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Standard Specification for Annealed Copper-Clad Steel Wire[1]

This standard is issued under the fixed designation B 910/B 910M; 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 bare round copper-clad steel for the following applications: electrical, electronic, grounding, telecommunications, and other applications.

1.2 Four conductivities are covered as follows: 21, 30, 40, and 70 %.

1.3 Temper is designated as annealed.

1.4 The values stated in inch-pound or SI units are to be regarded separately as the standard. Each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. For conductor sizes designated by AWG, the requirements in SI units have been numerically converted from corresponding values stated or derived in inch-pound units. For conductor sizes designated by SI units only, the requirements are stated or derived in SI units.

1.5 The following precautionary statement pertains to the test method portion only, Section 7, of 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.*

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:

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[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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2.2 *ASTM Standards:* [2]

B 193 Test Method for Resistivity of Electrical Conductor Materials

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

2.3 *NIST Document:*

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;

3.1.2 Wire size: diameter in inches (see 5.2);

3.1.3 Conductivity (see Table 1);

3.1.4 Wire to be used for redraw or not;

3.1.5 Packaging and shipping (see 10); 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.

5. General Requirements

5.1 *Tensile Strength and Elongation* —The copper-clad steel wire shall conform to the tensile strength requirements of Table 2. Because there are many carbon steel and copper thickness combinations available, the desired tensile strength should be agreed upon between the purchaser and manufacturer prior to placing an order. The elongation shall be 15.0 % minimum for all diameters listed in 5.2.

5.2 *Dimensions*—The wire size range for this specification shall be from 0.0253 (0.643 mm) to 0.2294 in. (5.827 mm) diameter (see Note 1).

5.2.1 *Permissible Variations*—The wire sizes shall meet the following tolerances:

5.2.1.1 For diameters 0.1000 in. (2.54 mm) and over, the wire shall not vary from the specified diameter by more than ± 1½ %, expressed to the nearest 0.0001 in. (0.003 mm).

5.2.1.2 For diameters under 0.1000 in. (2.54 mm) and above 0.0253 in. (0.643 mm), the wire shall not vary from the specified diameter by more than ±1 %, expressed to the nearest 0.0001 in. (0.003 mm).

NOTE 1—The values of the wire diameters in 5.2 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.*

5.3 *Adhesion and Surface 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.

5.4 *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.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards*, ~~Vol 02.03.~~ volume information, refer to the standard's Document Summary page on the ASTM website.

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

TABLE 1 Density (nom.) and Resistivity, (max.), at 20°C (Nominal Conductivity, Minimum Conductivity, and Nominal Density for Reference Only)

Nominal Conductivity (% IACS)	Nominal Density		Maximum Resistivity at 20°C		Minimum Conductivity (% IACS)
	lb/in.^{3}	(g/cm^3)	Ohm cmil/ft	(ohm mm^2/m)	
21	0.2885	(7.99)	54.58	(0.097408)	19.00
30	0.2944	(8.15)	35.26	(0.058616)	29.41
40	0.2975	(8.24)	26.45	(0.043970)	39.21
70	0.3098	(8.58)	15.96	(0.026524)	65.00

TABLE 2 Tensile and Minimum Copper Thickness (Conductivity and Nominal Copper Thickness for Reference Only)

Nominal Conductivity (% IACS)	Minimum Tensile Strength		Minimum Copper Thickness	Nominal Copper Thickness
	psi	(N/mm^2)	(% of Diameter)	(% of Diameter)
21	55 000	(379)	1.5	3
30	50 000	(345)	3.0	7
40	45 000	(310)	5.0	9
70	35 000	(241)	15.0	20

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

5.6 *Copper Thickness*— The minimum copper thickness due to eccentricity shall not be less than shown in Table 2.

