Designation: B 902 – 04

Standard Specification for Compressed Round Stranded Copper Conductors, Hard, Medium-Hard, or Soft Using Single Input Wire Construction[1]

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1. Scope

1.1 This specification covers stranded conductors made from round copper wires, either uncoated or coated with tin, lead, or lead alloy for general use in insulated conductor assemblies for electrical purposes. These conductors shall be composed of one or more roller shaped or die closed layers of helically laid wires using the single input wire (SIW) methodology. (see Note 1 and Explanatory Note 1)

NOTE 1—Sealed conductors which are intended to prevent longitudinal water propagation and are further covered/insulated, are also permitted within the guidelines of this specification.

1.2 The values stated in inch-pound or SI units are to be regarded separately as standard. The values in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.2.1 For density, resistivity, and temperature, the values stated in SI units are to be regarded as standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

B 1 Specification of Hard-Drawn Copper Wire
B 2 Specification for Medium-Hard-Drawn Copper Wire
B 3 Specification for Soft or Annealed Copper Wire
B 33 Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes
B 189 Specification for Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes[3]
B 193 Test Method for Resistivity of Electrical Conductor Materials
B 246 Specification for Tinned Hard-Drawn and Medium-Hard-Drawn Copper Wire for Electrical Purposes
B 263 Test Method for Determination of Cross-Sectional Area of Stranded Conductors
B 354 Terminology Relating to Uninsulated Metallic Electrical Conductors

2.2 *Other Standard:*[4]

NBS Handbook 100: Copper Wire Tables

3. Classification

3.1 The conductors described in this specification are intended for subsequent insulation or covering. The classification of these conductors is SIW compressed.

4. Ordering Information

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

4.1.1 Quantity of each size,
4.1.2 Conductor size: circular-mil area or AWG (see Section 7),
4.1.3 Class: SIW compressed (see 1.2 and Table 1),
4.1.4 Temper (see 5.3),
4.1.5 Whether coated or uncoated; if coated (see 5.1 and 5.2).
4.1.6 Details of special-purpose lays, if required (see 7.3).
4.1.7 When physical tests shall be made (see 10.2 and 10.3).
4.1.8 Package size (see 16.1).
4.1.9 Lagging, if required (see 16.2).
4.1.10 Special package marking, if required (see Section 16.3), and
4.1.11 Place of inspection (see Section 15).

5. Requirements for Wires

5.1 The purchaser shall designate the type of wire and the kind of coating, if any, to be used in the conductor.

5.2 Before stranding, the copper wire used shall meet all of the requirements of the following specifications of ASTM that are applicable to its type:

5.2.1 Specification B 3,
5.2.2 Specification B 33,
5.2.3 Specification B 2,
5.2.4 Specification B 1,
5.2.5 Specification B 189, and

[1] This specification is under the jurisdiction of ASTM Committee B01 of Electrical Conductors and is the direct responsibility of Subcommittee B01.04 on Conductors of Copper Alloys.

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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] Withdrawn.

[4] Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

TABLE 1 Construction Requirements of Compressed Round SIW Standard Copper Conductors

