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Standard Specification for Standard Nominal Diameters and Cross-Sectional Areas of AWG Sizes of Solid Round Wires Used as Electrical Conductors[1]

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1. Scope

1.1 This specification prescribes standard nominal diameters and cross-sectional areas of American Wire Gage (AWG) sizes of solid round wires, used as electrical conductors, and gives equations and rules for the calculation of standard nominal mass and lengths, resistances, and breaking strengths of such wires (Explanatory Note 1).

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 standard and the SI units may be approximate.

2. Referenced Documents

2.1 *ASTM Standards:*

A 111 Specification for Zinc-Coated (Galvanized) "Iron" Telephone and Telegraph Line Wire[2]
A 326 Specification for Zinc-Coated (Galvanized) High Tensile Steel Telephone and Telegraph Line Wire[2]
B 1 Specification for Hard-Drawn Copper Wire[3]
B 2 Specification for Medium-Hard-Drawn Copper Wire[3]
B 3 Specification for Soft or Annealed Copper Wire[3]
B 9 Specification for Bronze Trolley Wire[3]
B 33 Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes[3]
B 47 Specification for Copper Trolley Wire[3]
B 105 Specification for Hard-Drawn Copper Alloy Wires for Electrical Conductors[3]
B 189 Specification for Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes[3]
B 227 Specification for Hard-Drawn Copper-Clad Steel Wire[3]
B 230 Specification for Aluminum 1350-H19 Wire for Electrical Purposes[3]
B 314 Specification for Aluminum 1350 Wire for Communication Cable[3]
B 396 Specification for Aluminum-Alloy 5005-H19 Wire for Electrical Purposes[3]
B 398 Specification for Aluminum-Alloy 6201-T81 Wire for Electrical Purposes[3]
B 415 Specification for Hard-Drawn Aluminum-Clad Steel Wire[3]
B 609 Specification for Aluminum 1350 Round Wire, Annealed and Intermediate Tempers, for Electrical Purposes[3]
B 800 Specification for 8000 Series Aluminum Alloy Wire for Electrical Purposes—Annealed and Intermediate Tempers[3]
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[4]
F 205 Test Method for Measuring Diameter of Fine Wire by Weighing[5]

3. Standard Reference Temperature

3.1 For the purpose of this specification, all wire dimensions and properties shall be considered as occurring at the internationally standardized reference temperature of 20°C (68°F).

4. Standard Rules for Rounding

4.1 All calculations for the standard nominal dimensions and properties of solid round wires shall be rounded in the *final* value only, in accordance with rounding method of Practice E 29.

5. Standard Nominal Diameters

5.1 Standard nominal diameters of AWG sizes of solid round wires shall be calculated in accordance with the conventional mathematical law of the American Wire Gage (see Explanatory Note 1) and in accordance with Section 4.

5.2 For wire sizes 4/0 to 44 AWG, inclusive, nominal diameters shall be expressed in no more than four significant figures but in no case closer than the nearest 0.1 mil (0.0001 in.).

5.3 For wire sizes 45 to 56 AWG, inclusive, nominal diameters shall be expressed to the nearest 0.01 mil (0.00001 in.).

5.4 The standard nominal diameters expressed in mils have been calculated in accordance with these rules and are given in Table 1 for convenient reference (Explanatory Note 2).

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[1] This specification is under the jurisdiction of ASTM Committee B-1 on Electrical Conductors and is the direct responsibility of Subcommittee B01.02 on Methods of Test and Sampling Methods.

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[2] *Annual Book of ASTM Standards*, Vol 01.06.

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

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] *Annual Book of ASTM Standards*, Vol 10.04.

TABLE 1 Standard Nominal Diameters and Cross-Sectional Areas of AWG Sizes of Solid Round Wires at 20°C

