



# Standard Specification for Hard-Drawn Copper-Clad Steel Wire<sup>1</sup>

This standard is issued under the fixed designation B227; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers bare hard-drawn round copper-clad steel wire for electrical purposes (Note 1).

NOTE 1—Wire ordered to this specification is not intended for redrawing. If wire is desired for this purpose, consult the manufacturer.

1.2 Four grades of wire are specified, designated as follows (Note 2): Grade 40 HS, Grade 40 EHS, Grade 30 HS, and Grade 30 EHS.

NOTE 2—The grades covered by this specification correspond to the following commercial designations:

- Grade 40 HS, High Strength, 40 % Conductivity.
- Grade 40 EHS, Extra High Strength, 40 % Conductivity
- Grade 30 HS, High Strength, 30 % Conductivity.
- Grade 30 EHS, Extra High Strength, 30 % Conductivity.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

## 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*:<sup>2</sup>

- 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**

2.3 *National Institute of Standards and Technology*:

- NBS Handbook 100—Copper Wire Tables**<sup>3</sup>

<sup>1</sup> This specification is under the jurisdiction of the ASTM Committee B01 on Electrical Conductors and is the direct responsibility of Subcommittee B01.06 on Composite Conductors.

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<sup>2</sup> 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.

<sup>3</sup> Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, http://www.nist.gov.

## 3. Ordering Information

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

- 3.1.1 Quantity of each size and grade,
- 3.1.2 Wire size: diameter in inches (see 5.1 and Table 1),
- 3.1.3 Grade (see 1.2 and Table 1),
- 3.1.4 Method of measuring elongation (see 7.3 and 7.4),
- 3.1.5 Package size (see 14.1),
- 3.1.6 Special package marking, if required (Section 13), and
- 3.1.7 Place of inspection (Section 15).

## 4. Material

4.1 The wire shall be composed of a steel core with a substantially uniform and continuous copper cladding thoroughly bonded to it throughout.

4.2 The finished copper-clad steel wire shall conform to the requirements prescribed in this specification.

## 5. Dimensions and Permissible Variations

5.1 The size shall be expressed as the diameter of the wire in decimal fractions of an inch using four places of decimals, that is, in tenths of mils (Note 3).

NOTE 3—The values of wire diameters in Table 1 are given to the nearest 0.0001 in. and correspond to the standard sizes given in Specification B258. In specifying diameters of wire or in inspecting wire, express the diameter to the fourth decimal place. The diameters preceded by asterisks are not in the American Wire Gage series and are also given to four places of decimals. They correspond to certain numbers of the Birmingham Wire Gage of the British Standard Wire Gage and are used for communication lines. The use of gage numbers in specifying wire sizes is not recognized in these specifications because of the possibility of confusion. An excellent discussion of wire gages and related subjects is contained in *NBS Handbook 100* of the National Institute of Standards and Technology.<sup>3</sup>

5.2 Within the range of diameters included in Table 1, the wire shall not vary from the specified diameter by more than the following amounts rounded off to the nearest 0.1 mil (0.0001 in.):

Specified Diameter, in. (mm)	Permissible Variations in Specified Diameter
0.2043 (5.189) to 0.1000 (2.540), incl	±1.5 %
0.0999 (2.537) and under	±1.0 %

5.3 Ten percent, but not less than five coils or spools (or all if the lot is less than five) from any lot of wire, shall be gaged

