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Standard Specification for Silver-Coated, Copper-Clad Steel Wire for Electronic Application[1]

This standard is issued under the fixed designation B 501; 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 silver-coated, round, copper-clad steel wire for electronic application.

1.2 Silver coatings in mass percentages of the total mass of the coated wire are as follows: 1.25, 2.5, 4.0, 6.1, and 8.0.

1.2.1 Silver-coated wire having different minimum percentage of silver by mass may be obtained by mutual agreement between the manufacturer and the purchaser. For information purposes, the thickness of coating in microinches provided by the mass percentages listed in 1.2 is shown in Table 1.

1.3 Four classes of copper-clad steel wire are covered as follows: Class 30HS nominal 30 % conductivity hard-drawn, Class 30A nominal 30 % conductivity annealed, Class 40HS nominal 40 % conductivity hard-drawn, and Class 40A nominal 40 % conductivity annealed.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only except for resistivity, where the SI units are to be regarded as the standard.

1.5 The following safety hazards caveat pertains to the test method described in this specification. *This standard does not purport to address all of the safety problems, 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.* (See Note 1).

NOTE 1—**Caution:** Consideration should be given to toxicity and flammability when selecting solvent cleaners.

2. Referenced Documents

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

2.2 *ASTM Standards:*

B 193 Test Method for Resistivity of Electrical Conductor Materials[2]

B 258 Specification for Standard Nominal Diameters and Cross–Sectional Areas of AWG Sizes of Solid Round Wires Used as Electrical Conductors[2]

B 452 Specification for Copper–Clad Steel Wire for Electronic Application[2]

E 50 Practices for Apparatus, Reagents, and Safety Precautions for Chemical Analysis of Metals[3]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *lot*—any amount of wire of one class and size presented for acceptance at one time, such amount, however, not to exceed 10 000 lb (4500 kg) (Note 2).

3.1.2 *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.

3.1.3 *specimen*—a length of wire removed for test purposes from any individual production unit of the sample.

NOTE 2—A lot should comprise material taken from a product regularly meeting the requirements of this specification. Inspection of individual lots of less than 500 lb (250 kg) of wire cannot be justified economically. For small lots of 500 lb (250 kg) 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.

4. Ordering Information

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

4.1.1 Quantity of each size,
4.1.2 Wire size (see 7.1 and Table 1),
4.1.3 Class of basis wire (see 1.3),
4.1.4 Mass percentage of coating (see 1.2 and Table 1),
4.1.5 Package size (see Section 12),
4.1.6 Special packaging marking, if required, and
4.1.7 Place of inspection (see 9.1).

5. Materials and Manufacture

5.1 The basis material shall consist of copper-clad steel wire conforming to the product description, quality and specification requirements of Specification B 452.

5.2 The silver-coated wire shall consist of the basis wire coated with silver. The quality of the silver-coated wire shall be

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

[3] *Annual Book of ASTM Standards*, Vol 03.05.

