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Standard Specification for Tin-Coated Braid and Ribbon Flat Copper Wire intended for use in Electronic Application[1]

This standard is issued under the fixed designation B973; 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 hard-drawn copper braid and ribbon flat wire intended for electronic application (Explanatory Note 1).

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]

B1 Specification for Hard-Drawn Copper Wire

B3 Specification for Soft or Annealed Copper Wire

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:*[3]

NBS Handbook 100 Copper Wire Tables

3. Ordering Information

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

3.1.1 Quantity of each size,

3.1.2 Wire size-thickness and width in inches (see 5.3),

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—Specifications B1, B3, or B49 defines copper suitable for use.

5. General Requirements (See Section 8)

5.1 *Tensile and Elongation*—The tin-coated copper flat wire in the hard drawn condition shall conform to elongation requirements of 1 % minimum to 5 % maximum. The tensile strength shall be 55 000 psi (379 MPa) minimum.

5.2 *Resistivity (Explanatory Note 3)*—The electrical resistivity of the coated wire at a temperature of 20°C shall not exceed the values prescribed in Table 1.

5.3 *Dimensions and Permissible Variations*—The flat wire sizes shall be expressed as the thickness and width of the wire in decimal fractions of an inch to the nearest 0.0001 in. (0.0025 mm). The tin-coated flat wire shall not vary from the specified thickness and width by more than the amounts specified in Table 2 and Table 3, respectively.

5.4 *Continuity of Coating*—The tin coating shall be continuous. The continuity of coating on the flat wire shall be determined on representative samples taken before braiding

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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), 5301 Shawnee Rd., Alexandria, VA 22312, http://www.ntis.gov.

TABLE 1 Electrical Resistivity Requirements

Thickness Range, Inch (mm)	Resistivity at 20°C Ω·lb/mile2
0.0008 to 0.0012 (0.020 to 0.031), incl	1006.0
0.0013 to 0.0016 (0.033 to 0.041), incl	972.45
0.0017 to 0.0024 (0.043 to 0.061), incl	961.76
0.0025 to 0.0048 (0.064 to 0.122), incl	951.31
0.0049 to 0.0100 (0.125 to 0.254), incl	941.08

TABLE 2 Permissible Variations in Thickness

Nominal Thickness Range, Inch (mm)	Tolerance, Inch (mm)
0.0010 to 0.0014 (0.025 to 0.036)	+/- 0.0002 (0.005)
0.0015 to 0.0019 (0.038 to 0.048)	+/- 0.0003 (0.008)
0.0020 to 0.0049 (0.051 to 0.124)	+/- 0.0004 (0.010)
0.0050 to 0.0100 (0.127 to 0.254)	+/- 0.0005 (0.013)

TABLE 3 Permissible Variations in Width

Nominal Width Range, Inch (mm)	Tolerance, Inch (mm)
0.0100 to 0.0499 (0.254 to 1.27)	+/- 0.0013 (0.033)
0.0500 to 0.0699 (1.27 to 1.78)	+/- 0.0015 (0.038)
0.0700 to 0.0999 (1.78 to 2.54)	+/- 0.0020 (0.051)
0.1000 to 0.1249 (2.54 to 3.17)	+/- 0.0030 (0.076)
0.1250 to 0.1500 (3.18 to 3.81)	+/- 0.0040 (0.102)

applications or insulating. The continuity of coating shall be determined by the hydrochloric acid-sodium polysulfide test in accordance with 6.4.

5.5 *Joints*—Necessary joints in the wire and rods prior to final coating and drawing shall be made in accordance with the best commercial practice. There shall be no uncoated joints in the final product.

5.6 *Finish*—The coating shall consist of a smooth continuous layer, firmly adherent to the surface of the copper. The wire shall be free of all imperfections not consistent with the best commercial practice.