Size, AWG	Diameter, mils	Cross-Sectional Area		Size, AWG	Diameter, mils	Cross-Sectional Area	
		cmils	in.^{2}			cmils	in.^{2}
4/0	460.0	211 600	0.1662	29	11.3	128	0.000100
3/0	409.6	167 800	0.1318	30	10.0	100	0.0000785
2/0	364.8	133 100	0.1045	31	8.9	79.2	0.0000622
1/0	324.9	105 600	0.08291	32	8.0	64.0	0.0000503
1	289.3	83 690	0.06573	33	7.1	50.4	0.0000396
2	257.6	66 360	0.05212	34	6.3	39.7	0.0000312
3	229.4	52 620	0.04133	35	5.6	31.4	0.0000246
4	204.3	41 740	0.03278	36	5.0	25.0	0.0000196
5	181.9	33 090	0.02599	37	4.5	20.2	0.0000159
6	162.0	26 240	0.02061	38	4.0	16.0	0.0000126
7	144.3	20 820	0.01635	39	3.5	12.2	0.00000962
8	128.5	16 510	0.01297	40	3.1	9.61	0.00000755
9	114.4	13 090	0.01028	41	2.8	7.84	0.00000616
10	101.9	10 380	0.008155	42	2.5	6.25	0.00000491
11	90.7	8 230	0.00646	43	2.2	4.84	0.00000380
12	80.8	6 530	0.00513	44	2.0	4.00	0.00000314
13	72.0	5 180	0.00407	45	1.76	3.10	0.00000243
14	64.1	4 110	0.00323	46	1.57	2.46	0.00000194
15	57.1	3 260	0.00256	47	1.40	1.96	0.00000154
16	50.8	2 580	0.00203	48	1.24	1.54	0.00000121
17	45.3	2 050	0.00161	49	1.11	1.23	0.000000968
18	40.3	1 620	0.00128	50	0.99	0.980	0.000000770
19	35.9	1 290	0.00101	51	0.88	0.774	0.000000608
20	32.0	1 020	0.000804	52	0.78	0.608	0.000000478
21	28.5	812	0.000638	53	0.70	0.490	0.000000385
22	25.3	640	0.000503	54	0.62	0.384	0.000000302
23	22.6	511	0.000401	55	0.55	0.302	0.000000238
24	20.1	404	0.000317	56	0.49	0.240	0.000000189
25	17.9	320	0.000252				
26	15.9	253	0.000199				
27	14.2	202	0.000158				
28	12.6	159	0.000125				

6. Standard Nominal Cross-Sectional Areas

6.1 Standard nominal cross-sectional areas in circular mils and square inches shall be calculated in accordance with the following equations and shall be rounded in accordance with Section 4 to the same number of significant figures as used in expressing the standard diameters, but in no case to less than three significant figures:

$$\text{Area, cmil} = d^2$$

$$\text{Area, in.}^2 = d^2 \times 0.7854 \times 10^{-6}$$

where:
d = diameter of the wire in mils as given in Table 1.

Standard nominal cross-sectional areas in circular mils and square inches have been calculated in accordance with the foregoing rules and are given in Table 1 for convenient reference.

7. Rules for Calculations Involving Mass and Length

7.1 Standard nominal mass and lengths shall be calculated from the standard wire diameters specified in Table 1, in accordance with the following equations. They shall be rounded in the *final* value only, in accordance with Section 4, to the same number of significant figures as used in expressing the standard diameters, but in no case to less than three significant figures:

$$W = d^2 \times \delta \times 0.34049 \times 10^{-3}$$

$$L = (1/d^2) \times (1/\delta) \times 2.9369 \times 10^6$$

where:
W = mass, lb/1000 ft,
d = diameter of the wire in mils as given in Table 1,
δ = density of the wire material at 20°C in g/cm^3 as given in Table 2, and
L = length, ft/lb.

8. Rules for Calculations Involving Resistivity

8.1 Standard nominal resistances and other values derived from the resistivity units shall be calculated from the standard wire diameters specified in Table 1 in accordance with the following equations. All values so derived shall be rounded in the *final* value only, in accordance with Section 4, to the same number of significant figures as used in expressing the standard diameters, but in no case to less than three significant figures:

$$\text{D-c resistance at 20°C, } \Omega/1000 \text{ ft} = [\rho/(d^2 \times \delta)] \times 105.35$$

$$\text{D-c resistance at 20°C, } \Omega/\text{lb} = [\rho/(\delta^2 \times d^4)] \times 0.30940 \times 10^{-6}$$

$$\text{Length at 20°C, ft}/\Omega = [(d^2 \times \delta)/\rho] \times 9.4924$$

$$\text{Mass at 20°C, lb}/\Omega = [(\delta^2 \times d^4)/\rho] \times 3.2321 \times 10^{-6}$$

