Designation: B286 – 07 (Reapproved 2017)

Standard Specification for Copper Conductors for Use in Hookup Wire for Electronic Equipment[1]

This standard is issued under the fixed designation B286; 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 U.S. Department of Defense.

1. Scope

1.1 This specification covers uninsulated metallic-coated copper conductors for use in hookup wire for electronic equipment.

1.2 The SI values for density are to be regarded as standard. For all other properties, the inch-pound values are to be regarded as the standard.

1.3 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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]

B33 Specification for Tin-Coated Soft or Annealed Copper Wire for Electrical Purposes

B189 Specification for Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes

B193 Test Method for Resistivity of Electrical Conductor Materials

B258 Specification for Nominal Diameters and Cross-Sectional Areas of AWG Sizes of Solid Round Wires Used as Electrical Conductors

B298 Specification for Silver-Coated Soft or Annealed Copper Wire

B355 Specification for Nickel-Coated Soft or Annealed Copper Wire

3. Ordering Information

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

3.1.1 Quantity of each size, designation (Table 1) and type,

3.1.2 Conductor size, designation, construction, and type (Table 1).

3.1.3 Whether tin, lead alloy, silver-coated, or nickel-coated (see 4.1).

3.1.4 For silver-coated conductors and nickel-coated conductors, class of coating (see 4.1), and when required, unannealed (see 4.2),

3.1.5 Desired constructions where alternates are given (Table 1, Type II and, 5.1, 6.1, and 6.2),

3.1.6 Package size (Section 12).

3.1.7 Special package marking if required (Section 11), and

3.1.8 Place of inspection (Section 10).

4. General Requirements

4.1 *Coating of Wires*—The coating of the solid conductors and the wires composing stranded conductors (before stranding) shall conform to the coating requirements of ASTM Specifications B33, B189, B298, and B355, as indicated on the purchase order.

4.2 *Temper*—Unless otherwise specified, all coated conductors shall be furnished in the annealed temper. When so specified, silver-coated conductors or nickel-coated conductors shall be furnished unannealed (Explanatory Note 1).

NOTE 1—The term unannealed as used in this specification means cold-worked conductor as produced on commercial wire-drawing machines.

4.3 *Elongation*—The elongation of annealed Type I conductors shall be as specified in Specifications B33, B189, B298, and B355 as applicable. The elongation of stranded conductors shall be permitted to vary from the requirements of the applicable Specifications: B33, B189, B298, and B355 by the following amounts:

4.3.1 For stranded conductors 22 AWG and smaller, the test shall be performed on the whole conductor and the elongation

[1] This specification is under the jurisdiction of ASTM Committee B01 on Electrical Conductors and is the direct responsibility of Subcommittee B01.04 on Conductors of Copper and Copper Alloys.

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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.

TABLE 1 Details of Conductor Construction

Type I (Solid Conductors)							
Size Designation, AWG	Nominal Area, cmils	Nominal Diameter, in.	D-C Resistance at 20°C, Ω/1000 ft, max (Explanatory Note 2)				
			Annealed Tin or Lead-Alloy Coated	Annealed Silver Coated	Class 2 Nickel[A]	Class 10 Nickel	Class 27 Nickel
10	10380	0.1019	1.06	1.02	1.05	1.17	1.44
12	6530	0.0808	1.69	1.62	1.68	1.84	2.28
14	4110	0.0641	2.68	2.58	2.67	2.93	3.63
16	2580	0.0508	4.26	4.10	4.27	4.65	5.77
18	1620	0.0403	6.78	6.52	6.79	7.39	9.17
20	1020	0.0320	10.7	10.3	10.8	11.8	14.6
22	640	0.0253	17.2	16.5	17.3	18.8	23.3
24	404	0.0201	27.2	26.2	27.3	29.8	36.9
26	253	0.0159	44.5	41.9	43.8	47.5	58.9
28	159	0.0126	70.8	66.8	69.4	75.4	107.0
30	100	0.0100	114.0	106.0	110.0	120.0	149.0

