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Standard Specification for Cored, Annular, Concentric-Lay-Stranded Copper Conductors[1]

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1. Scope

1.1 This specification covers cored, annular, concentric-lay-stranded conductors made from round soft copper wires, either uncoated or coated with tin, lead, or lead alloy for use as electrical conductors (Explanatory Note 1 and Note 2).

1.2 The constructions prescribed herein are suitable for bare conductors, or for conductors to be covered with weather-resistant (weather-proof) material, or for conductors to be insulated with rubber, varnished cloth, or impregnated paper, except types such as "oil-filled" or "gas-filled" (Explanatory Note 3).

1.3 Cored, annular conductor constructions not included in this specification shall be specifically agreed upon between the manufacturer and the purchaser when placing the order.

1.4 These constructions are not recommended for use as electric furnace leads where great flexibility is required and special conductor designs are indicated in consideration of the particular service requirements.

1.5 The SI values for density are regarded as the 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

The following documents of the issue in effect at the time of reference form a part of these methods to the extent referenced herein:

2.1 *ASTM Standards:*

B 3 Specification for Soft or Annealed Copper Wire[2]

B 8 Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft[2]

B 33 Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes[2]

B 172 Specification for Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors[2]

B 173 Specification for Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members, for Electrical Conductors[2]

B 174 Specification for Bunch-Stranded Copper Conductors for Electrical Conductors[2]

B 189 Specification for Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes[2]

B 263 Test Method for Determination of Cross-Sectional Area of Stranded Conductors[2]

B 354 Terminology Relating to Uninsulated Metallic Electrical Conductors[2]

2.2 *American National Standard:*

ANSI C42.35 Definitions of Electrical Terms[3]

2.3 *NIST:*

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,

3.1.2 Conductor size: circular-mil area (Section 7 and Table 1),

3.1.3 Whether coated or uncoated; if coated, designate type of coating (Section 11),

3.1.4 Specific kind and treatment of core material (Section 4),

3.1.5 Details of special-purpose lays, if required (see 6.1 and 6.2 and Explanatory Note 3),

3.1.6 Package size (Section 14),

3.1.7 Lagging, if required (see 14.2),

3.1.8 Special package marking, if required (Section 14), and

3.1.9 Place of inspection (Section 13).

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

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

[4] *NBS Handbook 100*, available from National Technical Information Service (NTIS), U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.

TABLE 1 Construction of Cored, Annular, Concentric-Lay-Stranded Copper Conductors

Nominal Area of Copper Cross Section, cmils	Approximate Diameter of Core, in.	Diameter of Wires, in.	Number of Strands in Layers				Calculated Area of Copper, Cross Section, cmils	Maximum Outside Diameter,[A] in.
			1st	2nd	3rd	Total		
5 000 000	2.875	0.1620	57	63	69	189	4 960 116	3.897
4 500 000	2.500	0.1620	50	56	62	168	4 408 992	3.517
4 000 000	2.250	0.1620	45	51	57	153	4 015 332	3.262
3 500 000	2.000	0.1620	40	45	52	137	3 595 428	3.007
3 000 000	1.625	0.1620	33	38	45	116	3 044 304	2.627
2 500 000	1.500	0.1440	34	40	46	120	2 488 320	2.394
2 000 000	1.313	0.1284	34	40	46	120	1 978 387	2.114
1 750 000	1.125	0.1280	30	35	42	107	1 753 088	1.923
1 500 000	1.000	0.1255	26	32	38	96	1 512 024	1.783
1 250 000	0.750	0.1255	21	26	33	80	1 260 020	1.533
1 000 000	0.563	0.1255	16	21	28	65	1 023 766	1.346
900 000	0.500	0.1172	16	22	28	66	906 565	1.234
800 000	0.468	0.1110	16	21	28	65	800 865	1.164
750 000	0.375	0.1172	12	18	24	54	741 735	1.108

[A] The following plus tolerances are included in the calculation of maximum outside diameters:

Nominal Area, cmils	Plus Tolerance Included, mils
5 000 000 to 4 500 001	50
4 500 000 to 4 000 001	45
4 000 000 to 3 500 001	40
3 500 000 to 3 000 001	35
3 000 000 to 750 000	30

4. Core

4.1 The core may be of any material or materials suitable for the purpose as agreed upon by the manufacturer and the purchaser when placing the order.