TABLE 1 Silver Mass Percent and Thickness of Coating

Diameter		Cross-Sectional Area at 20°C			Thickness of Silver, µin. (for information only)				
in.	mm	cmil	in.^{2}	mm^2	1.25 %	2.5 %	4.0 %	6.1 %	8.0 %
0.0720	1.829	5 180	0.00407	2.63	176	352	569	876	1 158
0.0641	1.628	4 110	0.00323	2.08	156	313	507	779	1 031
0.0571	1.450	3 260	0.00256	1.65	139	279	451	694	918
0.0508	1.290	2 580	0.00203	1.31	124	248	401	618	817
0.0453	1.151	2 050	0.00161	1.04	111	222	358	551	728
0.0403	1.024	1 620	0.00128	0.823	98	197	318	490	648
0.0359	0.912	1 290	0.00101	0.653	88	176	284	437	577
0.0320	0.813	1 020	0.000804	0.519	78	156	253	389	515
0.0285	0.724	812	0.000638	0.412	70	139	225	347	458
0.0253	0.643	640	0.000503	0.324	62	124	200	308	407
0.0226	0.574	511	0.000401	0.259	55	111	179	275	363
0.0201	0.511	404	0.000317	0.205	49	98	159	244	323
0.0179	0.455	320	0.000252	0.162	44	88	141	218	288
0.0159	0.404	253	0.000199	0.128	39	78	126	193	256
0.0142	0.361	202	0.000158	0.102	35	69	112	173	228
0.0126	0.320	159	0.000125	0.0804	31	62	100	153	203
0.0113	0.287	128	0.000100	0.0647	28	55	89	137	182
0.0100	0.254	100	0.0000785	0.0507	24	49	79	122	161
0.0089	0.226	79.2	0.0000622	0.0401	22	44	70	108	143
0.0080	0.203	64.0	0.0000503	0.0324		39	63	97	129
0.0071	0.180	50.4	0.0000396	0.0255		35	56	86	114
0.0063	0.160	39.7	0.0000312	0.0201		31	50	77	101
0.0056	0.142	31.4	0.0000246	0.0159		26	44	68	90
0.0050	0.127	25.0	0.0000196	0.0127		24	40	61	80
0.0045	0.114	20.2	0.0000159	0.0103		22	36	55	72
0.0040	0.102	16.0	0.0000126	0.00811			32	49	64
0.0035	0.089	12.2	0.00000962	0.00621			28	43	56
0.0031	0.079	9.61	0.00000755	0.00487			24	38	50

such that the finished product meets the properties and requirements in this specification (Note 3).

NOTE 3—Silver coatings on copper-clad steel provide for:

(*a*) A barrier between the copper and insulation whose curing temperature in the process of fabricating is too high for the use of tin-coated wires.

(*b*) A low contact resistance between the strands of outer conductors of coaxial conductors used in high-frequency circuits.

(*c*) A low radio-frequency resistance of conductors used in high-frequency circuits (skin effect).

(*d*) Good solderability for high-temperature hook-up wires which prohibit the use of tin-coated wires due to high curing temperatures used in fabricating the finished wire.

6. General Requirements

6.1 Tensile strength and elongation of the silver-coated wire shall conform to the requirements of Specification B 452 for the applicable size and class of copper-clad steel wire.

6.2 *Resistivity*— The electrical resistivity at a temperature of 20°C shall not exceed the values prescribed in Table 2. See Note 4 for calculating electrical resistance.

6.3 *Continuity of Coating*—The coating shall be continuous. The continuity of the coating shall be determined on representative samples taken before stranding or insulating and shall be determined by the sodium polysulfide test, in accordance with 10.2.3.1. Wire whose coating mass corresponds to a thickness less than 0.00005 in. (50 µin.) shall not be subject to this test.

TABLE 2 Resistivity

Resistivity, max at 20°C	
Class of Wire	Ω·mm^2/m
30HS and 30A	0.05862 (0.0586160)
40HS and 40A	0.04397 (0.043970)

6.4 *Mass of Coating*— The mass of coating expressed in percent of the total mass of the wire shall be not less than the percentage specified and referred to in this specification or the percentage as agreed on between the manufacturer and purchaser at the time of the placing of the order. For ease of comparison, the thickness of coating for various percentages has been included in Table 1.

6.5 *Joints*—Necessary joints in the wire and rods prior to final coating and drawing shall be made in accordance with good commercial practice. Joints made after coating shall not be allowed to remain in the final product.

NOTE 4—Relationships which may be useful in connection with the values of electrical resistivity prescribed in this specification are shown in Table 2. 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 values 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 mass resistivity of annealed copper equal to 100 % conductivity. The latter term means that a copper wire 1 m in length and mass of 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 with mass of 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. 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 B 193. The use of five significant figures is required for complete reversible conversion from one set of resistivity units to another.

7. Dimensions and Permissible Variations

7.1 The wire sizes shall be expressed as the diameter of the wire in decimal fractions of an inch to the nearest 0.0001 in. (0.003 mm) (Note 5). For diameters under 0.0100 in. (0.254 mm), the wire shall not vary from the specified diameter by more than ±0.0001 in. (0.003 mm) and for diameters of 0.0100 in. (0.254 mm) and over, the wire shall not vary from the specified diameter by more than ±1 %, expressed to the nearest 0.0001 in. (0.003 mm).