6. Test Methods

6.1 *Tensile Strength and Elongation (Explanatory Note 4):*

6.1.1 The tensile strength, expressed in pounds per square inch, shall be obtained by dividing the maximum load carried by the specimen during the tension test by the original cross-sectional area of the specimen. Tensile strength and elongation may be determined simultaneously on the same specimen.

6.1.2 The elongation of the flat wire may be determined by measurements made between the jaws of the tensile testing machine. 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 the jaws of the testing machine and not closer than 1 in. (25.4 mm) to the 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 for width and thickness 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. Any measurement taken exceeding the dimensions and permissible variation requirements in 5.4 shall constitute failure to meet the dimensional conformance criterion.

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 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 6)*—A concentrated solution shall be made by dissolving sodium sulfide crystals (cp) in distilled water until

TABLE 4 Limiting Number of Test Specimens for Coating Test[A]

Equivalent Round Nominal Diameter		Maximum Number of Specimens to be Tested for 2 Cycles in 180 mL of Acid Solution
in.	mm	
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

[A] See Explanatory Note 2 for equivalent round calculation.

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.

6.4.3 *Procedure:*

6.4.3.1 *Immersion of Specimens*—Immerse a length of at least 4.5 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 *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, and continuity of coating 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

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

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

11. Keywords

11.1 copper flat wire tin-coated; tin-coated annealed copper flat wire; tin-coated copper electrical equipment flat wire; tin-coated copper flat wire

TABLE 5 Resistivity Relations

Conductivity at 20°C %	100.0	93.0	92.0	91.0	90.0	87.0
Ω·lb/mile^2	875.20	941.08	951.31	961.76	972.45	1006.0
Ω·g/m^2	0.15328	0.16481	0.16660	0.16844	0.17031	0.17618
Ω·cmil/ft	10.371	11.152	11.273	11.397	11.523	11.921
Ω·mm^2/m	0.017241	0.018539	0.018741	0.018947	0.019157	0.019818
μΩ·in.	0.67879	0.72989	0.73782	0.74593	0.75421	0.78022
μΩ·cm	1.7241	1.8539	1.8741	1.8947	1.9157	1.9818

EXPLANATORY NOTES

NOTE 1—*(1)* 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 as the size decreases, the resistivity of the wire increases as the size decreases.

(2) The manufacturer and user of the standard should also give consideration to any agreed upon cast and camber requirements for ribbon wire applications.

NOTE 2—The equivalent round diameter or size for a flat conductor is calculated from the cross-sectional area of the flat conductor, which is based on thickness and width. The nominal equivalent round diameter for a flat conductor is:

$$\textit{Nominal Equivalent round diameter} = \sqrt{((T \times W \times 4)/3.1416)}$$

where:

T = nominal thickness specification,
W = nominal width specification.

NOTE 3—Resistivity units are based on the International Annealed Copper Standard (IACS) adopted by IEC in 1913, which is 1/58 Ω·mm^2/m at 20°C for 100 % conductivity. The value of 0.017241 Ω·mm^2/m and the value of 0.15328 Ω·g/m^2 at 20°C are respectively the international equivalent of volume and weight resistivity of annealed copper equal (to 5 significant figures) to 100 % conductivity. The latter term means that a copper 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 copper wire 1 mile in length weighing 1 lb. It is also equivalent, for example, to 1.7241 μΩ/cm of length of a copper bar 1 cm^2 in cross section. A complete discussion of this subject is contained in *NBS Handbook 100* of the National Institute of Standards and Technology.[3] The use of five significant figures in expressing resistivity does not imply the need for greater accuracy of measurement than that specified in Test Method B193. The use of five significant figures is required for reasonably accurate reversible conversion from one set of resistivity units to another. The equivalent resistivity values in Table 5 were derived from the fundamental IEC value (1/58 Ω· mm^2/m) computed to 7 significant figures and then rounded to 5 significant figures.

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 or size. The smaller the diameter or size, the greater the percentage of coating present, and hence, the greater departure from the density of copper.