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Standard Specification for Concentric-Lay-Stranded Copper-Clad Steel Conductors[1]

This standard is issued under the fixed designation B 228; 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 concentric-lay-stranded conductors made from bare round copper-clad steel wires for general use for electrical purposes.

1.2 For the purpose of this specification, conductors are classified as follows: Grade 40 HS, Grade 30 HS, and Grade 30 EHS.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are in SI units.

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:

[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 227 Specification for Hard-Drawn Copper-Clad Steel Wire
B 354 Terminology Relating to Uninsulated Metallic Electrical Conductors
2.3 *ANSI Standards:*
C 42 Definitions of Electrical Terms[3]
2.4 *National Institute of Standards and Technology:*
NBS *Handbook 100—Copper Wire Tables*[4]

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 Conductor size: approximate diameter in fractions of an inch, or number and AWG size of individual wires (Section 7 and Table 1);
3.1.3 Grade (see 1.2 and Table 1);
3.1.4 Direction of lay of outer layer, if other than left-hand (see 6.3);
3.1.5 When physical tests shall be made (see 8.2);
3.1.6 Package size (see 13.1);
3.1.7 Special package marking, if required (Section 12);
3.1.8 Lagging, if required (see 13.2); and
3.1.9 Place of inspection (Section 14).
3.2 In addition, Supplementary Requirements shall apply only when specified by the purchaser in the inquiry, contract, or purchase order for direct procurement by agencies of the U. S. Government (S1, S2, and S3).

4. Material for Wires

4.1 The purchaser shall specify the grade of wire to be used in the conductor.

[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 American National Standards Institute (ANSI), ~~11~~ 25 W. ~~42nd~~ 43rd St., ~~13th~~ 4th Floor, New York, NY 10036.
[4] Available from National Institute of Standards and Technology~~,~~ (NIST), 100 Bureau Dr., Stop 3460, Gaithersburg, MD 20899-3460.

TABLE 1 Construction Requirements and Breaking Strength of Concentric-Lay-Stranded Copper-Clad Steel Conductors

NOTE 1—*Metric Equivalents*—For diameter, 1 in. = 25.40 mm (round to ~~4~~ four significant figures); for breaking strength, 1 lb = 0.45359 kg (round to ~~4~~ four significant figures).

Size Designation		Conductor Diameter, in.[A]	Rated Breaking Strength, min, lb[B]		
Inch[C]	AWG[D]		Grade 40 HS	Grade 30 HS	Grade 30 EHS
7/8	19 No. 5	0.910	50 240	55 570	66 910
13/16	19 No. 6	0.810	41 600	45 830	55 530
23/32	19 No. 7	0.721	34 390	37 740	45 850
21/32	19 No. 8	0.642	28 380	31 040	37 690
9/16	19 No. 9	0.572	23 390	25 500	30 610
5/8	7 No. 4	0.613	22 310	24 780	29 430
9/16	7 No. 5	0.546	18 510	20 470	24 650
1/2	7 No. 6	0.486	15 330	16 890	20 460
7/16	7 No. 7	0.433	12 670	13 910	16 890
3/8	7 No. 8	0.385	10 460	11 440	13 890
11/32	7 No. 9	0.343	8 616	9 393	11 280
5/16	7 No. 10	0.306	7 121	7 758	9 196
. . .	3 No. 5	0.392	8 373	9 262	11 860
. . .	3 No. 6	0.349	6 934	7 639	9 754
. . .	3 No. 7	0.311	5 732	6 291	7 922
. . .	3 No. 8	0.277	4 730	5 174	6 282
. . .	3 No. 9	0.247	3 898	4 250	5 129
. . .	3 No. 10	0.220	3 221	3 509	4 160
. . .	3 No. 12	0.174	2 236	. . .	. . .

[A] Diameter of circumscribing circle.
[B] Breaking loads of 7-wire and 19-wire conductors are taken as 90 % of the sum of the breaking loads of the individual wires; breaking load of 3-wire conductors is taken as 95 % of the sum of the breaking loads of the individual wires.
[C] The designation “Inch” is the approximate diameter in proper fraction of an inch.
[D] The designation of “AWG” is a combination of the number of wires each of the American Wire Gage size indicated by “No.”

4.2 Before stranding, the copper-clad steel wire shall meet all the requirements of Specification B 227.

4.3 All wires in the conductor shall be of the same grade and quality.

5. Joints

5.1 Joints or splices may be made in the finished individual copper-clad steel wires composing concentric-lay-stranded conductors, using more than three wires provided that such joints or splices have a protection equivalent to that of the wire itself and that they do not decrease the strength of the finished stranded conductor below the minimum breaking strength shown in Table 1. Such joints or splices shall be not closer than 50 ft (15 m) to any other joint in the same layer in the conductor (Note 1).

