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Standard Specification for Copper-Clad Aluminum Wire[1]

This standard is issued under the fixed designation B 566; 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 aluminum wire for electrical applications.

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

Class 10A—Nominal 10 volume % copper, annealed.
Class 15A—Nominal 15 volume % copper, annealed.
Class 10H—Nominal 10 volume % copper, hard-drawn.
Class 15H—Nominal 15 volume % copper, hard-drawn.

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

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:* [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 *National Institute of Standards and Technology: NBS Handbook 100—Copper Wire Tables*[3]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *lot*—a lot is any amount of wire of one class and size presented for acceptance at one time; such amount, however, not to exceed 100 production units.

3.1.2 *sample*—a quantity of production units (coils, reels, and so forth) 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.

4. Ordering Information

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

4.1.1 Quantity of each size and class;

4.1.2 Wire size, diameter in inches (see Section 7 and Table 1);

4.1.3 Class of wire (see 1.2 and Table 1);

4.1.4 Packaging and shipping (Section 14 and packaging inspection if required, 13.1); and

4.1.5 Place of inspection (see 13.1).

5. Materials and Manufacture

5.1 The wire shall consist of a core of aluminum 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.

6. General Requirements

6.1 *Tensile Strength and Elongation*—The copper-clad aluminum wire shall conform to the tensile strength and elongation requirements of Table 1. For intermediate diameters 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.

6.2 *Resistivity*—The electrical resistivity at a temperature of 20°C shall not exceed the values prescribed in Table 2. See Note 1 for calculating electrical resistance.

NOTE 1—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 1/58 $\Omega \cdot mm^2/m$ and the value of 0.15328 $\Omega \cdot g/m^2$ at 20°C are, respectively, the international equivalent of volume and weight resistivity of annealed copper equal to 100 % conductivity. The later 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 $\Omega \cdot lb/mile^2$, which signifies the resistance

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[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* 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.

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TABLE 1 Tensile and Elongation Requirements for Copper-Clad Aluminum Wire

Nominal Diameter		Tensile Strength				Elongation, min, % in 10 in. (or 250 mm)	
in.	(mm)	Minimum All H Classes		Maximum All A Classes		All H Classes	All A Classes
		ksi	(MPa)	ksi	(MPa)		
0.0349	8.252	16	110	20	138	1.5	15
0.2893	7.348	16	110	20	138	1.5	15
0.2576	6.543	18	124	20	138	1.5	15
0.2294	5.827	20	138	20	138	1.5	15
0.2043	5.189	22	152	20	138	1.5	15
0.1819	4.620	23	159	20	138	1.5	15
0.1620	4.115	24	166	20	138	1.5	15
0.1443	3.665	25	172	20	138	1.5	15
0.1285	3.264	26	179	20	138	1.0	15
0.1144	2.906	27	186	20	138	1.0	15
0.1019	2.588	28	193	20	138	1.0	15
0.0907	2.30	29	200	20	138	1.0	15
0.0808	2.05	30	207	20	138	1.0	15
0.0720	1.83	30	207	20	138	1.0	15
0.0641	1.63	30	207	20	138	1.0	15
0.0571	1.45	30	207	20	138	1.0	15
0.0508	1.29	30	207	20	138	1.0	15
0.0453	1.15	30	207	20	138	1.0	15
0.0403	1.02	30	207	20	138	1.0	15
0.0359	0.912	30	207	20	138	1.0	15
0.0320	0.813	30	207	20	138	1.0	15
0.0285	0.724	30	207	20	138	1.0	15
0.0253	0.643	30	207	20	138	1.0	15
0.0226	0.574	30	207	25	172	1.0	10
0.0201	0.511	30	207	25	172	1.0	10
0.0179	0.455	30	207	25	172	1.0	10
0.0159	0.404	30	207	25	172	1.0	10
0.0142	0.361	30	207	25	172	1.0	10
0.0126	0.320	30	207	25	172	1.0	5
0.0113	0.287	30	207	25	172	1.0	5
0.0100	0.254	30	207	25	172	1.0	5
0.0089	0.226	30	207	25	172	1.0	5
0.0080	0.203	30	207	25	172	1.0	5
0.0071	0.180	30	207	25	172	1.0	5
0.0063	0.160	30	207	25	172	1.0	5
0.0056	0.142	30	207	25	172	1.0	5
0.0050	0.127	30	207	25	172	1.0	5

TABLE 2 Resistivity

Resistivity, max, at 20°C	
Class of Wire	Ω·mm²/m
10A and 10H	0.02743
15A and 15H	0.02676

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.

