Designation: B 452 – 02

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

This standard is issued under the fixed designation B 452; 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.

1. Scope

1.1 This specification covers bare round copper-clad steel wire for electronic application.

1.2 Four classes of copper-clad steel wire are covered as follows:

1.2.1 *Class 30HS*—Nominal 30 % conductivity hard-drawn,

1.2.2 *Class 30A*—Nominal 30 % conductivity annealed,

1.2.3 *Class 40HS*—Nominal 40 % conductivity hard-drawn, and

1.2.4 *Class 40A*—Nominal 40 % conductivity annealed.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are in SI units.

2. Referenced Documents

2.1 The following documents of the issue in effect on the 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]

2.3 *National Institute of Standards and Technology:*

NBS *Handbook 100—Copper Wire Tables*[3]

3. Ordering Information

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

3.1.1 Quantity of each size and class,

3.1.2 Wire size, diameter in inches (see 5.3 and Table 1),

3.1.3 Class of wire (see 1.2 and Table 1),

3.1.4 Packaging and shipping (Section 10),

3.1.5 If inspection is required (see 6.3.3), and

3.1.6 Place of inspection (see 6.1).

4. Material

4.1 The wire shall consist of a core of homogeneous open-hearth, electric-furnace, or basic-oxygen steel with a continuous outer cladding of copper thoroughly bonded to the core throughout and shall be of such quality as to meet the requirements of this specification (Note 1).

NOTE 1—The copper-clad steel wire provides a high-strength conductor for use in wire and cable where greater strength is required and a lower conductivity can be tolerated. At high frequencies the reduced conductivity is less pronounced due to concentration of the current in the outer periphery of the wire. Minimum thickness of 6 % and 10 % of the radius for 30 and 40 % conductivity material, respectively, has been established to facilitate the inspection of thickness on fine wires.

5. General Requirements

5.1 *Tensile Strength and Elongation*—The copper-clad steel wire shall conform to the tensile strength and elongation requirements of Table 1. For intermediate sizes not listed in Table 1, the elongation requirements of the next smaller size shall apply; in the case of tensile strength, the requirements of the next larger size shall apply.

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

NOTE 2—Relationships which may be useful in connection with the values of electrical resistivity prescribed in this specification are shown in Table 3. Resistivity units are based on the International Annealed Copper Standard (IACS) adopted by IEC in 1913, which is $\frac{1}{58}$ 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 100 % conductivity. The latter term means that a copper wire 1 in. in length and weighing 1 g would have a resistance of 0.15328 Ω. This is equivalent to a resistivity value of 875.20Ω· 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*. 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.

5.3 *Dimensions and Permissible Variations*—The wire sizes

[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.

Current edition approved April 10, 2002. Published April 2002. Originally published as B 452 – 67. Last previous edition B 452 – 93(1998)$^{\epsilon 1}$.