TABLE 2 Density and Resistivity of Electrical Conductor Materials

Material	Density, δ, at 20°C, g/cm^3	Resistivity, ρ, at 20°C, Ω·lb/mile^2	Material	Density,δ , at 20°C, g/cm^3	Resistivity, ρ, at 20°C Ω·lb/mile^2
Copper (Specifications B 1, B 2, B			Aluminum-Clad Steel (Specification	6.59	3191
3, B 33, B 47 and B 189),			B 415)		
Volume Conductivity, %			Copper-Clad Steel (Specification B		
IACS:					
100	8.89	875.20	227):		
97.66	8.89	896.15	Grade 30 HS	8.15	2728
97.16	8.89	900.77	Grade 30 EHS	8.15	2728
96.66	8.89	905.44	Grade 40	8.15	2045
96.16	8.89	910.15	Grade 40 EHS	8.15	2045
94.16	8.89	929.52	Galvanized Steel (Telephone and		
93.15	8.89	939.51	Telegraph) (Specification A		
Bronze (Specification B 9):			111):		
Class A	8.89	2188	Class A Coating:		
Class B	8.89	1346	Grade EBB (Non-Copper	7.78	5000
Class C	8.89	1094	Bearing)		
Copper Alloys (Specification B			Grade BB (Copper Bearing)	7.78	5800
105 [A]):			Grade BB (Non-Copper	7.78	5600
Grade 8.5	8.78	10169	Bearing)		
Grade 13	8.78	6649	Class B Coating:		
Grade 15	8.54	5605	Grade EBB (Non-Copper	7.78	4900
Grade 20	8.89	4376	Bearing)		
Grade 30	8.89	2917	Grade BB (Copper Bearing)	7.78	5600
Grade 40	8.89	2188	Grade BB (Non-Copper	7.78	5450
Grade 55	8.89	1591	Bearing)		
Grade 65	8.89	1346	Class C Coating:		
Grade 74	8.89	1183	Grade EBB (Non-Copper	7.78	4800
Grade 80	8.89	1094	Bearing)		
Grade 85	8.89	1030	Grade BB (Copper Bearing)	7.78	5400
Aluminum, 1350 (Specifications B			Grade BB (Non-Copper	7.78	5300
230, B 314, and B 609),			Bearing)		
Volume Conductivity, %			Galvanized Steel (Telephone and		
IACS:					
61.8	2.705	430.91	Telegraph) (Specification A		
61.2	2.705	435.13	326):		
61.0	2.705	436.56	Class A Coating:		
Aluminum Alloys (Specifications B			Grade 85	7.83	5800
396 and B 398)			Class B Coating:		
Alloy 5005–H19	2.70	496.84	Grade 135	7.83	6500
Alloy 6201–T81	2.69	504.43	Grade 85	7.80	5600
Aluminum Alloy 8000 Series			Grade 135	7.80	6300
(Specification B 800)			Class C Coating:		
Volume Conductivity, %			Grade 85	7.77	5400
IACS:					
61.0	2.71	437.36	Grade 135	7.77	6100

[A] Various compositions are permitted for some of the grades in Specification B 105 and the density value may not apply to all materials supplied to this specification. In case of doubt, the density value should be determined or obtained from the manufacturer.

where:

d = diameter of the wire in mils as given in Table 1,
ρ = resistivity of the wire material at 20°C in Ω·lb/mile^2 as given in Table 2 (Explanatory Note 3), and
δ = density of the wire material at 20°C in g/cm^3 as given in Table 2.

9. Rules for Calculating Rated Strength

9.1 Standard rated strengths shall be calculated from the standard wire diameters specified in Table 1 in accordance with the following equation and shall be rounded in the *final* value only, in accordance with Section 4, to the same number of significant figures as used in expressing the standard diameters, but in no case to less than three significant figures:

$$\text{Rated strength, lb} = d^2 \times T \times 0.7854 \times 10^{-6}$$

where:

d = diameter of the wire in mils as given in Table 1, and
T = tensile strength, psi, applicable to the wire material, temper, and size, for which reference should be made to the specifications which cover the material.

10. Tolerances

10.1 The standard dimensions given in Table 1 and the calculated values for mass, resistances, and rated strengths obtained by the use of the formulas included in this specification are all *nominal* values. This specification is not concerned with quantitative values of tolerances *per se,* but it is contemplated that the standard nominal wire dimensions specified in Table 1, and the properties derived therefrom, shall be made subject to tolerances as indicated in either the individual specifications applicable to the wires of various materials and tempers or as may be mutually agreed by the manufacturer and the purchaser.

