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Standard Specification for High Performance Tin-Coated Annealed Copper Wire Intended for Electrical and Electronic Application for Solderability[1]

This standard is issued under the fixed designation B965; 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.

1. Scope

1.1 This specification covers tin-coated annealed copper wire intended for electrical and electronic applications where solderability is a requirement.

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 Standards:*

IPC/ECA J-STD-002 Solderability Test for Component Leads, Lugs, Terminals and Wires[3]

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 shall be electroplated for the coating and 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 %. Not withstanding the previous sentence, chemical analysis of the tin coating or of the tin used for coating shall not be required under this specification.

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.

5. General Requirements (See Section 8)

5.1 *Tensile Strength and Elongation (Explanatory Note 4)*—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 3)*—The electrical resistivity of tinned wire at a temperature of 20°C shall not exceed the values prescribed in Table 2.

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[1] This test method 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 IPC, 3000 Lakeside Drive, Suite 309S, Bannockburn, IL 60015, http://www.ipc.org, and ECA 2500 Wilson Blvd., Arlington, VA 22201, http://www.ec-central.org.

[4] Available from National Technical Information Service (NTIS), 5285 Port Royal Rd., Springfield, VA 22161, http://www.ntis.gov.

TABLE 1 Tensile Requirements

Diameter in.	mm	cmil	Area at 20°C in.^{2}	mm^2	Elongation in 10 in. (250 mm), % min
0.4600	11.684	211 600	0.1662	107.0	30
0.4096	10.404	167 800	0.1318	85.0	30
0.3648	9.266	133 100	0.1045	67.4	30
0.3249	8.252	105 600	0.08291	53.5	30
0.2893	7.348	83 690	0.06573	42.4	25
0.2576	6.543	66 360	0.05212	33.6	25
0.2294	5.827	52 620	0.04133	26.7	25
0.2043	5.189	41 740	0.03278	21.2	25
0.1819	4.620	33 090	0.02599	16.8	25
0.1620	4.115	26 240	0.02061	13.3	25
0.1443	3.665	20 820	0.01635	10.5	25
0.1285	3.264	16 510	0.01297	8.37	25
0.1144	2.906	13 090	0.01028	6.63	25
0.1019	2.588	10 380	0.008155	5.26	20
0.0907	2.304	8 230	0.00646	4.17	20
0.0808	2.052	6 530	0.00513	3.31	20
0.0720	1.829	5 180	0.00407	2.63	20
0.0641	1.628	4 110	0.00323	2.08	20
0.0571	1.450	3 260	0.00256	1.65	20
0.0508	1.290	2 580	0.00203	1.31	20
0.0453	1.151	2 050	0.00161	1.04	20
0.0403	1.024	1 620	0.00128	0.823	20
0.0359	0.912	1 290	0.00101	0.654	20
0.0320	0.813	1 020	0.000804	0.517	20
0.0285	0.724	812	0.000638	0.411	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	0.081	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	20.2	0.0000159	0.010	10
0.0040	0.102	16.0	0.0000126	0.0081	10
0.0035	0.089	12.2	0.00000962	0.0062	10
0.0031	0.079	9.61	0.00000755	0.0049	10

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. (0.0025 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 6.4.

5.5 *Thickness of Coating*—The wire shall have adequate free tin (Explanatory Note 1) to insure meeting solderability requirements as prescribed in 5.8. The thickness of coating shall be at the manufacturer's discretion or as agreed upon between the manufacturer and purchaser to insure compliance to 5.8 and further processing for solderability performance after insulation.

5.6 *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 after electroplating and prior to final drawing. The adherence of coating shall be determined by the wrapping test in accordance with 6.6.

5.7 *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.

5.8 *Solderability*—The solder must cover greater than 95 % of the surface of the specimen and show evidence of good wetting and of bonding. The solderability shall be tested in accordance with 6.7.