NOTE 5—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 wires 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*[4] of the National Institute of Standards and Technology.

8. Workmanship, Finish, and Appearance

8.1 The coating shall consist of a smooth, continuous layer, firmly adherent to the surface of the copper. The wire shall be bright and free from all imperfections not consistent with good commercial practice.

9. Sampling

9.1 The number of production units in a sample (Note 6) shall be as follows:

9.2 For elongation, resistivity, and mass of coating determinations, the sample shall consist of four production units. For continuity of coating determinations, 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 test.

9.3 For dimensional measurements and surface finish, the samples shall consist of a quantity of production units shown in Table 3 under the heading "First Sample."

9.4 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 4.

NOTE 6—Cumulative results secured on the product of a single manufacturer indicating continued conformance to the criteria, are necessary to ensure an overall product meeting the requirements of this specification. The sample size and conformance criteria given for the various characteristics are applicable only to lots produced under these conditions.

TABLE 4 Sampling for Surface Finish and Packaging Inspection

No. Units in Lot	No. of Units in Sample, *n*	Allowable No. 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	1
301 to 500, incl	100	2
501 to 800, incl	130	3
Over 800	155	4

10. Test Methods

10.1 For tensile strength, elongation, resistivity, dimensional measurement and the quality of the basis wire, the latest issue of Specification B 452 shall apply and the tests shall be performed on the silver-coated wire (Note 7).

NOTE 7—It is known that the rate of loading during tension testing affects the performance of the sample to a greater or lesser extent depending upon many factors. 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 case of tests on soft or annealed 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 (300 mm/min) do not alter the final results of tensile strength and elongation determinations to any practical extent. In the case of hard-drawn wire, these effects are pronounced when the speed of the moving head is excessive. It is suggested that tests be made at speeds of moving head which, under no-load conditions, are not greater than 3 in./min (76 mm/min), but in no case at a speed greater than that at which correct readings can be made.

10.2 *Continuity of Silver Coating*:

10.2.1 *Specimens*:

10.2.1.1 *Length of Specimens*—Test specimens shall each have a length of about 6 in. (150 mm). They shall be tagged or marked to correspond with the coil, spool, or reel from which they were cut.

10.2.1.2 *Treatment of Specimens*—The specimens shall be thoroughly cleaned by immersion in a suitable organic solvent such as benzene, ether, or trichlorethylene for at least 3 min; then removed and wiped dry with a clean, soft cloth. 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.

[4] Available from the National Institute of Standards and Technology, (NIST), Gaithersburg, MD 20899.

TABLE 3 Sampling for Dimensional Measurements

No. of Units in Lot	First Sample		Second Sample		
	No. of Units in Sample n_1	Allowable No. of Defects in Sample c_1	No. of Units in Sample n_2	$n_1 + n_2$	Allowable No. of Defects in both Samples, c_2
1 to 14, incl	all	0	...	...	0
15 to 50, incl	14	0	...	...	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

10.2.2 *Special Solutions*:

10.2.2.1 *Sodium Polysulfide Solution*—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 1.142 at 15.6°C (60°F). The sodium polysulfide test solution should have sufficient strength to blacken thoroughly a piece of clean uncoated 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 (Note 8).

NOTE 8—It is important that the polysulfide solution be of proper composition and strength at the time of test. A solution which is not saturated with sulfur or which 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 which has not deteriorated through exposure to air; and if exposure has occurred, the crystals should be tested for purity. The "Standard Reagents Test"[5] of the American Chemical Society are useful in this connection.

10.2.2.2 *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 the HCl solution having a volume of 180 mL shall be considered exhausted if it fails to remove within 15 s the discoloration of the silver due to the polysulfide immersion.

10.2.3 *Procedure*:

10.2.3.1 *Immersion in Polysulfide Solution*—Immerse a length of at least 4½ in. (115 mm) from each of the clean specimens for 30 s in the sodium polysulfide solution, described in 10.2.2.1, maintained at a temperature between 15.6 and 21°C (60 and 70°F).