**TABLE 1 Tensile Requirements**

Nominal Diameter in. (mm)	Area at 20°C		Tensile Strength, min, psi (MPa) <sup>A</sup>			
	cmil	in. <sup>2</sup> (mm <sup>2</sup> ) <sup>A</sup>	Grade 40 HS	Grade 40 EHS	Grade 30 HS	Grade 30 EHS
0.2043 (5.189)	41 740	0.03278 (21.15)	108 000 (745)	...	120 000 (828)	142 500 (983)
0.1819 (4.620)	33 090	0.02599 (16.77)	113 000 (780)	...	125 000 (863)	150 500 (1038)
0.1650 (4.191) <sup>B</sup>	27 230	0.02138 (13.79)	118 000 (814)	...	130 000 (897)	157 500 (1087)
0.1620 (4.115)	26 240	0.02061 (13.30)	118 000 (814)	...	130 000 (897)	157 500 (1087)
0.1443 (3.665)	20 820	0.01635 (10.55)	123 000 (849)	...	135 000 (932)	164 000 (1132)
0.1285 (3.264)	16 510	0.01297 (8.368)	128 000 (883)	...	140 000 (966)	170 000 (1173)
0.1280 (3.251) <sup>B</sup>	16 380	0.01287 (8.303)	128 000 (883)	...	140 000 (966)	170 000 (1173)
0.1144 (2.906)	13 090	0.01028 (6.632)	133 000 (918)	...	145 000 (1001)	174 100 (1201)
0.1040 (2.642) <sup>B</sup>	10 820	0.008495 (5.481)	138 600 (956)	156 000 (1076)	151 000 (1042)	175 000 (1208)
0.1019 (2.588)	10 380	0.008155 (5.261)	138 600 (956)	...	151 000 (1042)	179 000 (1235)
0.0808 (2.052)	6 530	0.005129 (3.309)	115 000 (794)	...	120 000 (828)	179 000 (1235)
0.0800 (2.032) <sup>B</sup>	6 400	0.005027 (3.243)	115 000 (794)	...	120 000 (828)	179 000 (1235)
0.0640 (1.626) <sup>B</sup>	4 096	0.003217 (2.076)	125 000 (863)	...	130 000 (897)	179 000 (1235)
0.0403 (1.024)	1 624	0.001276 (0.8232)	130 000 (897)	...	135 000 (932)	179 000 (1235)
0.0390 (0.9906) <sup>B</sup>	1 521	0.001195 (0.7710)	130 000 (897)	...	135 000 (932)	179 000 (1235)
0.0320 (0.8128)	1 024	0.000804 (0.5187)	135 000 (932)	161 000 (1111)	145 000 (1001)	179 000 (1235)

<sup>A</sup> Metric equivalents: 1 in. = 25.4 mm (round to four significant figures); 1 in.<sup>2</sup> = 645.16 mm<sup>2</sup> (round to four significant figures); 1 psi = 6.9 kPa (round to significant figure of U.S. customary units).

<sup>B</sup> These diameters are often employed by purchasers for communication lines but are not in the American Wire Gage (B & S Wire Gage) series, as are the other diameters listed (Note 3).

**TABLE 2 Approximate Properties of Hard-Drawn Copper-Clad Steel Wire**  
(For Information Only)

Nominal Diameter in. (mm)	Breaking Strength, min lbf (N) <sup>A</sup>				Mass/Unit Length		
	Grade 40 HS	Grade 40 EHS	Grade 30 HS	Grade 30 EHS	lb/1000 ft	lb/mile	kg/km <sup>A</sup>
0.2043 (5.189)	3435 (15280)	...	3817 (16979)	4532 (20159)	115.8	611.6	172.3
0.1819 (4.620)	2849 (12673)	...	3152 (14021)	3795 (16881)	91.86	485.0	136.7
0.1650 (4.191)	2448 (10889)	...	2697 (11997)	3267 (14532)	75.55	398.9	112.4
0.1620 (4.115)	2360 (10498)	...	2600 (11565)	3150 (14012)	72.85	384.6	108.4
0.1443 (3.665)	1952 (8683)	...	2142 (9528)	2602 (11574)	57.77	305.0	85.97
0.1285 (3.264)	1611 (7166)	...	1762 (7838)	2139 (9515)	45.81	241.9	68.17
0.1280 (3.251)	1598 (7108)	...	1748 (7775)	2122 (9439)	45.47	240.1	67.67
0.1144 (2.906)	1326 (5898)	...	1446 (6432)	1736 (7722)	36.33	191.8	54.06
0.1040 (2.642)	1142 (5080)	1286 (5720)	1245 (5538)	1442 (6414)	30.01	158.5	44.66
0.1019 (2.588)	1097 (4880)	...	1195 (5316)	1416 (6299)	28.81	152.1	42.87
0.0808 (2.052)	578 (2571)	...	603 (2682)	900 (4003)	18.12	95.68	26.97
0.0800 (2.032)	567 (2522)	...	591 (2629)	882 (3923)	17.76	93.77	26.43
0.0640 (1.626)	394 (1753)	...	410 (1824)	564 (2509)	11.37	60.03	16.92
0.0403 (1.024)	163 (725)	...	169 (752)	224 (996)	4.507	23.80	6.707
0.0390 (0.9906)	152 (676)	...	158 (703)	210 (934)	4.221	22.29	6.282
0.0320 (0.8126)	106 (472)	127 (565)	114 (507)	141 (627)	2.842	15.00	4.229