5.9 *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 4):*

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. (242 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 *Resistivity (Explanatory Note 3)*—The electrical resistivity of the material shall be determined in accordance with Test Method B193. The purchaser may accept certification that the wire was drawn from rod stock meeting the international standard for annealed copper instead of resistivity tests on the finished wire.

6.3 *Dimensional Measurements*—Dimensional measurements shall be made with a 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

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 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 %

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 *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.

6.4.2 *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 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.

6.4.3 *Special Solutions Required:*

6.4.3.1 *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.

6.4.3.2 *Sodium Polysulfide Solution (sp gr 1.142) (Explanatory Note 6)*—A concentrated solution shall be made by dissolving sodium sulfide crystals (cp) 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.

6.4.4 *Procedure:*

6.4.4.1 *Immersion of Specimens*—Immerse a length of at least 4-1/2 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.

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

6.4.4.3 *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		Maximum Number of Specimens to be Tested for 2 Cycles in 180 mL of Acid Solution
in.	mm	
0.460 to 0.141, incl	11.7 to 3.6, incl	2
Under 0.141 to 0.0851, incl	Under 3.6 to 2.2, incl	4
Under 0.0851 to 0.0501, incl	Under 2.2 to 1.3, incl	6
Under 0.0501 to 0.0381, incl	Under 1.3 to 0.97, incl	10
Under 0.0381 to 0.0301, incl	Under 0.97 to 0.76, incl	12
Under 0.0301 to 0.0030, incl	Under 0.76 to 0.076, incl	14

6.5 *Thickness of Coating*—Conformance to free tin requirements may be determined in accordance with Test Method A as prescribed in Appendix X1.

6.6 *Adherence of Coating:*

6.6.1 *Specimens:*

6.6.1.1 *Length of Specimens*—Test specimens shall be approximately 20 in. (508 mm) prior to wrapping and shall be tagged or marked to correspond with the coil, spool, or reel from which they are cut.

6.6.2 *Procedure:*

6.6.2.1 *Wrapping*—Slowly wrap the test specimen in a suitable manner in an open helix around its own diameter. 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. An appropriate number of wraps shall be made so that a sample no less than eight inches in length will be obtained.

6.6.2.2 *Examination of Specimens*—Visually examine 0.0428 in. (1.09 mm) and smaller test specimens at ×20 magnification. Test specimens larger than 0.0428 in. (1.09 mm) shall be examined at ×10 magnification. Examine the outer peripheral surface of the helically wrapped portion of the specimen. The test specimens shall be rotated 360° to examine both the inside and outside of the helix for surface imperfections/defects.

6.6.2.3 *Acceptance Criteria*—A defect condition would be where bare metal is exposed. Examples of defects would be cracking, flaking, slivers, or die lines that expose the base metal. A sample that has a defect along the test length shall be cause for rejection. Imperfections would be conditions that do not expose the base metal or would not adversely affect the product quality or next manufacturing process. Examples of imperfections would be scratches, light die lines or slight band marks. An imperfection would not be cause for rejection.

6.7 *Solderability Test*—The solderability test shall be tested in accordance with Test A of IPC/ECA J-STD-002.

6.7.1 For solderability requirements indicated in Section 5, the manufacturer may elect to perform the solderability test on finished stranded product being supplied to the purchaser with in-process material according to this standard.

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

7. Inspection

7.1 *General (Explanatory Note 7)*—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*—any amount of wire of one type and size presented for acceptance at one time.

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 7)*—The number of production units in a sample shall be as follows:

7.3.1 A full (100 % inspection) will be completed at every set-up prior to running the order.

7.3.2 For elongation, resistivity, dimensional measurements, continuity of coating, thickness of coating (free tin), adherence of coating, and solderability determinations, the sample shall consist of sequential production units from the lot.

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 sequential production units from the lot.

