Designation: B 559 – 93 (Reapproved 2002)ε1

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

This standard is issued under the fixed designation B 559; 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.

ε[1] NOTE—A cautionary note was moved into the section text editorially October 2002.

1. Scope

1.1 This specification covers nickel-coated, round, copper-clad steel wire for electronic application.

1.2 Nickel coatings in mass percentages of the total mass of the coated wire are as follows: 2, 4, 7, 10, and 27 %. Nickel-coated wire having different minimum mass percentages of nickel may be obtained by mutual agreement between the manufacturer and the purchaser. For information purposes, the thickness of coating in microinches provided by the percentages listed above is shown in Table 1.

1.3 Four classes of nickel-coated, copper-clad steel wire are covered as follows:

1.3.1 *Class N30HS*—Nominal 30 % conductivity, hard drawn.

1.3.2 *Class N30A*—Nominal 30 % conductivity, annealed.

1.3.3 *Class N40HS*—Nominal 40 % conductivity, hard drawn.

1.3.4 *Class N40A*—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 only to the test method described in this specification. *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.* (**Warning**—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 75 Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys[3]

2.3 *American Chemical Society:*

Standard Reagents Tests[4]

2.4 *NIST Standard:*

NBS *Handbook 100—Copper Wire Tables*[5]

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 1).

NOTE 1—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 (230 kg) of wire cannot be justified economically. For small lots of 500 lb (230 kg) or less, the purchaser may agree to the manufacturers' regular inspection of the product as a whole as evidence of acceptability of such small lots.

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

[1] This specification is under the jurisdiction of ASTM Committee B01 on Electrical Conductors and is the direct responsibility of Subcommittee B01.06 on Composite Conductors.

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

[3] *Annual Book of ASTM Standards*, Vol 03.06.

[4] *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.

[5] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 3460, Gaithersburg, MD 20899-3460.

TABLE 1 Nickel Mass Percent and Thickness of Coating

Diameter		Cross-Sectional Area at 20°C			Thickness of Nickel,μ in. (for information only)				
in.	mm	cmil	$in.^2$	mm^2	2.0 %	4.0 %	7.0 %	10.0 %	27.0 %
0.0720	1.829	5 180	0.00407	2.63	334	637	1 181	1 703	4 892
0.0641	1.628	4 110	0.00323	2.08	298	566	1 050	1 514	4 349
0.0571	1.450	3 260	0.00256	1.65	266	505	936	1 350	3 880
0.0508	1.290	2 580	0.00203	1.31	236	450	833	1 200	3 452
0.0453	1.151	2 050	0.00161	1.04	211	401	743	1 071	3 077
0.0403	1.024	1 620	0.00128	0.823	202	357	661	953	2 738
0.0359	0.912	1 290	0.00101	0.653	167	318	589	849	2 439
0.0320	0.813	1 020	0.000804	0.519	149	283	525	757	2 174
0.0285	0.724	812	0.000638	0.412	133	252	467	686	1 937
0.0253	0.643	640	0.000503	0.324	118	224	415	598	1 719
0.0226	0.574	511	0.000401	0.259	105	200	371	535	1 536
0.0201	0.511	404	0.000317	0.205	94	178	330	475	1 366
0.0179	0.455	320	0.000252	0.162	83	158	294	423	1 216
0.0159	0.404	253	0.000199	0.128	74	141	261	376	1 080
0.0142	0.361	202	0.000158	0.102	66	126	233	336	965
0.0126	0.320	159	0.000125	0.0804	59	112	207	298	856
0.0113	0.287	128	0.000100	0.0647	53	100	185	267	768
0.0100	0.254	100	0.0000785	0.0507	47	89	164	237	680
0.0089	0.226	79.2	0.0000622	0.0401	41	80	146	211	605
0.0080	0.203	64.0	0.0000503	0.0324	...	71	131	189	544
0.0071	0.180	50.4	0.0000396	0.0255	...	63	116	168	482
0.0063	0.160	39.7	0.0000312	0.0201	...	56	103	149	428
0.0056	0.142	31.4	0.0000246	0.0159	...	50	92	132	381
0.0050	0.127	25.0	0.0000196	0.0127	...	44	82	118	340
0.0045	0.114	20.2	0.0000159	0.0103	...	40	74	106	306
0.0040	0.102	16.0	0.0000126	0.00811	...	...	66	95	272
0.0035	0.089	12.2	0.00000962	0.00621	...	...	57	83	238
0.0031	0.079	9.61	0.00000755	0.00487	...	...	51	73	211

from any individual production unit of the sample.

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 Section 7 and Table 1).