NOTE 1—Joints or splices in individual copper-clad steel wires in their finished size are made by electrical butt welding. Two types of joints are used and are described as follows:

(a) Weld-Annealed Joints—After butt welding, the wire is annealed for a distance of approximately 5 in. (127 mm) on each side of the weld. The weld is then protected from corrosion with a snug fitting seamless copper sleeve which extends at least ⅜ in. (9.5 mm) on each side of the weld and which is thoroughly sealed to the wire with solder. The wall thickness of the sleeve is at least 10 % of the radius of the wire.

This joint has a tensile strength of approximately 60 000 psi (415 MPa). This is less than the strength of the individual wires, but an allowance is made for this in the rated strength of the conductor as a whole. The completed conductor when containing such joints is required to have the full rated strength.

This type of joint is but slightly larger than the wire itself and is applicable for 7, 12, and 19-wire stranded conductors.

(b) Compression-Weld Joints—Compression-weld joints differ from weld-annealed joints in that the wire is not annealed after the butt-welding operation but is reinforced with a hard-drawn, seamless, silicon-tin bronze sleeve which is applied by means of a hydraulic compressor over the weld. This sleeve is covered with solder so as to completely seal the ends. These sleeves have a wall thickness of 25 to 50 % of the radius of the wire, depending on the wire size. Their use is usually limited to 3-wire conductors where the relatively large diameter is not objectionable. This joint develops the full strength of the wire.

6. Lay

6.1 For 3-wire conductors the preferred lay is 16½ times the outside diameter, but the lay shall not be less than 14 times nor more than 20 times this diameter.

6.2 For 7- and 19-wire conductors the preferred lay is 13½ times the diameter of that layer, but the lay shall not be less than 10 nor more than 16 times this diameter.

6.3 The direction of lay of the outer layer shall be left-hand unless the direction of lay is specified otherwise by the purchaser.

6.4 The direction of lay shall be reversed in consecutive layers.

6.5 All wires in the conductor shall lie naturally in their true positions in the completed conductor. They shall tend to remain in position when the conductor is cut at any point and shall permit restranding by hand after being forcibly unraveled at the end of the conductor.

7. Construction

7.1 The numbers and diameters of the wires in the concentric-lay-stranded conductors shall conform to the requirements prescribed in Table 1 (Note 2).

NOTE 2—For definitions of terms relating to conductors, reference should be made to (*1*) ANSI C42.35-latest revision and (*2*) Terminology B 354.

8. Physical and Electrical Tests

8.1 Tests for physical and electrical properties of wires composing concentric-lay-stranded conductors made from copper-clad steel wire shall be made before stranding.

8.2 At the option of the purchaser, tension and elongation tests before stranding may be waived and the complete conductors may be tested as a unit. The breaking strength of the conductors so tested shall be not less than that required in Table 1.

8.3 Where breaking strength tests are required on the finished conductor, they shall be made on representative samples, not less than 4 ft (1.22 m) in length. For lots of 10 000 lb (4540 kg) or less, two samples shall be taken from separate reels or coils in the lot except that but one sample shall be required where the total amount of conductor is 5000 ft (1525 m) or less. For quantities over 10 000 lb, one sample for each 10 000 lb, or fraction thereof, shall be taken, but the minimum number of samples shall be three.

8.4 Specimens of the completed conductor shall be tested in a tensile testing machine equipped with jaws suitable for gripping of the conductor or equipped for holding properly socketed specimens. Any test in which the result is below the stated value and which is obviously caused by improper socketing of the specimen, or due to the break occurring in or at the gripping jaws of the machine, shall be disregarded and another sample from the same coil or reel shall be tested.

9. Density

9.1 For the purpose of calculating mass per unit length (Note 3), cross sections, ~~etc.,~~ and so forth, the density of the copper-clad

TABLE 2 Density of Copper-Clad Steel

Units	Grade 40 Density at 20°C	Grade 30 Density at 20°C
Grams per cubic centimetre	8.24	8.15
Pounds per cubic inch	0.2975	0.2944
Pounds per circular mil-foot	0.0000028039	0.0000027750

steel wire shall be taken as shown in Table 2 (Note 4).

NOTE 3—The term mass per unit length is used in this specification as being more technically correct replaces the term "weights."

NOTE 4—The value of density of copper-clad steel is an average value which has been found to be in accordance with usual values encountered in practice. Equivalent expressions of density at 20°C are given in Table 2.

10. Mass and Resistance

10.1 The mass and electrical resistance of a unit length of stranded conductor are a function of the length of lay. The approximate mass and electrical resistance may be determined using the standard increments shown in Table 3. When greater accuracy is desired, the increment based on the specific lay of the conductor may be calculated (Note 5).

NOTE 5—The increment of mass or electrical resistance of a completed concentric-lay-stranded conductor (k) in percent is

$$k = 100(m - 1)$$

where m is the stranding factor, and is also the ratio of the mass or electrical resistance of a unit length of stranded conductor to that of a solid conductor of the same cross-sectional area or of a stranded conductor with infinite length of stranding, that is, all wires parallel to the conductor axis. The stranding factor m for the completed stranded conductor is the *numerical average* of the stranding factors for each of the individual wires in the conductor, including the straight core wire, if any (for which the stranding factor is unity). The stranding factor (m_{ind}) for any given wire in a concentric-lay-stranded conductor is

$$m_{ind} = \sqrt{1 + (9.8696/n^2)}$$

where n = length of lay/diameter of helical path of the wire. The derivation of the above is given in *NBS Handbook 100*.