8. Conformance Criteria (Explanatory Note 7)

8.1 Any lot of wire, the samples of which comply with the conformance criteria of Section 5, shall be considered as complying with the requirements of this standard. Individual production units that fail to meet one or more of the requirements shall be rejected. If a failure of an individual production unit occurs, material which was made between the non-conforming unit and the last production unit which passed the conformance criteria must be inspected for the non-conforming characteristic.

9. Density (Explanatory Note 8)

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 (Explanatory Note 9)

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

10.2 The tin-coated wire shall be protected against damage in ordinary handling and shipping.

11. Keywords

11.1 tinned annealed copper wire; tin-coated copper electrical wire; tin-coated soft copper wire; solderability

EXPLANATORY NOTES

NOTE 1—It has been found that the tin coating on copper wire consists of two parts, an envelope of pure or free tin on the outside, with an intermetallic layer of copper-tin alloy. The presence of free tin will assure the integrity of the solderability conformance requirement. 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 B258. 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—"Resistivity" is used in place of "percentage conductivity." The value of 0.15328 Ω · 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 5, each column containing equivalent expressions at 20°C.

NOTE 4—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 5—**Caution:** Consideration should be given to toxicity and flammability when selecting solvent cleaners.

NOTE 6—It is important that the polysulfide solution be of proper composition and strength at the time of test. A solution that is not saturated 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 7—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 8—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.

NOTE 9—The manufacturer and user of this standard should avoid elevated temperatures when considering storage or shelf life of material. Elevated temperatures from storage over time can affect the durability of the tin plating, which will affect conformance to the solderability requirements of this standard. Best practice would be to re-inspect material to the conformance criteria of 5.8 after storage and prior to soldering.

NOTE 10—*Principle of Operation of the Electronic Thickness Tester*—The unit operates by anodically deplating a small surface area of the specimen in a cell containing the test solution. The cell serves as cathode and the piece to be tested is the anode. At the start of the test and until the base metal is exposed, a voltage characteristic of the plating exists across the cell; when all the plating has been removed from the test spot, this voltage changes sharply and assumes a new value which is now characteristic of the base metal. This rapid voltage change is the "end point" of the test, and is amplified and caused to operate a relay which turns off the instrument. The time required to dissolve the plating on the test spot is proportional to the thickness of the deposit; by correlating the area of the test spot with the current used to strip the plating, the counter is made to read directly in units of thickness. Essentially, therefore, the electronic thickness tester embodies a miniature reverse-current plating cell in which the piece to be tested is the anode and the cell itself is the cathode. The test solution used is specifically designed to give 100 % anodic current efficiency. It does not attack the plating unless current is flowing through the test cell. The anode efficiency is further maintained by providing agitation of the solution in the test cell.

TABLE 5 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

APPENDIX

(Nonmandatory Information)

X1. DETERMINATION OF THE THICKNESS OF COATING OF FREE TIN ON TIN-COATED COPPER WIRE
Method A—Electronic Determination (see Explanatory Note 10)

X1.1 Apparatus and Reagent

X1.1.1 Electronic Thickness Tester with Accessory Unit "WT."[5]

X1.1.2 Solution R-50[5]

X1.2 Limitations of Method A

X1.2.1 This method is suitable for the determination of the free tin thickness of coatings as follows:

Wire Size	Sample Length, in.
0.0720 to 0.0240	0.50
0.0239 to 0.0115	1.00
0.0114 to 0.0058	2.00
0.0057 to 0.0031	4.00

X1.3 Procedure

X1.3.1 Connect the tester to 110-V, 60 Hz, ac. Insert the jack plug on accessory unit lead wire into the jack marked "WT" on the *left* side of the thickness tester. Turn "Plate" selector to setting marked "TIN." Turn power on and allow a 5 min warmup period.

X1.3.2 Fill the stainless steel beaker to within 1/2 to 1/4 in. from the top with Solution R-50. Maintain the temperature of the solution at 20 to 25°C.

