Designation: B228 − 11a (Reapproved 2021)

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

This standard is issued under the fixed designation B228; 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 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, Grade 30 EHS, Grade 40 DSA, and Grade 30 DSA.

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

Grade 40 HS,	High Strength, 40 % Conductivity, Hard Drawn
Grade 30 HS,	High Strength, 30 % Conductivity, Hard Drawn
Grade 30 EHS,	Extra High Strength, 30 % Conductivity, Hard Drawn
Grade 40 DSA,	40 % Conductivity, Dead Soft Annealed
Grade 30 DSA,	30 % Conductivity, Dead Soft Annealed

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.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *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 the date of material purchase form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards:*[2]

B227 Specification for Hard-Drawn Copper-Clad Steel Wire

B354 Terminology Relating to Uninsulated Metallic Electrical Conductors

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

B910/B910M Specification for Annealed Copper-Clad Steel Wire

2.3 *ANSI Standards:*[3]

C 42 Definitions of Electrical Terms

2.4 *NIST Standards:*[4]

NBS *Handbook 100—Copper Wire Tables*

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).

[1] This specification is under the jurisdiction of ASTM Committee B01 on Electrical Conductors and is the direct responsibility of Subcommittee B01.06 on Bi-Metallic Conductors.

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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 American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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

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 four significant figures); for breaking strength, 1 lb = 0.45359 kg (round to 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	Grade 40 DSA	Grade 30 DSA
7/8	19 No. 5	0.910	48 740	53 910	64 910	17 250	19 410
13/16	19 No. 6	0.810	40 370	44 470	53 880	13 680	15 390
23/32	19 No. 7	0.721	33 360	36 610	44 480	10 850	12 200
21/32	19 No. 8	0.642	27 550	30 140	36 590	8610	9686
9/16	19 No. 9	0.572	22 690	24 730	29 700	6823	7676
5/8	7 No. 4	0.613	21 630	24 040	28 540	8012	9014
9/16	7 No. 5	0.546	17 960	19 860	23 910	6356	7150
1/2	7 No. 6	0.486	14 870	16 390	19 850	5041	5672
7/16	7 No. 7	0.433	12 290	13 490	16 390	3996	4496
3/8	7 No. 8	0.385	10 150	11 100	13 480	3172	3569
11/32	7 No. 9	0.343	8359	9113	10 940	2514	2828
5/16	7 No. 10	0.306	6913	7531	8928	1995	2244
. . .	3 No. 5	0.392	8122	8985	10 820	2875	3235
. . .	3 No. 6	0.349	6728	7412	8980	2281	2566
. . .	3 No. 7	0.311	5559	6102	7413	1808	2034
. . .	3 No. 8	0.277	4592	5023	6099	1435	1614
. . .	3 No. 9	0.247	3781	4122	4950	1137	1279
. . .	3 No. 10	0.220	3127	3407	4039	903	1015
. . .	3 No. 12	0.174	1647	1719	2564	573	645

[A] Diameter of circumscribing circle.
[B] Minimum breaking strength is calculated using the minimum diameter of the individual wire and the minimum tensile strength from Specification B227. 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. Material for Wires

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

4.2 Before stranding, the copper-clad steel wire shall meet all the requirements of Specification B227 for Grade 40 HS, Grade 30 HS and Grade 30 EHS and the requirements of Specification B910/B910M for Grade 40 DSA and Grade 30 DSA.

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 one of two approaches:

1. A snug fitting seamless copper sleeve which extends at least 3/8 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.

2. Protect the weld from corrosion and ensure acceptable conductivity through the use of a silver solder that extends at least 3/8 in. (9.5 mm) on each side of the weld.

This type of joint is applicable for 7, 12, and 19 wire stranded configurations. When joints made on annealed individual wires, the completed stranded conductor is required to have the full rated strength. For hard drawn material, 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

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

conductor as a whole. The completed conductor when containing such joints is required to have the full rated strength. Other protection methods may also be used as agreed upon between the purchaser and manufacturer.

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 B354.

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, and so forth, the density of the copper-clad 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 97 % 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). For the purpose of determining conformance to this standard, a measured or calculated value for cross sectional

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