Type II (Stranded Conductors)											
Size Designation[B]	Conductor Construction		Calculated Cross-Sectional Area, cmils	Maximum Allowable Diameter, in.[D]	Length of Lay, in. (Explanatory Note 3)	D-C Resistance at 20°C, Ω/1000 ft, max (Explanatory Note 2)				
	Number of Wires[C]	Nominal Diameter of Each Wire, in.				Annealed Tin or Lead-Alloy Coated	Annealed Silver Coated	50 to 100 µin. of Nickel[E]	Class 10 Nickel	Class 27 Nickel
0000–2109	2109[F]	0.0100	210 900	0.635	...	0.0576	0.0537	0.0559(2)	0.0610	0.0756
000–1672	1672[F]	0.0100	167 200	0.545	...	0.0727	0.0677	0.0705(2)	0.0770	0.0954
00–1330	1330[F]	0.0100	133 000	0.486	...	0.0914	0.0851	0.0887(2)	0.0967	0.120
0–1064	1064[F]	0.0100	106 400	0.435	...	0.114	0.106	0.111(2)	0.121	0.150
0–1045	1045[F]	0.0100	104 500	0.431	...	0.116	0.108	0.113(2)	0.123	0.153
1–836	836[F]	0.0100	83 600	0.386	...	0.145	0.135	0.141(2)	0.154	0.191
1–817[E]	817[F]	0.0100	81 700[E]	0.382	...	0.149	0.139	0.144(2)	0.158	0.195
2–665	665[F]	0.0100	66 500	0.342	...	0.183	0.170	0.177(2)	0.194	0.240
4–133[E]	133[F]	0.0179	42 615[E]	0.274	...	0.280	0.263	0.274(2)	0.299	0.371
4–420	420[G]	0.0100	42 000	0.275	...	0.289	0.270	0.281(2)	0.306	0.380
6–133[E]	133[F]	0.0142	26 818[E]	0.217	...	0.444	0.418	0.436(2)	0.475	0.589
6–266	266[G]	0.0100	26 600	0.220	...	0.457	0.426	0.443(2)	0.484	0.600
8–133[E]	133[F]	0.0113	16 983[E]	0.173	...	0.701	0.661	0.688(2)	0.751	0.930
8–168	168[G]	0.0100	16 800	0.177	...	0.724	0.674	0.702(2)	0.766	0.949
10–105	105[G]	1.0100	10 500	0.130	1.2 to 1.8	1.15	1.07	1.11(2)	1.21	1.50
10–104	104[H]	0.0100	10 400	0.130	1.7 to 2.1	1.16	1.08	1.12(2)	1.23	1.52
10–49[E]	49[G]	0.0142	9 880[G]	0.132	...	1.21	1.14	1.18(2)	1.29	1.60
10–37[E]	37[E]	0.0159	9 354[E]	0.115	1.10 to 1.75	1.26	1.19	1.24(2)	1.35	1.67
12–65	65[H]	0.0100	6 500	0.099	1.3 to 1.7	1.85	1.73	1.80(2)	1.96	2.43

Type II (Stranded Conductors)										
Size Designation[B]	Conductor Construction					D-C Resistance at 20°C, Ω/1000 ft, max (Explanatory Note 2)				
	Number of Wires[C]	Nominal Diameter of Each Wire, in.	Calculated Cross-Sectional Area, cmils	Maximum Allowable Diameter, in.[D]	Length of Lay, in. (Explanatory Note 2)	Annealed Tin or Lead-Alloy Coated	Annealed Silver Coated	50 to 100 µin. of Nickel[I]	Class 10 Nickel	Class 27 Nickel
12–37[E]	37[E]	0.0126	5 874[E]	0.091	0.90 to 1.45	2.01	1.89	1.97(2)	2.15	2.66
12–19[E]	19[J]	0.0179	6 088[E]	0.093	0.90 to 1.45	1.92	1.81	1.88(2)	2.05	2.55
14–41	41[H]	0.0100	4 100	0.081	0.80 to 1.35	2.94	2.74	2.85(2)	3.11	3.85
14–19[E]	19[J]	0.0142	3 831[E]	0.073	0.80 to 1.15	3.05	2.87	2.99(2)	3.26	4.05
16–26	26[H]	0.0100	2 600	0.062	0.60 to 0.90	4.59	4.27	4.45(2)	4.86	6.02
16–19[E]	19[J]	0.0113	2 426[E]	0.059	0.60 to 0.90	4.82	4.54	4.73(2)	5.15	6.39
18–26[E]	26[H]	0.0080	1 664[E]	0.050	0.50 to 0.70	7.20	6.71	7.14(4)	7.63	9.45
18–19[E]	19[J]	0.0100	1 900[E]	0.052	0.50 to 0.70	6.22	5.79	6.03(2)	6.58	8.16