5.7 *Resistivity*— The electrical resistivity at a temperature of 20°C shall not exceed the values prescribed in Table 1. 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 2. Resistivity units are based on the International Annealed Copper Standard (IACS) adopted by IEC in 1913, which is ~~1/58~~ 1⁄58 ohm mm^2/m at 20°C for 100 % conductivity. The value of 0.017241 ohm mm^2/m and the value of 0.15328 ohm 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 ohm. This is equivalent to a resistivity value of 875.20 ohm $lb/mile^2$, which signifies the resistance of a copper wire 1 mile in length weighing 1 lb. It is also equivalent, for example, to 1.7241 ohm/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.

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 material is being furnished in accordance with this specification (Note 3).

NOTE 3—Cumulative results secured on the product of a single manufacturer, indicating continued conformance to the criteria, are necessary to ensure an over-all product meeting the requirements of this specification. The sample sizes and conformance criteria given for the various characteristics are applicable only to lots produced under these conditions.

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, is not to exceed 40 000 lb (18 144 kg) (Note 4).

NOTE 4—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.~~) and so forth) 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 3) shall be as follows:

6.3.1 For tensile strength, elongation, resistivity, adhesion, and other defects, the sample shall consist of four production units. For surface finish the sampling shall be in accordance with Table 3. From each unit, one test specimen of sufficient length shall be removed for the performance of the required tests. Samples found defective shall not be used.

7. Test Methods

7.1 *Tensile Strength and Elongation* —Obtain the tensile strength, expressed in pounds per square inch (or kilograms-force per square millimetre), 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 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 5). The elongation of wire shall be determined as described above or by measurements made between the jaws of the testing machine (cross-head movement). When the latter method is used, the zero length shall be the distance between the

TABLE 3 Sampling for Surface Finish and Packaging Inspection

~~Number of Units in Lot~~	~~Number of Units in Sample, *n*~~	~~Allowable N o. of Defective Units, *c*~~
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

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 5—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. It is suggested that tests be made at speeds of moving head which, under no-load conditions, are not greater than ~~3~~ 12 in./min (~~76~~ (305 mm/min), but in no case at a speed greater than that at which correct readings can be made.

7.1.2 Measure the elongation 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. Observe the elongation while applying a tension load to the specimen and take the reading when fracture occurs as the elongation of the specimen. Disregard tests 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.

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

7.3 *Dimensional Measurements*—Make dimensional measurements with a micrometer caliper equipped with a vernier (or better instrument) graduated in 0.0001 in. (0.0025 mm). Gage each coil at three places, one near each end and one near the middle. From each spool unreel approximately 12 ft (3600 mm) and gage the wire in six places between the second (600th mm) and twelfth foot (3600th mm) from the end.

7.4 *Torsion (Twist) 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 5.3 of this specification.

7.5 *Finish*—Surface finish inspection shall be made with the unaided eye (normal spectacles excepted) for wire diameters above 0.100 in. (2.54mm). For sizes of 0.100 in. (2.54 mm) and below a magnifier of 10× may be used.

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 3)

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* —The lot shall be considered conforming, if the values of the four specimens are not less than the appropriate values in Tables 2 and 3.

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 5.7.

8.4 *Dimensions*—The dimensions of the first sample (Table 4) shall conform to the requirements of 5.2. 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.

8.5 *Adhesion*—Adhesion of the copper cladding to the steel of each of the four specimens shall conform to the requirements of 5.3. 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.

TABLE 4 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 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

8.6 *Finish*—The finish of the samples taken in accordance with Table 3 shall conform to the requirements of 5.5. 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 3. 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 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.

9. Density

9.1 For the purpose of calculating mass/unit length, cross sections, ~~etc.,~~ and so forth, the nominal density of the wire shall be as shown in Table 1 at 20°C for the material covered by this specification (Note 6).

NOTE 6—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 7). The wire shall be protected against damage in ordinary handling and shipping.

NOTE 7—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 annealed copper clad steel wire; clad steel electrical conductor; copper electrical conductor—copper-clad steel; copper-clad steel electrical conductor; electrical conductor; steel wire—copper-clad