6.3 *Cohesion*—The copper-clad aluminum wire, when tested in accordance with 10.4, shall be free from seams or splits. Examination of the wire shall be made at a magnification not to exceed 10×.

6.4 *Adhesion*—The copper-clad aluminum wire, when tested in accordance with 10.5, shall be free from cladding delamination. Examination of the wire shall be made at a magnification not to exceed 10×.

6.5 *Joints*—The finished wire shall contain no joints or splices.

6.6 *Copper Thickness*—The minimum copper thickness, when tested in accordance with 10.6, shall be not less than the following:

6.6.1 Class 10A and 10H wire shall have a minimum thickness of not less than 3.5 % of the wire radius.

6.6.2 Class 15A and 15H wire shall have a minimum thickness of not less than 5.0 % of the wire radius.

6.7 *Copper Volume (Area)*—The copper volume (area) per class, when tested in accordance with 10.6, shall meet the following tolerances:

6.7.1 Class 10A and 10H wire shall contain not less than 8 % and not more than 12 % copper by volume (area).

6.7.2 Class 15A and 15H wire shall contain not less than 13 % and not more than 17 % copper by volume (area).

7. Dimensions, Mass and Permissible Variations

7.1 The wire size 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 2). 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 2—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. A discussion of wire gages and related subjects is contained in "Copper Wire Tables," *NBS Handbook 100.*

8. Workmanship, Finish, and Appearance

8.1 The wire, when tested in accordance with 8.2, shall be free from pits, slivers, exposed aluminum, or other imperfections not consistent with good commercial practice.

8.2 For wire diameters of 0.0720 in. (1.829 mm) and larger, surface finish inspection shall be made with the unaided eye (normal spectacles excepted), and for wire diameters smaller than 0.0720 in., surface finish inspection shall be made at a magnification not to exceed 10×.

9. Sampling

9.1 The number of production units in a sample shall be as follows:

9.1.1 For tensile strength, elongation, resistivity, adhesion, cohesion, and dimensional measurements, the sample shall consist of a quantity of production units shown in Table 4

TABLE 3 Equivalent Resistivity Values

Class	Volume Conductivity at 20°C % IACS	Resistivity Equivalents at 20°C					
		Volume				Mass/Unit Length	
		Ω·mm²/m	Ω·cmil/ft	μΩ·in.	μΩ·cm	Ω·lb/mile2	Ω·g/m²
10A and 10H	62.854	0.027430	16.500	1.0799	2.7430	526.26	0.092164
15A and 15H	64.416	0.026765	16.100	1.0537	2.6765	560.88	0.098227

TABLE 4 Sampling for Mechanical and Electrical Tests

Number of Units	First Sample		Second Sample		
	Number of Units in Sample, n_1	Allowable Number of Defects in Sample to Accept Lot, c_1	Number of Units in Sample, n_2	$n_1 + n_2$	Allowable Number of Defects in Both Samples to Accept Lot, c_2
1–3	all	0	...	...	0
4–8	4	0	...	...	0
9–15	4	0	5	9	1
16–25	5	0	9	14	1
26–40	8	0	12	20	1
41–65	12	0	18	30	1
66–100	19	0	23	42	1

under heading "First Sample." From each unit, one test specimen of sufficient length shall be removed for the performance of the required tests.

9.1.2 For surface finish and 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 5.

10. Test Methods

10.1 *Tensile Strength and Elongation*—The tensile strength, expressed in pounds-force per square inch (or megapascals), shall be obtained by dividing the maximum load attained 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.