TABLE 1 *Continued*

Type II (Stranded Conductors)										
Conductor Construction						D-C Resistance at 20°C, Ω/1000 ft, max (Explanatory Note 2)				
Size Designation[B]	Number of Wires[C]	Nominal Diameter of Each Wire, in.	Calculated Cross-Sectional Area, cmils	Maximum Allowable Diameter, in.[D]	Length of Lay, in. (Explanatory Note 2)	Annealed Tin or Lead-Alloy Coated	Annealed Silver Coated	50 to 100 µin. of Nickel[I]	Class 10 Nickel	Class 27 Nickel
18–7[E]	7[J]	0.0159	1 770[E]	0.050	0.50 to 0.70	6.54	6.16	6.42(2)	7.00	8.67
20–19[E]	10[J]	0.0080	1 216[E]	0.042	0.45 to 0.55	9.76	9.10	9.68(4)	10.3	12.8
20–19†	10[H]	0.0100	1 000	0.040	0.45 to 0.55	11.8	11.0	11.5(2)	12.5	15.5
20–7[E]	7[J]	0.0126	1 111[E]	0.039	0.45 to 0.55	10.4	9.81	10.2(2)	11.1	13.8
22–19[E]	19[J]	0.0063	754[E]	0.033	0.25 to 0.43	15.9	14.8	15.7(4)	16.8	20.8
22–7[E]	7[J]	0.0100	700[E]	0.031	0.25 to 0.43	16.7	15.6	16.2(2)	17.7	21.9
24–19[E]	19[J]	0.0050	475[E]	0.027	0.25 to 0.35	25.4	23.6	25.2(4)	26.9	33.3
24–7[E]	7[J]	0.0080	448[E]	0.025	0.25 to 0.35	26.2	24.5	26.0(4)	27.8	34.4
26–19[E]	19[J]	0.0040	304[E]	0.022	0.25 to 0.30	40.1	37.3	41.0(7)	42.4	52.6
26–7[E]	7[J]	0.0063	278[E]	0.020	0.25 to 0.30	42.6	39.7	42.2(4)	45.1	55.9
28–19[E]	19[J]	0.0031	183[E]	0.017	0.25 to 0.30	67.7	63.1	69.3(7)	71.7	88.8
28–7[E]	7[J]	0.0050	175[E]	0.016	0.25 to 0.30	68.2	63.6	67.6(4)	72.2	89.5
30–7[E]	7[J]	0.0040	112[E]	0.013	0.25 to 0.30	108.0	100.0	110.0(7)	114.0	141.0
32–7[E]	7[J]	0.0031	67[g]	0.011	0.10 to 0.30	182.0	170.0	186.0(7)	193.0	239.0

[A] Provides minimum of 50 µin. of nickel.
[B] These size designations are solely for purposes of identification. They should not be confused with AWG sizes.
[C] The stranded conductor constructions shown in this table provide for finished noninsulated conductors having the indicated cross-sectional area. The number of component wires may vary slightly provided the specified resistances are not exceeded.
[D] The maximum allowable diameters of these conductors are given here for guidance in making calculations regarded insulating material, etc. These diameters do not include allowance for distortion of the conductor during stranding and are not intended to be used as limiting values.
[E] The cross-sectional areas of these conductor-size designations deviate by more than 2 per cent from the nominal areas of the standard AWG sizes as defined in Specification B258.
[F] Nineteen member ropes.
[G] Seven member ropes.
[H] Bunch-stranded.
[I] The numbers in parentheses indicate the class of nickel coating required to meet resistance values tabulated. These classes appear in Specification B355.
[J] Concentric-stranded.
†Editorially corrected.

measured when the first strand of the conductor breaks. The minimum average elongation shall not be less than 10 % with no individual specimen less than 5 %.

4.3.2 For stranded conductors larger than 22 AWG, strands shall be carefully removed from the conductor and tested for elongation. The minimum average elongation shall not be less than 10 % with no individual strand less than 5 %.