4.2 The size of the core and its surface firmness as a base for the overlaid wires shall be adequate to prevent the forcing or dropping of any wire out of its layer position (Explanatory Note 4).

4.3 If a specific kind of fibrous core is required by the purchaser (such as manila rope, sisal, asbestos, and so forth) it shall be specified by him when placing the order (Explanatory Note 4).

4.4 The proper treatment of the fibrous core, if any treatment be required, shall be left to the discretion of the manufacturer unless other arrangements are made at the time of purchase.

4.5 If a metal supporting type of core is required, special arrangements will be necessary between the manufacturer and the purchaser.

5. Joints

5.1 No splice shall be made in the conductor as a whole. Welds or brazes may be made in the finished individual wires. Not more than one of the wires in any given layer shall be spliced in any 1-ft length of that layer.

5.2 All joints shall be made in a workmanlike manner and shall be approximately the diameter of the unjointed wire.

6. Lay

6.1 The length of lay of the respective layers of wires shall be at the option of the manufacturer unless otherwise agreed upon with the purchaser (Explanatory Note 3).

6.2 The direction of lay of the outer layer of wires shall be left hand, unless specified otherwise by the purchaser (Explanatory Note 3).

6.3 The direction of lay shall be reversed in successive layers (Explanatory Note 3).

7. Construction

7.1 The nominal conductor size, number of layers of wires, number, diameter, lay-up of wires, approximate core diameter, and maximum conductor diameter shall conform to the requirements prescribed in Table 1 (Explanatory Note 4).

8. Physical and Electrical Tests

8.1 Tests for the electrical properties of wires composing conductors made from soft or annealed copper wire, bare or coated, shall be made before stranding.

8.2 Tests for the physical properties of soft or annealed copper wire, bare or coated, may be made upon the wires before stranding or upon wires removed from the completed stranded conductor, but need not be made upon both. Care shall be taken to avoid mechanical injury to wire removed from the conductor for the purpose of testing.

8.3 The physical properties of wire when tested before stranding shall conform to the applicable requirements of 11.2.

8.4 The physical properties of wires removed from the completed stranded conductor shall be permitted to vary from the applicable requirements of 11.2 by the following amounts (Explanatory Note 5):

8.4.1 *Average of Results Obtained on All Wires Tested*—The minimum elongation required shall be reduced in numerical value 5 (for example, from 30 to 25 %) from the numerical requirements for the wire before stranding.

8.4.2 *Results Obtained on Individual Wires*—The elongation of individual wires shall be reduced in numerical value 15 from the minimum requirements before stranding (that is, 10 in addition to the 5 allowed in 8.4.1) but in no case shall the elongation of any individual wire be less than 5 %.

8.5 In the event that the requirements prescribed in 8.4.2 are met but those prescribed in 8.4.1 are not met, a retest shall be permitted wherein all wires of the conductor shall be tested for the purpose of final determination of conformance to 8.4.

8.6 Elongation tests to determine compliance shall not be made on the conductor as a unit.

8.7 If a tinning, lead coating, or lead alloy-coating test is required, it shall be made on wires prior to stranding.

9. Density

9.1 For the purpose of calculating mass, cross-sections, and so forth, the density of copper shall be taken as 0.32117 lb/in.^{3}(8.89 g/cm^3) at 20°C (Explanatory Note 6).

10. Mass

10.1 The mass per unit length and electrical resistance of a unit length of stranded conductor are a function of the length of lay. The approximate mass per unit length and electrical resistance may be determined using the standard increments shown in Table 2. When greater accuracy is desired, the increment based on the specific lay of the conductor may be calculated (Explanatory Note 7).

10.2 The approximate mass per unit length of completed conductors are given in Table 3 for information only, and include mass per unit lengths of core calculated on the basis of 437 lb/in.^{2}·1000 ft, using approximate core areas.

11. Requirements for Wires

11.1 The purchaser shall designate the type of wire coating (see 11.2), if any, to be used on the copper wire.

11.2 Before stranding, the copper wire used shall meet all of the requirements of the following specifications that are applicable to its type: Specifications B 3, B 33, and B 189.