EXPLANATORY NOTES

NOTE 1—Except for certain classes of wire products, the American

TABLE 3 American Wire Gage Series

Ascending Wire Sizes:											
Step No.	1	2	3	4	5	...	37	38	39	40	
AWG No.	36	35	34	33	32	...	1/0	2/0	3/0	4/0	
Wire diameter, mils	5	$5r$	$5r^2$	$5r^3$	$5r^4$	...	$5r^{36}$	$5r^{37}$	$5r^{38}$	$5r^{39}$	= 460
Descending Wire Sizes:											
Step No.	1	2	3	4	5	...	37	38	39	40	
AWG No.	4/0	3/0	2/0	1/0	1	...	33	34	35	36	
Wire diameter, mils	460	$460/r$	$460/r^2$	$460/r^3$	$460/r^4$	...	$460/r^{36}$	$460/r^{37}$	$460/r^{38}$	$460/r^{39}$	= 5

Since the last wire diameter term of both the ascending and descending series indicates that $r^{39} = 460/5 = 92$, the value for r is $92^{1/39} = 1.1229322$, and the value of $1/r$ is 0.89052571.

Wire Gage (formerly known as the Brown & Sharpe Gage) has been almost universally employed in the United States for many years for the designation of wire sizes. This gage is based upon fixed diameters for two wire sizes (4/0 and 36 AWG, respectively), and the simple mathematical law that the thirty-eight intermediate gage designations vary in size in geometric progress. The extent of the American Wire Gage is not, however, limited to the forty gage numbers from 4/0 to 36 AWG, inclusive, both larger and smaller sizes being determined by extrapolation in accordance with the geometric progression mentioned. Like many other wire gages, the American Wire Gage is an inverse gage, that is, a higher size number denotes a wire of smaller size.

The specified diameters for sizes 4/0 AWG and 36 AWG are 460 mils and 5 mils, respectively (1 mil is equal to 0.001 in.). Designating the ratio between ascending adjacent wire sizes by r, and the ratio between descending adjacent wire sizes by $1/r$, the law of the American Wire Gage is indicated explicitly by an ascending and descending series, expressed in tabular form as shown in Table 3.

It is implicit in these series that the diameters of the various AWG wire sizes may be calculated either by ascending from $d = 5$ for size 36 AWG, or descending from $d = 460$ for 4/0 AWG, for intermediate sizes, as well as descending from = 5 for size 36 AWG, for sizes 37 AWG and smaller. It is further implicit in these series that the diameter of any AWG size of wire may be derived directly from any other AWG size whose diameter is known by multiplying the known diameter by r^n or $1/r^n$, as the case may be, where n is the number of steps between the two gage numbers. For example, size 18 AWG is eighteen gage numbers apart from 36 AWG, and twenty-one gage numbers apart from size 4/0 AWG. The diameter of size 18 AWG is, then,

$$d_{18} = d_{36r}{}^{18} = 5 \times 1.1229322^{18} = 5 \times 8.06053 = 40.30 \text{ mils}$$

or:

$$d_{18} = d_{4/0}/r^{21} = 460 \times 0.89052571^{21}$$
$$= 460 \times 0.0876144 = 40.30 \text{ mils}$$

Similarly, size 45 AWG is nine gage numbers removed from size 36 AWG, from which the diameter of size 45 AWG is:

$$d_{45} = d_{36}/r^{9} = 5 \times 0.89052571^{9} = 5 \times 0.352223 = 1.761 \text{ mils}$$

Since areas and mass vary directly as the square of wire diameter, it can be shown similarly that the mathematical law of the American Wire Gage holds rigorously for these quantities when the ratio of r^2(1.2609767) or $1/r^2$(0.79303605), as the case may be (depending upon the quantity involved and whether the calculation is an ascending or descending one), is assigned to the properties of adjacent gage sizes. Thus, for size 18 AWG, the circular-mil area is given by the expression:

$$A_{18} = A_{36}r^{36} = 25 \times 1.2609767^{18} = 25 \times 64.9721 = 1624 \text{ cmils}$$

or:

$$A_{18} = A_{4/0}/r^{42}$$
$$= 211{,}600 \times 0.79303605^{21}$$
$$= 211{,}600 \times 0.00767629$$
$$= 1624 \text{ cmils}$$

Similar calculations can be made for mass where these quantities are known for size 36 AWG or size 4/0 AWG.

NOTE 2—AWG numbers appearing in Columns 1 and 5 of Table 1 are given only to facilitate conversion from AWG numbers to the wire size in mils. It is emphasized that this is not intended to be an endorsement of the use of AWG numbers to designate wire sizes. Wire diameters should be specified in mils as shown in Table 1, Columns 2 and 6.