11. Variation in Area

11.1 The area of cross section of the completed conductor shall be not less than 98 % of the area specified. The area of cross section of a conductor shall be considered to be the sum of the cross-sectional areas of its component wires at any section when measured perpendicularly to their individual axes (Note 6).

NOTE 6—For the convenience of the users of this specification, Table 4 has been prepared giving areas, resistances per 1000 ft, and mass per 1000 ft, and per mile, of the various constructions referred to in Table 1.

12. Inspection

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

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

12.3 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.

13. Packaging and Package Marking

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

13.2 The conductors shall be protected against damage in ordinary handling and shipping. If heavy wood lagging is required, it shall be specified by the purchaser at the time of the purchase.

13.3 The net mass, length (or lengths, and number of lengths, if more than one length is included in the package), size, grade 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.

14. Keywords

14.1 clad steel electrical conductor; concentric-lay-stranded copper-clad steel electrical conductor; copper electrical conductor—copper-clad steel; copper electrical conductor—stranded; copper-clad steel electrical conductor; electrical conductor

TABLE 3 Standard Increments Due to Stranding

Type of Conductor	Increment (Increase) of Resistance and Mass, %
3 Wire	0.8
7 Wire	1.0
19 Wire	1.4

TABLE 4 Data Concerning Areas, Mass, and Resistances of Concentric-Lay-Stranded Copper-Clad Steel Conductors (For Information Only)

NOTE 1—*Metric Equivalents*—For area, 1 in.^{2} = 645.16 mm^2 (round to 4 significant figures); for mass, 1 lb/1000 ft = 1.48816 kg/km (round to 4 significant figures); for resistance, 1 ohm/ 1000 ft = 3.281 ohms/km (round to 4 significant figures).

NOTE 2—The modulus of elasticity of conductors manufactured in accordance with this specification may be taken as 23 000 000 psi (160 GPa); likewise the coefficient of linear expansion may be taken as 0.0000072/°F (0.0000129/°C).

Size Designation		Conductor Area		30 % Density Mass		40 % Density Mass		Resistance, max, ohms/1000 ft	
Inch[A]	AWG[B]	cmils	in.^{2}	lb/1000 ft	lb/mile	lb/1000 ft	lb/mile	Grade 40	Grade 30
7⁄8	19 No. 5	628 900	0.4940	1770	9344	1788	9442	0.04264	0.05685
13⁄16	19 No. 6	498 800	0.3917	1403	7409	1418	7487	0.05377	0.07168
23⁄32	19 No. 7	395 500	0.3107	1113	5877	1125	5939	0.06780	0.09039
21⁄32	19 No. 8	313 700	0.2464	882.7	4660	892.0	4710	0.08550	0.1140
9⁄16	19 No. 9	248 800	0.1954	700.0	3696	707.3	3735	0.1078	0.1437
5⁄8	7 No. 4	292 200	0.2295	818.9	4324	827.5	4369	0.09143	0.1219
9⁄16	7 No. 5	231 700	0.1820	649.4	3429	656.2	3465	0.1153	0.1537
1⁄2	7 No. 6	183 800	0.1443	514.9	2719	520.3	2747	0.1454	0.1938
7⁄16	7 No. 7	145 700	0.1145	408.6	2157	412.9	2180	0.1833	0.2444
3⁄8	7 No. 8	115 600	0.09077	323.9	1710	327.3	1728	0.2312	0.3081
11⁄32	7 No. 9	91 650	0.07198	256.8	1356	259.5	1370	0.2915	0.3886
5⁄16	7 No. 10	72 680	0.05708	203.7	1075	205.8	1087	0.3676	0.4900
. . .	3 No. 5	99 310	0.07800	277.8	1467	280.7	1482	0.2685	0.3579
. . .	3 No. 6	78 750	0.06185	220.3	1163	222.6	1175	0.3385	0.4513
. . .	3 No. 7	62 450	0.04905	174.7	922.3	176.5	932.0	0.4269	0.5691
. . .	3 No. 8	49 530	0.03890	138.5	731.4	140.0	739.1	0.5383	0.7176
. . .	3 No. 9	39 280	0.03085	109.9	580.1	111.0	586.2	0.6788	0.9049
. . .	3 No. 10	31 150	0.02446	87.10	459.9	88.02	464.7	0.8559	1.141
. . .	3 No. 12	19 590	0.01539	54.80	289.4	55.38	292.4	1.361	. . .

[A] The designation "Inch" is the approximate diameter in proper fraction of an inch.
[B] The designation "AWG" is a combination of the number of wires each of the American Wire Gage size indicated by "No."