<sup>A</sup> Metric equivalents: 1 lbf = 4.4482 N (round to significant figure of customary units); 1 lb/1000 ft = 1.48816 kg/km (round to four significant figures).

at three places. If accessible, one gaging shall be taken near each end and one near the middle. If any of the selected coils or spools fail to conform to the requirements for diameter as prescribed in 5.2, all coils or spools shall be gaged in the manner specified.

## 6. Workmanship, Finish, and Appearance

6.1 The surface of the wire shall be smooth and free from imperfections not consistent with good commercial practice.

## 7. Tensile Properties

7.1 The wire shall conform to the tensile requirements prescribed in Table 1 (Note 4).

NOTE 4—The approximate properties of hard-drawn copper-clad steel wire are shown in Table 2 for the information of the user of this specification.

7.2 Wire whose nominal diameter is more than 0.001 in. (1 mil) (0.03 mm) greater than a size listed in Table 1 shall conform to the tensile requirements of the next larger size.

7.3 Tension tests shall be made on representative samples. Unless otherwise agreed upon between the manufacturer and the purchaser, the elongation shall be determined by measurements made between the jaws of the testing machine. The zero length shall be the distance between the jaws when a load equal to 10 % of the specified tensile strength shall have been

applied, and the final length shall be the distance between the jaws at the time of rupture. The zero length shall be as near 10 in. (250 mm) as possible. The fracture shall be between the jaws of the testing machine and not closer than 1 in. (25.4 mm) to either jaw. The elongation as thus determined shall be not less than 1.0 %.

7.4 When agreed upon by the manufacturer and the purchaser, measure the elongation by means of an extensometer 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, as thus determined, shall be not less than 1.5 %. Tests in which the extensometer reading is less than 1.5 %, but in which the fracture does not occur between the two attachments of the extensometer to the specimen, shall be disregarded.

7.5 *Retests*—If upon testing a sample from any coil or spool of wire, the results do not conform to the tensile requirements prescribed in **Table 1** and the elongation requirements of **7.4**, two additional samples shall be tested, and the average of the three tests shall determine the acceptance or rejection of the coil or spool.

## 8. Twist Test

8.1 The wire shall withstand, without fracture, not less than 20 twists in a length equivalent to 100 times the nominal diameter of the specimen. In the twist test, the rate of applying the twists shall be approximately 15/min.

8.2 Specimens shall be twisted to destruction and shall not reveal under test any seams, pits, slivers, or surface imperfections of sufficient magnitude to indicate inherent defects or imperfections in the wire. Examination of the wire at the break shall show no separation of copper from the steel.