10.1.1 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 3). The elongation of wire shall be determined as described preceding 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 approximately 10 % of the specified tensile strength has been applied and be as near 10 in. 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.

TABLE 5 Sample for Surface Finish and Packaging Inspection

Number of Units in Lot	Number of Units in Sample, n	Allowable Number of Defects in Sample to Accept Lot, c
1–3	all	0
4–8	4	0
9–15	9	0
16–25	14	0
26–40	20	0
41–65	30	0
66–100	42	0

NOTE 3—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 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.

10.1.2 For Classes 10H and 15H, the elongation may be measured by means of an extensometer or other device suitable for measuring percent elongation in 10 in., and having a vernier reading to 0.01 in. (0.25 mm) attached to the test specimen at a load of approximately 10 % of the specified tensile 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 in which the elongation is less than specified, but in which the fracture has occurred within 1 in. of the jaws or extensometer clamps, shall be disregarded.

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

10.3 *Dimensional Measurements*—Dimensional measurements shall be made with a micrometer caliper equipped with a vernier graduated in 0.001 in. (0.0025 mm). each coil shall be measured at three places, one near each end and one near the middle. From each spool approximately 12 ft (3.7 m) shall be unreeled and the wire measured in six places between the second (approximately 0.6 m) and twelfth foot from the end.

10.4 *Cohesion Test*—The wire shall be twisted three turns per length equivalent to 15 diameters of the wire to be tested and untwisted the same number of turns. An initial wire length longer than specified may be used and the number of twists increased proportionately. The rate of applying the twist is not critical.

10.5 *Adhesion Test*—The wire shall be repeatedly reverse bent to fracture by any convenient means.

10.6 *Copper Thickness and Volume*—Determination of the minimum copper thickness or copper volume shall be performed by microscopical examination of the polished end or by a stripping method or by any other suitable method agreed upon between the manufacturer and the purchaser.

11. Conformance Criteria

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 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 6 are as follows:

11.2 For tensile strength, elongation, resistivity, adhesion, cohesion, and dimensional measurements, the sample shall consist of a quantity of production units shown in Table 4 under heading "First Sample." If there are no defects, the lot shall be considered as conforming to these requirements. If there are defects, 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 conformance criterion.

11.2.1 *Tensile Strength and Elongation*—The tensile strength and elongation of each of the specimens shall conform to the requirements of 6.1 and Table 1.

11.2.2 *Resistivity*—The electrical resistivity of each of the specimens shall conform to the requirements of 6.2 and Table 2.

11.2.3 *Dimensions*—The dimensions of each of the specimens shall conform to the requirements of Section 7.

11.2.4 *Cohesion*—Cohesion of the copper cladding of each of the specimens shall conform to the requirements of 6.3.

11.2.5 *Adhesion*—Adhesion of the copper cladding to the aluminum of each of the specimens shall conform to the requirements of 6.4.

11.3 For surface finish and packaging (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 5. The number of units in the sample showing nonconformance to the requirements shall not exceed the allowable defect number *c* in Table 5. Failure to meet the requirements shall constitute failure to meet the conformance criterion.

11.3.1 *Finish*—The surface finish of each of the samples shall conform to the requirements of 8.1.

12. Density

12.1 For the purpose of calculating mass/unit length, cross sections, and so forth, the density of the wire shall be taken as shown in Table 6 (see Note 4).

NOTE 4—The term mass per unit length is used in this specification 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).

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

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 when requested, prior to inspection, shall 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. The wire shall be protected against damage in ordinary handling and shipping.

15. Keywords

15.1 aluminum electrical conductor—copper-clad; aluminum wire; aluminum wire—copper-clad; copper-clad aluminum wire; copper-clad electrical conductors; electrical conductor

TABLE 6 Density

Class of Wire	Density, max, at 20°C g/cm^3 ($lb/in.^3$)
10A and 10H	3.32 (0.12000)
15A and 15H	3.63 (0.13118)

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