4.1.3 Class of basis wire (see 1.3).

4.1.4 Mass percentage of nickel coating (see 1.2 and Table 1).

4.1.5 Package size (see 14.2 and Section 14). Packaging inspection, if required (see 9.1.3).

4.1.6 Special package marking, if required.

4.1.7 Place of inspection (see 13.1).

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 nickel-coated wire shall consist of the basis wire coated with nickel (Note 2). The quality of the nickel-coated wire shall be such that the finished product meets the properties and requirements in this specification.

NOTE 2—Nickel on copper-clad steel wire provides a protective coating for a prevention of oxidation of the copper either during fabrication or service.

6. General Requirements

6.1 Tensile strength and elongation of the nickel-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 3 for calculating electrical resistance.

NOTE 3—Relationships which may be useful in connection with the values of electrical resistivity prescribed in this specification are shown in Table 3. Resistivity units ⅛₈ Ω-mm^2/m and 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 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. The volume resistivity is equivalent, for example, to 1.7241 $\mu\Omega$ 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*. The use of five significant figures in expressing resistivity does not imply the need for a 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.

TABLE 2 Resistivity

Resistivity, max at 20°C		
Class of Wire	Nickel Mass %	Ω-mm^2/m
N30A and N30HS	2	0.05906 (0.059062)
	4	0.05951 (0.059513)
	7	0.06021 (0.060210)
	10	0.06093 (0.060926)
	27	0.06543 (0.065433)
N40A and N40HS	2	0.04442 (0.044418)
	4	0.04490 (0.044902)
	7	0.04561 (0.045614)
	10	0.04636 (0.046362)
	27	0.05122 (0.051216)

TABLE 3 Equivalent Resistivity Values

Class	Nickel Mass %	Volume Conductivity at 20°C % IACS	Resistivity Equivalents at 20°C					
			Volume				Mass	
			Ω·mm²/m	Ω·cmil/ft	μΩ·in.	μΩ·cm	Ω·lb/mile²	Ω·g/m²
N40A and N40HS	2	38.814	0.044418	26.72	1.7489	4.4418	2067.2	0.36202
	4	38.379	0.044902	27.01	1.7679	4.4902	2089.7	0.36596
	7	37.795	0.045614	27.44	1.7960	4.5614	2122.8	0.37176
	10	37.185	0.046362	27.89	1.8254	4.6362	2157.6	0.37786
	27	33.661	0.051216	30.81	2.0165	5.1216	2383.5	0.41742
N30A and N30HS	2	29.190	0.059062	35.53	2.3253	5.9062	2748.5	0.48135
	4	28.969	0.059513	35.80	2.3431	5.9513	2769.5	0.48503
	7	28.633	0.060210	36.22	2.3706	6.0210	2802.0	0.49071
	10	28.297	0.060926	36.65	2.3987	6.0926	2835.3	0.49654
	27	26.349	0.065433	39.36	2.5762	6.5433	3045.0	0.53328

6.3 *Continuity of Coating*—The nickel 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. Wire whose coating weight corresponds to a thickness less than 50 μ in. (0.00005 in.) (1.3 μm) shall not be subject to this test.

6.4 *Adherence of Coating*—The nickel coating shall be firmly adhered to the surface of the copper-clad steel wire. The adherence of coating on the wire shall be determined on representative samples taken before stranding or insulating. The adherence of coating shall be determined by the wrapping, and immersion test in accordance with 10.3.

6.5 *Mass of Coating*—The mass of nickel 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.

6.6 *Joints*—Necessary joints in the wire and rods prior to final coating and drawing shall be made in accordance with good commercial practice.

7. Dimensions, Mass, 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 4). For diameters under 0.0100 in. (0.254 mm), the wire shall not vary from the specified diameter by more than + 0.0003 in. (0.009 mm) and − 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 + 3 % and − 1 %, expressed to the nearest 0.0001 in. (0.003 mm).

NOTE 4—The values of the wire diameters in Table 1 are given to the nearest 0.0001 in. (0.003 mm) 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*.

8. Workmanship, Finish, and Appearance

8.1 The nickel 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.

8.2 The finish of the samples taken in accordance with Table 4 shall conform to the requirements of 8.1. 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 4. Failure to meet this requirement shall constitute failure to meet the finish conformance criterion.

9. Sampling

9.1 The number of production units in a sample (Note 5) shall be as follows:

NOTE 5—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 size and conformance criteria given for the various characteristics are applicable only to lots produced under these conditions.

9.1.1 For tensile strength, elongation, resistivity, mass of coating and adhesion and other defects, the sample shall consist of four production units. For surface finish the sampling shall be in accordance with Table 4. From each unit, one test specimen of sufficient length shall be removed for the performance of required tests.

9.1.2 For dimensional measurements, the sample shall consist of a quantity of production units shown in Table 5 under heading“ First Sample.”