12. Variation in Area

12.1 The area of the copper cross-section of the completed conductor shall be not less than 98 % of the calculated area given in Table 1. 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. Alternatively, the cross-section of a condutor may be calculated by the weight method as specified in Test Method B 263. In case of dispute, Test Method B 263 shall be the referee.

TABLE 2 Standard Increments Due to Stranding

Nominal Area of Copper Cross Section, cmils	Increment (Increase) in Mass per Unit Length of Copper Cross Section, %
5 000 000 to 4 000 001	5
4 000 000 to 3 000 001	4
3 000 000 to 750 000	3

TABLE 3 Approximate Areas and Linear Densities of Cored, Annular, Concentric Lay-Stranded Copper Conductors

Nominal Size, cmils	Calculated Area of Copper Cross Section, in.^{2}	Calculated Mass per Unit Length, lb/1000 ft		
		Copper	Core[A]	Total
5 000 000	3.896	15 760	2926	18 690
4 500 000	3.463	14 010	2213	16 220
4 000 000	3.154	12 640	1792	14 430
3 500 000	2.823	11 320	1416	12 740
3 000 000	2.391	9 492	935	10 430
2 500 000	1.954	7 758	797	8 555
2 000 000	1.554	6 168	610	6 778
1 750 000	1.377	5 466	448	5 914
				5 068
1 500 000	1.188	4 714	354	4 127
1 250 000	0.9896	3 928	199	3 304
1 000 000	0.8041	3 192	112	
			79	2 905
900 000	0.7120	2 826	78	2 575
800 000	0.6290	2 497	50	2 362
750 000	0.5826	2 312		

[A] Impregnated manila rope core assumed (see 4.3). For dry core 20 percent should be deducted from these tabular values of weights of cores, with corresponding changes in total weights (Explanatory Note 4).

13. Inspection

13.1 All tests and inspection shall be made at the place of manufacture, unless otherwise especially agreed upon between the manufacturer and the purchaser at the time of purchase. The manufacturer shall afford the inspector representing the purchaser all reasonable facilities, to satisfy him that the material is being furnished in accordance with this specification.

14. Packaging and Package Marking

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

14.2 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 placing the order.

14.3 The net mass, length (or lengths, if more than one length is included in the package), size, kind of conductor, purchase order number, reel number, and any other markings required by the purchase order shall be marked on a tag attached to the end of the conductor inside 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.

15. Keywords

15.1 concentric-lay stranded copper conductor; copper electrical conductor; cored; annular; concentric-lay-stranded; electrical conductor; electrical conductor–copper; stranded copper conductor

EXPLANATORY NOTES

NOTE 1—In this specification cored, annular, concentric-lay-stranded conductor constructions only are specifically designated. Requirements for non-cored constructions will be found in the following specifications: Specifications B 8, B 172, B 173, and B 174.

NOTE 2—For definitions of terms relating to conductors, reference should be made to ANSI C42.35 and Terminology B 354.

NOTE 3—If service applications for conductors of this type are unusual as to flexibility requirements, variation in the construction may be desirable. Details concerning such should be arranged between the manufacturer and the purchaser at the time of placing the order.

NOTE 4—Fiber cores are available in commercial sizes. It has been found impracticable to prescribe fiber cores made to special diameters. It is permissible for the manufacturer to use a fiber core which is slightly oversize or to build up a slightly undersized core with servings of suitable material to bring it up to the diameter required for compliance with 4.2.

NOTE 5—Wires unlaid from conductors manifestly will have different physical properties from those of the wires when prepared for cabling, on account of the deformation brought about by laying and again straightening for test.

NOTE 6—The value of density of copper is in accordance with the International Annealed Copper Standard. The corresponding value at 0°C is 8.90 g/cm^3 (0.32150 lb/in.^{3}). As pointed out in the discussion of this subject in *NBS Handbook 100*, there is no appreciable difference in values of density of harddrawn and annealed copper wire. In calculations involving density it must be borne in mind that the apparent density of coated wire is not 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.

NOTE 7—The increment of linear density 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 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 lay, that is, all wires parallel to the conductor axis. The stranding factor m for the completed stranded conductor is the *numerical average* of the lay 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*.