X1.3.3 Cut a straight length of the wire to be tested, approximately 4 in. longer than the required sample length. Lay the wire sample on a flat surface along a ruler and, using a crayon, mark off the appropriate sample length from one end of the wire. Make this measurement as accurately as possible. Specimens having 4 in. sample lengths should be given an open 180° bend half way between the crayon mark and the end to allow them to be submerged in the test solution without touching the beaker.

X1.3.4 Insert the wire sample into the terminal on the horizontal arm of the accessory unit, then tighten the terminal so that the wire is held firmly in a vertical position. Lower the wire into the beaker until the liquid level is exactly at the crayon mark. Adjust the arm so that the wire is in the approximate center of the beaker.

X1.3.5 Press the "Test Button" to start the test. When the test is complete the instrument will turn off. Multiply the counter readings by the factors corresponding to the size of the wire tested as listed in Table X1.1. The result will be the thickness of the plating in microinches.

NOTE X1.1—Two distinct endpoints or shut-offs will occur for tin-plated copper consisting of an outer layer of free tin and an intermetallic layer of copper-tin alloy. The first endpoint (shut-off) would represent the free tin thickness of the wire sample. Upon examination after the test, the test sample will show evidence of a grayish color indicating balance to be copper-tin alloy.

TABLE X1.1 Thickness Factors

NOTE 1—The thickness factor for sizes not shown in Table X1.1 may be calculated by the following equation:

$$F = (a D^b / test\ length)$$

where:
D = wire diameter,
b = –1.0044
a = 0.0453, and
F = thickness factor.

Wire Size, Diam, in.	Test Length, in.	Thickness, μ in. (x reading)
0.1285	0.50	0.71
0.1144	0.50	0.80
0.1019	0.50	0.90
0.0907	0.50	1.01
0.0808	0.50	1.13
0.0720	0.50	1.27
0.0641	0.50	1.43
0.0571	0.50	1.61
0.0508	0.50	1.81
0.0453	0.50	2.03
0.0403	0.50	2.28
0.0359	0.50	2.56
0.0320	0.50	2.87
0.0285	0.50	3.23
0.0253	0.50	3.64
0.0226	1.00	2.04
0.0201	1.00	2.29
0.0179	1.00	2.58
0.0159	1.00	2.90
0.0142	1.00	3.25
0.0126	1.00	3.66
0.0113	2.00	2.04
0.0100	2.00	2.31
0.0089	2.00	2.60
0.0080	2.00	2.89
0.0071	2.00	3.26
0.0063	2.00	3.68
0.0056	4.00	2.07
0.0050	4.00	2.32
0.0045	4.00	2.58
0.0040	4.00	2.90
0.0035	4.00	3.32
0.0031	4.00	3.75

X1.4 Precautions

X1.4.1 Make no adjustments to the specimen while instrument is in operation. If an adjustment is necessary, stop the test by pressing the" Stop" button, make the adjustment, and repeat the test with a new sample.

X1.4.2 Avoid spilling test solutions into the accessory unit.

X1.4.3 Wire samples must be clean. If the wire is lacquered, remove the lacquer with a solvent before testing.

[5] The above named apparatus and reagent is the product of Kocour Company, 4800 South St. Louis Avenue, Chicago, IL 60632.

X1.4.4 Do not store test solutions in the stainless steel beaker. After daily use or after a series of tests have been completed, return the test solution to a re-use storage bottle, and rinse the beaker thoroughly with water and dry it. Do not return used solutions to the original stock solution. Use a separate bottle for the used solution.

X1.4.5 Test solutions may be reused. The extent to which the solutions become exhausted depends upon the number and size of the parts tested, as well as upon the thickness of the deposits which are stripped. In general, solutions may be reused approximately eight or ten times, or until erratic results are obtained, before discarding.

X1.4.6 The minimum thickness of deposit which can be tested on a particular gage of wire is determined by multiplying the factor for the wire gage by 5.