



## Designation: B 559 – 93 (Reapproved 1998)<sup>ε1</sup>

AMERICAN SOCIETY FOR TESTING AND MATERIALS  
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# Standard Specification for Nickel-Coated, Copper-Clad Steel Wire for Electronic Application<sup>1</sup>

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.

<sup>ε1</sup> NOTE—Editorial changes were made throughout in March 1998.

## 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.* 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:

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee B-1 on Electrical Conductors and is the direct responsibility of Subcommittee B01.06 on Composite Conductors.

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## 2.2 ASTM Standards:

B 193 Test Method for Resistivity of Electrical Conductor Materials<sup>2</sup>

B 258 Specification for Standard Nominal Diameters and Cross-Sectional Areas of AWG Sizes of Solid Round Wires Used as Electrical Conductors<sup>2</sup>

B 452 Specification for Copper-Clad Steel Wire for Electronic Application<sup>2</sup>

E 75 Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys<sup>3</sup>

## 2.3 American Chemical Society:

Standard Reagents Tests<sup>4</sup>

## 2.4 NIST Standard:

NBS Handbook 100—Copper Wire Tables<sup>5</sup>

## 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).

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 (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 from any individual production unit of the sample.

<sup>2</sup> Annual Book of ASTM Standards, Vol 02.03.

<sup>3</sup> Annual Book of ASTM Standards, Vol 03.05.

<sup>4</sup> 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 Pharmacopoeia and National Formulary*, U.S. Pharmaceutical Convention, Inc. (USPC), Rockville, MD.

<sup>5</sup> Available from the National Institute of Standards and Technology, (NIST), Gaithersburg, MD 20899.

**TABLE 1 Nickel Mass Percent and Thickness of Coating**

Diameter		Cross-Sectional Area at 20°C			Thickness of Nickel, $\mu$ in. (for information only)				
in.	mm	cmil	in. <sup>2</sup>	mm <sup>2</sup>	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

#### 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 3). The quality of the nickel-coated wire shall be such that the finished product meets the properties and requirements in this specification.

NOTE 3—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 4 for calculating electrical resistance.

**TABLE 2 Resistivity**

Class of Wire	Resistivity, max at 20°C	
	Nickel Mass %	$\Omega$ -mm <sup>2</sup> /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)

NOTE 4—Relationships which may be useful in connection with the values of electrical resistivity prescribed in this specification are shown in Table 3. Resistivity units  $\frac{1}{88} \Omega$ -mm<sup>2</sup>/m and 0.15328  $\Omega$ -g/m<sup>2</sup> 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  $\Omega$ . This is equivalent to a resistivity value of 875.20  $\Omega$ -lb/mile<sup>2</sup>, 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<sup>2</sup> 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.

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

**TABLE 3 Equivalent Resistivity Values**

Class	Nickel Mass %	Volume Conductivity at 20°C % IACS	Resistivity Equivalents at 20°C					
			Volume			Mass		
			$\Omega\text{-mm}^2/\text{m}$	$\Omega\text{-cmil/ft}$	$\mu\Omega\text{-in.}$	$\mu\Omega\text{-cm}$	$\Omega\text{-lb/mile}^2$	$\Omega\text{-g/m}^2$
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

to a thickness less than 50  $\mu$  in. (0.00005 in.) (1.3  $\mu$ m) 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 5). 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 5**—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

**TABLE 4 Sampling for Surface Finish and Packaging Inspection**

Number of Units in Lot	Number of Units in Sample, <i>n</i>	Allowable Number of Defective Units, <i>c</i>
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

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 6) shall be as follows:

**NOTE 6**—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.

## 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