Micrometer calipers calibrated to measure 0.1 mil (0.0001 in.) should be considered satisfactory for measuring the diameters of 4/0 to 44 AWG (0.4600 to 0.0020 in.) inclusive.

For greater accuracy in obtaining the mean diameter of ultrafine wire size 45 to 56 AWG (0.00176 to 0.00049 in.) inclusive, Test Method F 205 should be considered satisfactory. The density values in Table 2 shall be used in determining constants C and K.

NOTE 3—The value of 875.20Ω· lb/mile^2 at 20°C (68°F) is the mass resistivity equivalent to the International Annealed Copper Standard (IACS) for 100 % conductivity. This term means that a wire one mile in length, with a mass of 1 lb, would have a resistance of 875.20 Ω. This is equivalent to a resistivity value of 0.15328 Ω·g/m^2 which signifies the resistance of a wire 1 m in length with a mass of 1 g. It is also equivalent for example to a volume resistivity of 1.7241 μΩ/cm of length of a bar 1 cm^2 in cross section. A complete discussion of this subject is contained in *NBS Handbook 100* of the National Institute of Standards and Technology.[6] Conversion of the various units of mass resistivity, volume resistivity, and conductivity may be facilitated by employing the formulas and factors shown in Table 4. The factors given therein are applicable to all metallic electrical conductor material. Table 2 lists values of δ for the common electrical conductor materials.

[6] *NBS Handbook 100*, Nat. Institute of Standards and Technology, , is sold by the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

TABLE 4 Resistivity and Conductivity Conversion

NOTE 1—These factors are applicable only to resistivity and conductivity values corrected to 20°C (68°F). They are applicable for any temperature when used to convert between volume units only or between mass units only. Values, of density, δ, for the common electrical conductor materials, are listed in Table 2.

Perform indicated operation to obtain	Given *N*							
	Volume Resistivity at 20°C				Mass Resistivity at 20°C		Conductivity at 20°C	
	Ω·cmil/ft	$\Omega \cdot mm^2/m$	μΩ·in.	μΩ·cm	$\Omega \cdot lb/mile^2$	$\Omega \cdot g/m^2$	Percent IACS (Volume Basis)	Percent IACS (Mass Basis)
Volume Resistivity at 20°C								
Ohm—circular mil/ft	...	*N* × 601.53	*N* × 15.279	*N* × 6.0153	*N* × 0.10535 × 1/δ	*N* × 601.53 × 1/δ	1/*N* × 1037.1	1/*N* × 9220.0 × 1/δ
Ohm—mm^2/metre	*N* × 0.0016624	...	*N* × 0.025400	*N* × 0.010000	*N* × 0.00017513 × 1/δ	*N* × 1/δ	1/*N* × 1.7241	1/*N* × 15.328 × 1/δ
Microhm—inch	*N* × 0.065450	*N* × 39.370	...	*N* × 0.39370	*N* × 0.0068950 × 1/δ	*N* 39.370 × 1/δ	1/*N* × 67.879	1/*N* × 603.45 × 1/δ
Microhm—cm	*N* × 0.16624	*N* × 100.00	*N* × 2.5400	...	*N* 0.017513 × 1/δ	*N* 100.00 × 1/δ	1/*N* × 172.41	1/*N* × 1532.8 × 1/δ
Mass Resistivity at 20°C								
Ohm—pound/$mile^2$	*N* × 9.4924 ×δ	*N* × 5710.0 × δ	*N* × 145.03 × δ	*N* × 57.100 × δ	...	*N* × 5710.0	1/*N* × 9844.8 × δ	1/*N* × 875.20
Ohm—gram/$metre^2$	*N* × 0.0016624 × δ	*N* × δ	*N* × 0.025400 × δ	*N* × 0.010000 ×δ	*N* × 0.00017513	...	1/*N* × 1.7241 × δ	1/*N* × 15.328
Conductivity at 20°C								
Percent IACS (volume basis)	1/*N* × 1037.1	1/*N* × 1.7241	1/*N* × 67.879	1/*N* × 172.41	1/*N* × 9844.8 × δ	1/*N* × 1.7241 × δ	...	*N* × 0.11249 × δ
Percent IACS (mass basis)	1/*N* × 9220.0 × 1/δ	1/*N* × 15.328 × 1/δ	1/*N* × 603.45 × 1/δ	1/*N* × 1532.8 × 1/δ	1/*N* × 87520	1/*N* × 15.328	*N* × 8.89 × 1/δ	...