4.4 *D-C Resistance*—The d-c resistance in ohms per 1000 ft of annealed solid and stranded conductor shall not exceed, before insulating, the appropriate values prescribed in Table 1 (Explanatory Note 2).

5. Conductor Construction

5.1 Solid conductors shall conform to the requirements for Type I conductors prescribed in Table 1.

5.2 Stranded conductors shall conform to the requirements for Type II conductors prescribed in Table 1. The method of stranding for conductor size designations 32-7 through 10-104 inclusive shall be at the option of the manufacturer unless otherwise specified. Stranded conductors size designation 10-105 and larger shall normally be furnished in a rope-lay-stranded construction consisting of either 7 or 19 bunch-stranded members.

6. Lay of Stranded Conductors

6.1 The direction of lay of the outside layer of stranded conductors shall be left-hand. The direction of lay of the bunch-stranded members composing rope-lay-stranded conductors shall be at the option of the manufacturer unless otherwise specified.

6.2 The direction of lay of the outer layer of rope-lay-stranded conductors shall be lefthand. The direction of lay of the other layers shall be reversed in successive layers, unless otherwise specified.

6.3 The length of lay of the outside layer of stranded conductors in size designation 32-7 through 10-104, inclusive, shall conform to the values in Table 1 (Explanatory Note 3). For strand constructions containing more than one distinct layer the length of lay of the inner layer shall not exceed the maximum value shown in Table 1 for the conductor in question. For rope-lay-stranded conductors size designation 10-105 and larger, and size 49/0.0142, the length of lay of the wires composing the bunch-stranded members shall be not more than 30 times the diameter of the member, and the length of lay of the outer layer of rope-lay-stranded conductors shall be not less than 8 nor more than 16 times the outside diameter of the completed conductor.

7. Joints

7.1 Necessary joints in the individual wires of conductors size designation 32-7 through size designation 10-104, inclusive, may be silver soldered, brazed, or butt welded. (Explanatory Note 4). Bunch-stranded members composing ropelay-stranded conductors may be joined as a unit by brazing and these joints shall be at least two lay lengths apart and be finished off so that the conductor diameter is not increased at the joint. Disposition of joints throughout the conductor shall be such that the diameter, configuration, conductor resistance, flexibility, and mechanical strength are not substantially affected.

8. Physical and Electrical Tests

8.1 Tests to determine conformance of the coating to the requirements of Specifications B33, B189, B298, or B355 shall be performed on Type I conductors before insulating and on the individual wires of Type II conductors before stranding.

8.2 Tests to determine conformance to the elongation requirements prescribed in 4.3 shall be made before insulating.

8.3 Tests to determine conformance to the electrical resistance requirements prescribed in Table 1 shall be made on the uninsulated conductor in accordance with Test Method B193 (Explanatory Note 2).

8.4 *Examination for Workmanship of Finished Uninsulated Stranded Conductor*—A visual inspection with the unaided eye shall be performed on the outer layer of the conductor on the supplied package. Use a white card (as a background) to ascertain if any base metal is exposed through a break in the coating. Detection of any base metal constitutes rejection.

8.5 *Examination for Workmanship of Finished Uninsulated Stranded Conductor*—A visual inspection with 10X magnification and with a white background shall be performed on a conductor sample taken from the top of the supplied spool. The sample shall be a minimum of 12 in. (30 cm) in length. The outer surface of all stranded constructions shall be examined.

Detection of excessive exposed base metal due to the stranding process, such as indications along one side of the sample due to excessive localized abrasion during stranding, constitutes rejection. Continuous lines or patterns of exposed base metals constitute rejection. Small random point failures shall not be cause for rejection.

9. Density

9.1 For the purpose of calculating mass, cross-sectional area, etc., the density of the coated copper shall be taken as 8.89 g/cm^3 (0.32117 lb/in.^{3}) at 20°C (Explanatory Note 5).

10. Inspection

10.1 All tests and inspection shall be made at the place of manufacture unless otherwise especially agreed upon by the manufacturer and the purchaser at the time of purchase. The manufacturer shall afford the inspector representing the purchaser all reasonable facilities, without charge, to satisfy him that the material is being furnished in accordance with this specification.

11. Product Marking

11.1 The net mass, length (or lengths, and number of lengths, if more than one length is included in the package), size designation, type of conductor, purchase order number, and any other marks required by the purchase order shall be marked on a tag attached to the end of the conductor inside of the package. The same information, together with the manufacturer's serial number (if any) and all shipping marks required by the purchaser, shall appear on the outside of each package.