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

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

TABLE 1 Tensile and Elongation Requirements

Diameter		Cross-Sectional Area at 20°C			Tensile Strength, psi (kgf/mm^2)				Elongation, min. % in 10 in. (250 mm)	
in.	mm	cmil	in.^{2}	mm^2	Class 30HS, min	Class 30A, min	Class 40HS, min	Class 40A, min	Class 30HS and 40HS	Class 30A and 40A
0.0720	1.83	5180	0.00407	2.63	127 000 (89.3)	50 000 (35.2)	110 000 (77.3)	45 000 (31.6)	1.5	15
0.0641	1.63	4110	0.00323	2.08	127 000 (89.3)	50 000 (35.2)	110 000 (77.3)	45 000 (31.6)	1.5	15
0.0571	1.45	3260	0.00256	1.65	127 000 (89.3)	50 000 (35.2)	110 000 (77.3)	45 000 (31.6)	1.5	15
0.0508	1.29	2580	0.00203	1.31	127 000 (89.3)	50 000 (35.2)	110 000 (77.3)	45 000 (31.6)	1.5	15
0.0453	1.15	2050	0.00161	1.04	127 000 (89.3)	50 000 (35.2)	110 000 (77.3)	45 000 (31.6)	1.5	15
0.0403	1.02	1620	0.00128	0.823	127 000 (89.3)	50 000 (35.2)	110 000 (77.3)	45 000 (31.6)	1.0	15
0.0359	0.912	1290	0.00101	0.653	127 000 (89.3)	50 000 (35.2)	110 000 (77.3)	45 000 (31.6)	1.0	15
0.0320	0.813	1020	0.000804	0.519	127 000 (89.3)	50 000 (35.2)	110 000 (77.3)	45 000 (31.6)	1.0	15
0.0285	0.724	812	0.000638	0.412	127 000 (89.3)	55 000 (38.7)	110 000 (77.3)	50 000 (35.2)	1.0	15
0.0253	0.643	640	0.000503	0.324	127 000 (89.3)	55 000 (38.7)	110 000 (77.3)	50 000 (35.2)	1.0	15
0.0226	0.574	511	0.000401	0.259	127 000 (89.3)	55 000 (38.7)	110 000 (77.3)	50 000 (35.2)	1.0	15
0.0201	0.511	404	0.00317	0.205	127 000 (89.3)	55 000 (38.7)	110 000 (77.3)	50 000 (35.2)	1.0	10
0.0179	0.455	320	0.000252	0.162	127 000 (89.3)	55 000 (38.7)	110 000 (77.3)	50 000 (35.2)	1.0	10
0.0159	0.404	253	0.000199	0.128	127 000 (89.3)	55 000 (38.7)	110 000 (77.3)	50 000 (35.2)	1.0	10
0.0142	0.361	202	0.000158	0.102	127 000 (89.3)	55 000 (38.7)	110 000 (77.3)	50 000 (35.2)	1.0	10
0.0126	0.320	159	0.000125	0.0804	127 000 (89.3)	55 000 (38.7)	110 000 (77.3)	50 000 (35.2)	1.0	10
0.0113	0.287	128	0.000100	0.0647	127 000 (89.3)	55 000 (38.7)	110 000 (77.3)	50 000 (35.2)	1.0	10
0.0100	0.254	100	0.0000785	0.0507	127 000 (89.3)	55 000 (38.7)	110 000 (77.3)	50 000 (35.2)	1.0	10
0.0089	0.226	79.2	0.0000622	0.0401	127 000 (89.3)	55 000 (38.7)	110 000 (77.3)	50 000 (35.2)	1.0	10
0.0080	0.203	64.0	0.0000503	0.0324	127 000 (89.3)	55 000 (38.7)	110 000 (77.3)	50 000 (35.2)	1.0	10
0.0071	0.180	50.4	0.0000396	0.0255	127 000 (89.3)	55 000 (38.7)	110 000 (77.3)	50 000 (35.2)	1.0	10
0.0063	0.160	39.7	0.0000312	0.0201	127 000 (89.3)	55 000 (38.7)	110 000 (77.3)	50 000 (35.2)	1.0	10
0.0056	0.142	31.4	0.0000246	0.0159	127 000 (89.3)	55 000 (38.7)	110 000 (77.3)	50 000 (35.2)	1.0	10
0.0050	0.127	25.0	0.0000196	0.0127	127 000 (89.3)	55 000 (38.7)	110 000 (77.3)	50 000 (35.2)	1.0	10
0.0045	0.114	20.2	0.0000159	0.0103	127 000 (89.3)	55 000 (38.7)	110 000 (77.3)	50 000 (35.2)	1.0	10
0.0040	0.102	16.0	0.0000126	0.00811	127 000 (89.3)	55 000 (38.7)	110 000 (77.3)	50 000 (35.2)	1.0	10
0.0035	0.089	12.2	0.00000962	0.00621	127 000 (89.3)	55 000 (38.7)	110 000 (77.3)	50 000 (35.2)	1.0	10
0.0031	0.079	9.61	0.00000755	0.00487	127 000 (89.3)	55 000 (38.7)	110 000 (77.3)	50 000 (35.2)	1.0	10

TABLE 2 Resistivity, max, at 20°C

Class of Wire	Ω·mm^2/m
30HS and 30A	0.05862 (0.058616)
40HS and 40A	0.04397 (0.043970)

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 3). 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 3—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.*

5.4 *Adhesion and Other Defects*—The copper-clad steel wire, when tested in accordance with 7.4, shall not reveal any seams, pits, slivers, or other imperfection of sufficient magnitude to indicate inherent defects or imperfections. Examination of the wire at the break with the unaided eye (normal spectacles excepted) shall show no separation of copper from the steel.

5.5 *Joints*—Necessary joints in the wire and rods prior to final drawing shall be made in accordance with good commercial practice. The finished wire shall contain no joints or splices made at finished size.

5.6 *Finish*—The wire shall be free from copper discontinuities and all imperfections not consistent with good commercial practice (see 7.5).

5.7 *Copper Thickness*—The minimum copper thickness due to eccentricity shall be not less than the following:

5.7.1 The 30 % conductivity wire shall have a minimum thickness of not less than 6 % of the wire radius.

5.7.2 The 40 % conductivity wire shall have a minimum thickness of not less than 10 % of the wire radius (see 7.6 and Note 3).

6. Inspection

6.1 *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 to satisfy him that the

TABLE 3 Equivalent Resistivity Values

Class	Volume Conductivity at 20°C, %	IACS Resistivity Equivalents at 20°C					
		Volume				Mass	
		$\Omega\cdot mm^2/m$	$\Omega\cdot cmil/ft$	$\mu\Omega\cdot in.$	$\mu\Omega\cdot cm$	$\Omega\cdot lb/ mile^2$	$\Omega\cdot g/m^2$
40A and 40HS	39.210	0.043970	26.45	1.7312	4.3970	2046.3	0.35836
30A and 30HS	29.413	0.058616	35.26	2.3078	5.8616	2727.8	0.47772

material is being furnished in accordance with this specification (Note 4).

NOTE 4—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 sizes and conformance criteria given for the various characteristics are applicable only to lots produced under these conditions.

6.1.1 Unless otherwise agreed by the manufacturer and the purchaser, 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.

6.1.2 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.

6.2 *Definitions*:

6.2.1 *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 5).