## 9. Resistance

9.1 The electrical resistance of the wire (**Note 5**) shall be determined by resistance measurements and maximum resistance shall be based on the minimum diameter of the wire and the following resistivity values:

Resistivity at 20°C Ωcmil/ft

40 HS and 40 EHS	26.45
30 HS and 30 EHS	35.26

NOTE 5—Electrical resistance is calculated by the following equation:

$$\text{maximum resistance (ohms/ft)} = \frac{\text{resistivity, ohm}\cdot\text{circular mil/ft}}{(\text{minimum diameter, mils})^2} \quad (1)$$

9.2 The maximum resistance values are given in **Table 3**.

9.3 When resistance measurements are made at temperatures other than 20°C, corrections shall be based on a temperature coefficient of resistance of 0.0038/°C.

9.4 Tests to determine conformance to the electrical resistance requirements of **Table 3** shall be made in accordance with Test Method **B193**.

## 10. Thickness of Copper

10.1 The thickness of copper on the wire shall be not less than the following:

**TABLE 3 Maximum Resistance Values**

Nominal Diameter	Maximum Resistance at 20°C Ω/1000 ft <sup>A</sup> (Ω/km)	
	Grades 40 HS and 40 EHS	Grades 30 HS and 30 EHS
in. (mm)		
0.2043 (5.189)	0.6532 (2.143)	0.8707 (2.857)
0.1819 (4.620)	0.8239 (2.703)	1.098 (3.603)
0.1650 (4.191)	1.001 (3.284)	1.335 (4.380)
0.1620 (4.115)	1.039 (3.409)	1.385 (4.544)
0.1443 (3.665)	1.309 (4.295)	1.745 (5.725)
0.1285 (3.264)	1.651 (5.417)	2.201 (7.221)
0.1280 (3.251)	1.664 (5.460)	2.218 (7.277)
0.1144 (2.906)	2.083 (6.834)	2.777 (9.111)
0.1040 (2.642)	2.521 (8.271)	3.360 (11.02)
0.1019 (2.588)	2.625 (8.613)	3.500 (11.48)
0.0808 (2.052)	4.134 (13.56)	5.511 (18.08)
0.0800 (2.032)	4.217 (13.84)	5.622 (18.45)
0.0640 (1.626)	6.589 (21.62)	8.784 (28.82)
0.0403 (1.024)	16.62 (54.53)	22.15 (72.67)
0.0390 (0.9906)	17.74 (58.21)	23.66 (77.63)
0.0320 (0.8128)	26.36 (86.49)	35.14 (115.3)

<sup>A</sup> Metric equivalents: 1 Ω/1000 ft = 3.281 Ω/km (round off to four significant figures).

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

10.1.2 The 40 % conductivity wire shall have a minimum thickness of not less than 10 % of the wire radius.

## 11. Joints

11.1 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.

## 12. Density

12.1 For the purpose of calculating mass/unit length, cross sections, and so forth, the density of Grade 30 wire shall be taken as 0.2944 lb/in.<sup>3</sup> (8.15 g/cm<sup>3</sup>) at 20°C and Grade 40 as 0.2975 lb/in.<sup>3</sup> (8.24 g/cm<sup>3</sup>).

## 13. Inspection

13.1 Unless otherwise specified in the contract or purchase order, the manufacturer shall be responsible for the performance of all inspection and test requirements specified.

13.2 All inspections and tests shall be made at the place of manufacture unless otherwise especially agreed upon between the manufacturer and the purchaser at the time of the purchase.

13.3 The manufacturer shall afford the inspector representing the purchaser all reasonable manufacturer's facilities necessary to ensure that the material is being furnished in accordance with this specification.

## 14. Certification

14.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the purchaser showing that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. When

specified in the purchase order or contract, a report of the test results shall be furnished.

## **15. Packaging and Package Marking**

15.1 Package sizes shall be agreed upon between the manufacturer and the purchaser in the placing of individual purchase orders.

15.2 The wire shall be protected against damage in ordinary handling and shipping.

15.3 Each coil shall bear a tag showing the manufacturers' name or trademark, size, and class of material. If additional information is to be required on the tags, it shall be arranged with the manufacturer at the time of purchase.

## **16. Keywords**

16.1 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

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