpose and that wrap tests, other than that provided for in 6.5, which is a test for adhesion, are likewise undesirable and inconclusive as to results and significance.

NOTE 4—"Resistivity" is used in place of "percentage conductivity." The value of 0.15328Ω· g/m^2 at 20°C is the international standard for the resistivity of annealed copper equal to 100% conductivity. This term means that a wire 1 m in length and weighing 1 g would have a resistance of 0.15328 Ω. This is equivalent to a resistivity value of 875.20 Ω·lb/mile^2, which signifies the resistance of a wire 1 mile in length weighing 1 lb. It is also equivalent, for example, to 1.7241 μΩ/cm of length of a bar 1 cm^2 in cross section. A complete discussion of this subject is contained in *NBS Handbook 100* of the National Bureau of Standards. The presence of tin and of copper-tin alloy in the coating of the wire increases the resistance of the finished wire as mentioned in Note 1. Relationships that may be useful in connection with the values of resistivity prescribed in this specification are as shown in Table 7, each column containing equivalent expressions at 20°C.

NOTE 5—In general, tested values of tensile strength are increased and tested values of elongation are reduced with increase of speed of the moving head of the testing machine in the tension testing of copper wire. In the case of tests on soft or annealed copper wire, however, the effects of speed of testing are not pronounced. Tests of soft wire made at speeds of moving head, which under no-load conditions are not greater than 12 in./min, do not alter the final results of tensile strength and elongation determinations to any practical extent.

NOTE 6—**Caution:** Consideration should be given to toxicity and flammability when selecting solvent cleaners.

NOTE 7—It is important that the polysulfide solution be of proper composition and strength at the time of test. A solution that is not saturated

TABLE 7 Resistivity Values

Conductivity at 20°C, %	100.00	97.66	97.16	96.16	94.16	93.15
Ω·lb/mile^2	875.20	896.15	900.77	910.15	929.52	939.51
Ω·g/m^2	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·mm^2/m	0.017241	0.017654	0.017745	.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

with sulfur or that has been made from decomposed sodium sulfide crystals may give a false indication of failure. Therefore, the requirement that the solution be tested by observing its blackening effect on a bright copper wire is significant. Significant also is the requirement that the solution be saturated with sulfur by allowing the solution to stand at least 24 h after preparation. Attention is called also to the necessity for the use of sodium sulfide that has not deteriorated through exposure to air; and if exposure has occurred, the crystals should be tested for purity. The "Standard Reagents Tests" of the American Chemical Society are useful in this connection.

NOTE 8—A lot should comprise material taken from a product regularly meeting the requirements of this specification. Inspection of individual lots of less than 5000 lb of wire cannot be justified economically. For small lots of 5000 lb or less, the purchaser may agree to the manufacturer's regular inspection of the product as a whole, as evidence of acceptability of such small lots.

NOTE 9—Cumulative results secured on the product of a single manufacturer, indicating continued conformance to the criteria, are necessary to ensure an over-all product meeting the requirements of this specification. The sample sizes and conformance criteria given for the various characteristics are applicable only to lots produced under these conditions.

NOTE 10—The value of density of copper is in accordance with the International Annealed Copper Standard. The corresponding value at 0°C is 8.90 g/cm ^{3}(0.32150 lb/in.^{3}). In calculations involving density it must be borne in mind that the apparent density of coated wire is not a constant but a variable function of wire diameters. The smaller the diameter, the greater the percentage of coating present and hence the greater departure from the density of copper.