9.1.3 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 as shown in Table 4.

TABLE 4 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	1
301 to 500, incl	100	2
501 to 800, incl	130	3
Over 800	155	4

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 Sample c_1	Number of Units in Sample n_2	$n_1 + n_2$	Allowable Number 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. Test Methods

10.1 *Tensile Properties*—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 nickel-coated wire (Note 6).

NOTE 6—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 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 trichloroethylene for at least 3 min, then removed and wiped dry with a clean, soft cloth (**Warning**—See 1.5). The specimen 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.

10.2.2 *Special Solution* (sp gr 1.142)—Make concentrated solution by dissolving sodium sulfide crystals (cp) in distilled water until the solution is saturated at about 21°C (70°F), and add 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. Make the test solution 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 7).

NOTE 7—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 treated 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 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.

10.2.3 *Procedure*—Immerse a length of at least 4½ in. (114 mm) from each of the clean specimens for 30 s in the sodium polysulfide solution (10.2.2) maintained at a temperature between 15.6 and 21°C (60 and 70°F). After the immersion, immediately wash the specimens in clean water and wipe dry with a clean, soft cloth or tissue. After immersion and washing, examine the specimens to ascertain if copper exposed through openings in the nickel coating has been blackened by action of the sodium polysulfide. Examine the specimen with the normal eye against a white background. Consider the specimens 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 *Adherence of Coating*:

10.3.1 *Specimens*—Test specimens shall be approximately 12 in. (300 mm) in length and shall be tagged or marked to correspond with coil, spool, or reel from which they are cut. The specimens shall be thoroughly cleaned, if required, by immersion in a suitable organic solvent such as benzene, ether, or trichlorethylene for at least 3 min, then removed and dried (**Warning**—See 1.5). 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 of the surface to be subjected to test. Wire sizes 0.005 in. (0.13 mm) and smaller may be cleaned after wrapping around the mandrel.

10.3.2 *Procedure*:

10.3.2.1 *Wrapping*—Wrap the test specimen slowly in a suitable manner in an open helix around a wire of 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. For wire sizes 0.021 in. (0.53 mm) and smaller, use approximately six helical turns for the test. For wire larger than 0.021 in., use approximately three turns.

10.3.2.2 *Immersion Test*—Remove the helically wrapped

portion of the test specimen from the mandrel and completely immerse it in the sodium polysulfide solution (10.2.2) for 30 s at the temperature prescribed in 10.2.3. On removal from the sodium polysulfide solution, rinse the specimen immediately in clean water and remove the excess by shaking.

10.3.2.3 *Examination of Specimens*—Examine the outer surface of the helically wrapped portion of the specimen under magnification not to exceed 7× diameter. Any cracking or flaking of the coating in this area shown by blackening of the copper area shall be cause for rejection. A grayish appearance of the coating after immersion shall not constitute failure.

10.4 *Mass of Coating*—Determine the conformance to the mass requirement in accordance with Test Method A. In case of disagreement, use Test Method B and the result obtained shall be final. Test Methods A and B are given in the Annex.

10.5 *Finish*—Make the surface finish inspection with the unaided eye (normal spectacles excepted).

11. Conformance Criteria (Note 5)

11.1 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 following criteria shall constitute cause for rejection of the lot. The conformance criteria for each of the prescribed properties given in a Section 6 are as follows:

11.1.1 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.

11.1.2 *Resistivity*—The electrical resistivity of each of the four specimens shall conform to the requirements of Table 2. Failure to meet these requirements shall constitute failure to meet the resistivity conformance criteria of 6.2.

11.1.3 *Dimensions*—The dimensions of the first sample (Table 4) shall conform to the requirements of Section 7. If there are no failures, the lot shall be considered as conforming to these requirements. If there are failures, but the number of these do not exceed the allowable defect number c_2(Table 4) for the respective number of units in the sample, a second sample equal to n_2 shall be taken and the total defects of the $n_1 + n_2$ units shall not exceed the allowable defect number c_2. Failure to meet this requirement shall constitute failure to meet the dimensional conformance criterion.

11.1.4 *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 constitute failure to meet the continuity criterion. If one or two specimens fail to meet the continuity criteria, 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.

11.1.5 *Mass of Coating*—The mass of coating of each of the four specimens shall conform to the requirements of 6.5. Failure of more than one specimen shall constitute failure to meet the mass criterion. If only one specimen fails to meet the mass criteria, 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.

11.1.6 *Adherence of Coating*—The adherence of the coating of each of the eight specimens shall conform to the requirements of 6.4. Failure of more than two specimens shall constitute failure to meet the adherence criterion. If there is failure on not more than two specimens, 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.