12. Packing and Package Marking

12.1 Package sizes for conductors shall be agreed upon by the manufacturer and the purchaser in the placing of individual orders.

12.2 The conductors shall be protected against damage in ordinary handling and shipping.

13. Keywords

13.1 copper hookup wire; electronic equipment hookup wire; electronic hookup wire; hookup wire

EXPLANATORY NOTES

NOTE 1—Unannealed silver-coated conductors or nickel-coated conductors should be used only when the insulating process will produce an annealed insulated conductor.

NOTE 2—Because of the difficulties encountered in determining correctly the cross-sectional area of stranded conductors, this requirement has been superseded by a d-c ohmic resistance per 1000-ft length of conductor. Since this specification described uninsulated conductors intended for ultimate use as insulated conductors in various electronic devices, maximum resistance values are shown for the conductors before insulating to serve as the minimum acceptance requirement for the conductor. In order that all commercial or other specifications for finished insulated conductors which may be derived from this basic specification be uniform as to the resistance requirements of the insulated product, it is recommended that values for size designations 0000-2109 through 18-7 be used as maximum resistance requirements for the conductors in the finished insulated product. For size designations 20-19 through 32-7, some increase of resistance may occur during the insulating process due to stretching so that an allowance in the maximum resistance requirement is recommended. The values appearing in Table 1 under the heading "Annealed Silver Coated" are applicable to silver-coated conductors whether annealed or unannealed prior to insulating.

The method used to calculate the values appearing in Table 1 is shown below:

D-C Resistance at 20°C for the Bare Conductors (Table 1):

$$\text{Maximum ohms per 1000 ft} = 10.371\ K/(1000\ NC \times d^2 f)$$

where:

K = stranding factor as follows:

Number of Strands	Factor
1	1.00
7	1.03
up through 19	1.04
up through 37	1.05
up through 133	1.06
over 133	1.07

N = number of strands in the conductor.

C = minimum wire conductivity divided by 100 as shown in the following table:

Type of Wire	Range of Wire Sizes, in.	C
Annealed silver coated	all	1.00
Annealed tin or lead-alloy coated	up to 0.0110, incl	0.9315
	over 0.0110 to 0.0200, incl	0.9416
	over 0.0200	0.9616
Annealed nickel coated, Class 2	all	0.96
Annealed nickel coated, Class 4	all	0.94
Annealed nickel coated, Class 7	all	0.91
Annealed nickel coated, Class 10	all	0.88
Annealed nickel coated, Class 27	all	0.71

d = single wire and strand diameter as follows:

For wire and strand 0.0100 in. and larger, except nickel-coated over 0.0508 in., use nominal diameter in inches.

For nickel-coated wire over 0.0508 in., use nominal wire diameter in inches less 0.0005 in.

For strand under 0.0100 in., use nominal diameter in inches less 0.0001 in.

f = diameter factor (allowance for min dia).

	f
Wire and strand 0.0100 in. and larger, except nickel coated over 0.0508 in.	0.98
Nickel-coated wire over 0.0508 in.	1.00
Strand under 0.0100 in.	1.00

NOTE 3—The peculiarities of the applications for which these stranded conductors are used require some degree of flexibility along with the characteristic that the wires of the conductor shall not untwist or fray when the insulation is stripped to make soldered or other joints in the electronic devices. To accomplish this requires that the conductor be stranded with a shorter lay than is normally permitted in conductors for flexible cords.

NOTE 4—Though joints in stranded conductors as a whole are not recognized in this specification, it is intended that with certain types of stranding equipment, these joints may be necessary to provide for economical insulating operations. When by mutual agreement between the manufacturer and the purchaser such joints are used, they shall be conspicuously marked, and removed from the conductor at the final insulating operation.

NOTE 5—The value of density of copper is in accordance with the International Annealed Copper Standard. The corresponding value at 0°C (32°F) is 8.90 g/cm^3 (0.32150 lb/in.^{3}). In calculations involving density it must be borne in mind that the apparent density of coated wire is not a constant but a variable function of wire diameter. The smaller the diameter the greater the percentage of coating present and hence the greater departure from the density of copper.