NOTE 5—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 manufacturer's regular inspection of the product as a whole as evidence of acceptability of such small lots.

6.2.2 *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.

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

6.3 *Sample Size*—The number of production units in a sample (see Note 4) shall be as follows:

6.3.1 For tensile strength, elongation, resistivity, 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 the required tests.

TABLE 4 Sampling for Surface Finish and Packaging Inspection

No. of 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

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

6.3.3 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.

7. Test Methods

7.1 *Tensile Strength and Elongation*—The tensile strength, expressed in pounds per square inch (or kilograms-force per square millimetre), 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.

7.1.1 For Classes 30A and 40A, the elongation of wire may be determined as the permanent increase in length, expressed in percent of the original length, due to the breaking of the wire in tension, measured between gage marks placed originally 10 in. (250 mm) apart upon the test specimen (Note 6). The elongation of wire shall be determined as described above or by measurements made between the jaws of the testing machine. When the latter method is used, the zero length shall be the distance between the jaws at the start of the tension test when 10 % of the minimum specified breaking load has been applied and be as near 10 in. (250 mm) as practicable, and the final length shall be the distance between the jaws at the time of rupture. The fracture shall be between gage marks in the case of specimens so marked or between the jaws of the testing machine and not closer than 1 in. (25 mm) to either gage mark or either jaw.

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.

7.1.2 For Classes 30HS and 40HS, the elongation shall be measured by means of an extensometer or other device suitable for measuring elongation in 10 in. (250 mm), and having a vernier reading to 0.01 in. (0.25 mm) attached to the test specimen at a tension load of approximately 10 % of rated strength. The elongation shall be observed while applying a tension load to the specimen and the reading when fracture occurs shall be taken as the elongation of the specimen. Tests

TABLE 5 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	. . .	. . .	. . .
15 to 50, incl	14	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

in which the elongation is less than specified, but in which the fracture has occurred within 1 in. (25 mm) of the jaws or extensometer clamps, shall be disregarded.

7.2 *Resistivity*—The electrical resistivity of the material shall be determined in accordance with Test Method B 193.

7.3 *Dimensional Measurements*—Dimensional measurements shall be made with a micrometer caliper equipped with a vernier graduated in 0.0001 in. (0.0025 mm). Each coil shall be gaged at three places, one near each end and one near the middle. From each spool approximately 12 ft (3600 mm) shall be unreeled and the wire gaged in six places between the second (600th mm) and twelfth foot (3600th mm) from the end.

7.4 *Torsion Test*—The wire shall withstand without fracture not less than 20 torsions in a length equivalent to 100 times the nominal diameter of the specimen. All twists shall be made in the same direction. The rate of applying the twists shall be approximately 15/min. Specimens shall be twisted to destruction and shall meet the requirements of 5.4 of this specification.

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

7.6 *Copper Thickness*—Determination of the minimum copper thickness shall be done by microscopical examination of the polished end or by standard stripping methods or by any other suitable method agreed upon between the manufacturer and the purchaser.

8. Conformance Criteria (See Note 4)

8.1 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 5. 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. The conformance criteria for each of the prescribed properties given in Section 5 are as follows:

8.2 *Tensile Strength and Elongation (for all Classes)*—The lot shall be considered conforming, if the values of the four specimens are not less than the appropriate values in Table 1.

8.3 *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 criterion of 5.2.

8.4 *Dimensions*—The dimensions of the first sample (Table 4) shall conform to the requirements of 5.3. 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 5) 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.

8.5 *Adhesion*—Adhesion of the copper cladding to the steel of each of the four specimens shall conform to the requirements of 5.4. Failure of more than two specimens shall constitute failure to meet the adhesion criterion. If more than two specimens fail to meet the adhesion criterion, four additional specimens from the lot shall be tested, all of which shall conform to the adhesion criterion. However, any individual production unit from which the specimen failed to meet the adhesion criterion shall be rejected.

8.6 *Finish*—The finish of the samples taken in accordance with Table 5 shall conform to the requirements of 5.6. 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 5. Failure to meet this requirement shall constitute failure to meet the finish conformance criterion.

8.7 *Packaging*—Conformance to the packaging requirements specified by the purchaser shall be determined in accordance with Table 5. 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.

9. Density

9.1 For the purpose of calculating mass/unit length, cross sections, etc., the density of the wire shall be taken as shown below at 20°C for the material covered by this specification (Note 7).

Product	English Units	Metric Units
30 % conductivity	0.2944 lb/in^3	8.15 g/ mm^3
40 % conductivity	0.2975 lb/in^3	8.24 g/mm^3

NOTE 7—The term mass per unit length is used in this standard as being more technically correct. It replaces the term weight.

10. Packaging and Shipping

10.1 The package size shall be agreed upon by the manufacturer and the purchaser in the placing of individual orders (Note 8). The wire shall be protected against damage in ordinary handling and shipping.

NOTE 8—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.

11. Keywords

11.1 clad steel electrical conductor; copper electrical conductor—copper-clad steel; copper-clad steel electrical conductor; electrical conductor; hard drawn copper-clad steel wire; steel wire—copper-clad