12. Density

12.1 For the purpose of calculating mass/unit length (Note 8), cross section, 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 material covered by this specification.

NOTE 8—The term mass per unit length is used in the standard as being more technically correct. It replaces the term "weights."

13. Inspection

13.1 *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 5).

13.1.1 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.

13.1.2 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.

14. Packaging and Package Marking

14.1 The package size shall be agreed upon by the manufacturer and the purchaser in the placing of individual orders (Note 9). The wire shall be protected against damage in ordinary handling and shipping.

NOTE 9—Attention is called to the desirability for agreement between the manufacturer and the purchaser on package sizes that 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 4. The number of units in the sample showing nonconformance to the requirements shall not exceed the allowable defect number *c* in Table 4. 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; copper-clad steel wire; electrical conductor; nickel-coated; nickel-electrical/electronic application

ANNEX

(Mandatory Information)

A1. DETERMINATION OF THE MASS OF NICKEL ON NICKEL-COATED, COPPER-CLAD STEEL WIRE

A1.1 Test Method A—Electronic Determination
(Explanatory Note A1.1)

NOTE A1.1—*Principle or 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 as 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 of 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 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.

A1.1.1 *Apparatus and Reagent*:

A1.1.1.1 Electronic Thickness Tester with Accessory Unit" WT".[6]

A1.1.1.2 Solution R-54.[6]

A1.1.2 *Limitations of Test Method A*

This test method is suitable for the determination of the thickness of coatings as follows:

Wire Size Diameter, in.	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

A1.1.3 *Procedure:*

A1.1.3.1 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 "Nickel." Turn power on and allow a 5-min warm-up period.

A1.1.3.2 Fill the stainless steel beaker to within ½ to ¼ in. from the top with Solution R-54. Maintain temperature of solution at 20 to 25°C.

A1.1.3.3 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.

A1.1.3.4 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.

A1.1.3.5 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 A1.1. The result will be the thickness of the plating in microinches. The weight of nickel, in percent of the total mass of the wire, may be calculated as follows (Note A1.2):

TABLE A1.1 Thickness Factors

Wire Size Diameter, in.	Test Length, in.	Thickness, μ in.[A]
0.0720	0.50	1.28
0.0641	0.50	1.44
0.0571	0.50	1.62
0.0508	0.50	1.80
0.0453	0.50	2.04
0 0403	0.50	2.32
0.0359	0.50	2.56
0.0320	0.50	2.86
0.0285	0.50	3.28
0.0253	0.50	3.70
0.0226	1.00	2.05
0.0201	1.00	2.30
0.0179	1.00	2.55
0.0159	1.00	2.90
0.0142	1.00	3.25
0.0126	1.00	3.70
0.0113	2.00	2.05
0.0100	2.00	2.30
0.0089	2.00	2.60
0.0080	2.00	2.90
0.0071	2.00	3.25
0.0063	2.00	3.65
0.0056	4.00	2.06
0.0050	4.00	2.32
0.0045	4.00	2.60
0.0040	4.00	2.90
0.0035	4.00	3.28
0.0031	4.00	3.68

[A] Values given must be multiplied by the gage reading to obtain the actual thickness.

[6] This apparatus and the reagent available from Kocour Co., 4800 S. St. Louis Ave., Chicago, IL 60632 have been found suitable for this purpose.

$$\text{Nickel, \%} = t/d \times 0.43628 \times 10^{-3}$$

where:
t = thickness of plate μin.,
d = over-all diameter of wire, in.

NOTE A1.2—The equation given for the mass of the nickel on the wire is for most purposes sufficiently accurate. However, in the case of heavy coatings, the results obtained by the use of this equation will indicate a slightly higher percent mass than is actually present. The more correct equation for all cases based on a density of 8.89 g/cm^3 for nickel and 8.15 g/cm^3 for copper-clad steel is as follows:

$$\text{Nickel, \%} = 436.28/[1.3632 + (d/t) + (t/(d - t))]$$

where:
d = over-all wire diameter, in., and
t = thickness of plate, in.

A1.1.4 *Precautions*:

A1.1.4.1 Make no adjustments at 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.

A1.1.4.2 Avoid spilling test solutions into the accessory unit.

A1.1.4.3 Wire samples must be clean. If the wire is lacquered, remove the lacquer with a solvent before testing.

A1.1.4.4 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.

A1.1.4.5 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.

A1.1.4.6 The minimum thickness of deposit that can be tested on a particular gage of wire is determined by multiplying the factor for the wire gage by 5.

A1.2 Test Method B—Gravimetric Determination

A1.2.1 *Procedure*

The percentage of nickel shall be determined on samples having 50 to 150 mg nickel content in accordance with Test Methods E 75.