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

10.2.3.3 *Immersion in Hydrochloric Acid*—After washing the specimen immerse immediately for 15 s in the HCl solution described in 10.2.2.2, wash thoroughly in clean water, and wipe dry with a clean, soft cloth.

10.2.3.4 *Examination of Specimens*—After immersion and washing examine the specimens to ascertain if copper exposed through openings in the silver coating has been blackened by action of the sodium polysulfide. Examine the specimen with the unaided eye (normal spectacles excepted) against a white background. 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. (13 mm) of the cut end.

10.3 *Mass of Coating*—Methods of determining thickness of plated material and the subsequent calculation of silver mass, assuming concentricity of the underlying wire, include X-ray, chemical, and various thickness measurement techniques utilizing cross sectional area and mass formulas. Any of these techniques may be utilized for silver mass determination.

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

11. Inspection

11.1 *General*—All tests and inspections shall be made at the place of manufacture unless otherwise agreed upon between the manufacturer and the purchaser at the time of the purchase. The manufacturer shall afford the inspector representing the purchaser all reasonable facilities necessary to ensure that the material is being furnished in accordance with this specification (Note 6).

11.1.1 Unless otherwise agreed by the manufacturer and the purchaser, conformance of the wire to the various requirements listed in Section 6 shall be determined on samples taken from each lot of wire presented for acceptance.

11.1.2 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.

12. Conformance Criteria

12.1 Any lot of wire, the samples of which comply with the conformance criteria of this section, shall be considered as complying with the requirements of Section 6. 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.

12.2 The lot shall be considered conforming if the conformance criteria of Specification B 452 have been met for tensile properties and the quality characteristics relative to the basis wire.

12.3 *Resistivity*— The electrical resistivity of each of the four specimens shall conform to the requirements of 6.2. Failure to meet these requirements shall constitute failure to meet the resistivity conformance criterion.

12.4 *Dimensions*—The dimensions of the first sample (Table 3) shall conform to the requirements of 7.1. If there are no failures, the lot conforms to this requirement. If there are failures, but the number of these do not exceed the allowable defect number, c_2 (Table 3), 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 $n_1 + n_2$ units shall not exceed the allowable defect number, c_2. Failure to meet this requirement shall constitute failure to meet the dimensional conformance criterion.

12.5 *Continuity of Coating*—The continuity of the coating of each of the eight specimens shall conform to the requirements of 6.3. Failure of more than two specimens shall

[5] *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmaceutical Convention, Inc. (USPC), Rockville, MD.

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.

12.6 *Mass of Coating*— The mass of coating of each of the four specimens shall conform to the requirements of 6.4. Failure of more than one specimen shall constitute failure to meet the mass criterion. If only one specimen fails to meet the mass criterion, four additional specimens from the lot shall be tested, all of which shall conform to the mass criterion. However, any individual production unit, the specimen from which failed the mass criterion, shall be rejected.

13. Density

13.1 For the purpose of calculating mass per unit length (Note 9), cross sections, etc., the density of the wire shall be taken as 0.29444 lb/in.^{3}(8.15 g/cm^3) at 20°C for the materials covered by this specification. The value is an average for the classes of the basis wire with no allowance being made for the silver coating.

NOTE 9—The term mass per unit length is used in the specification as being more technically correct. It replaces the term "weights."

14. Packaging and Package Marking

14.1 The package size shall be agreed upon by the manufacturer and purchaser in the placing of individual orders. The wire shall be protected against damage in ordinary handling and shipping (Note 10).

NOTE 10—Attention is called to the desirability for agreement between the manufacturer and the purchaser on package sizes which will be sufficiently large and yet not so heavy or bulky that the wire may likely be damaged in handling.

14.2 Conformance to the packaging requirements specified by the purchaser shall be determined in accordance with Table 3. The number of units in the sample showing nonconformance to the requirements shall not exceed the allowable defect number, *c*, in Table 3. Failure to meet this requirement shall constitute failure to meet the packaging conformance criterion.

15. Keywords

15.1 clad steel electrical conductor; copper-clad steel electrical conductor; electrical conductor; silver—electrical/electronic application; silver-coated; copper-clad steel wire.