Compressed Strand Dimensions									
Conductor Size			Minimum Number of Wires	Nominal Diameter of SIW Compressed Conductor, in.	Nominal Diameter of SIW Compressed Conductor, mm.	Mass		DC Resistance at 20°C	
cmils	AWG	mm^2				lb/1000ft	kg/km	Ω/1000ft	Ω/km
5 000 000		2534	217	2.424	61.57	15890	23649	0.00218	0.00715
4 500 000		2280	217	2.300	58.41	14300	21283	0.00242	0.00794
4 000 000		2027	217	2.168	55.07	12590	18738	0.00270	0.00886
3 500 000		1773	169	2.028	51.51	11020	16401	0.00308	0.01010
3 000 000		1520	169	1.878	47.69	9353	13920	0.00365	0.01197
2 500 000		1267	127	1.714	43.54	7794	11600	0.00428	0.01404
2 000 000		1013	127	1.533	38.94	6175	9190	0.00529	0.01735
1 900 000		962.7	127	1.494	37.95	5866	8730	0.00557	0.01827
1 800 000		912.1	127	1.454	36.93	5558	8272	0.00588	0.01929
1 750 000		886.7	127	1.434	36.42	5403	8041	0.00604	0.01981
1 700 000		861.4	127	1.413	35.89	5249	7812	0.00622	0.02040
1 600 000		810.7	127	1.371	34.82	4940	7352	0.00661	0.02168
1 500 000		760.1	90	1.327	33.71	4631	6892	0.00705	0.02312
1 400 000		709.4	90	1.282	32.56	4323	6434	0.00756	0.02480
1 300 000		658.7	90	1.236	31.39	4014	5974	0.00814	0.02670
1 250 000		633.4	90	1.212	30.78	3859	5743	0.00847	0.02778
1 200 000		608.0	90	1.187	30.15	3705	5514	0.00882	0.02893
1 100 000		557.4	90	1.137	28.88	3396	5054	0.00962	0.03155
1 000 000		506.7	53	1.084	27.53	3088	4596	0.0106	0.0348
900 000		456.0	53	1.028	26.11	2779	4136	0.0118	0.3087
800 000		405.4	53	0.969	24.61	2470	3676	0.0132	0.0433
750 000		380.0	53	0.939	23.85	2316	3447	0.0141	0.0462
700 000		354.7	34	0.907	23.04	2161	3216	0.0151	0.0495
650 000		329.4	34	0.874	22.20	2007	2987	0.0163	0.0535
600 000		304.0	34	0.840	21.34	1883	2802	0.0177	0.0581
550 000		278.7	34	0.804	20.42	1698	2527	0.0192	0.0630
500 000		253.4	30	0.766	19.46	1544	2298	0.0212	0.0695
450 000		228.0	30	0.727	18.47	1389	2067	0.0235	0.0771
400 000		202.7	24	0.685	17.40	1235	1838	0.0264	0.0866
350 000		177.3	24	0.641	16.28	1081	16.09	0.3002	0.0991
300 000		152.0	18	0.594	15.09	926.3	1379	0.0353	0.1158
250 000		126.7	18	0.542	13.77	771.9	1149	0.0423	0.1387
211 600	0000	107.2	17	0.498	12.65	653.1	972.0	0.0500	0.1640
167 800	000	85.03	15	0.443	11.25	518.1	771.1	0.0630	0.2066
133 100	00	67.44	12	0.395	10.03	410.9	611.5	0.0795	0.2607
105 600	0	53.51	7	0.352	8.94	325.8	484.9	0.100	0.328
83 690	1	42.41	7	0.313	7.95	258.4	384.6	0.127	0.417
66 360	2	33.63	6	0.283	7.19	204.9	305.0	0.159	0.521
52 620	3	26.66	6	0.252	6.40	162.5	241.8	0.201	0.659
41 740	4	21.15	6	0.225	5.72	128.9	191.8	0.253	0.830
33 090	5	16.77	6	0.200	5.08	102.2	152.1	0.319	1.046
26 240	6	13.30	6	0.178	4.52	81.05	120.6	0.403	1.322
20 820	7	10.55	6	0.159	4.04	64.28	95.67	0.509	1.669
16 510	8	8.366	6	0.142	3.61	50.97	75.86	0.640	2.099
13 090	9	6.633	6	0.126	3.20	40.42	60.16	0.809	2.653
10 380	10	5.260	6	0.113	2.87	32.06	47.71	1.02	3.35
6 530	12	3.309	6	0.089	2.26	20.16	30.00	1.63	5.35
4 110	14	2.083	6	0.071	1.80	12.68	18.87	2.58	8.46
2 580	16	1.307	6	0.054	1.37	7.974	11.87	4.10	13.45
1 620	18	0.8209	6	0.043	1.09	5.015	7.464	6.54	21.45
1 020	20	0.5168	6	0.034	0.86	3.154	4.694	10.3	33.8
640	22	0.3243	6	0.027	0.69	1.992	2.965	16.4	53.8
404	24	0.2047	6	0.022	0.56	1.249	1.859	26.1	85.6

5.2.6 Specification B 246.

5.3 In SIW compressed conductors, the central core shall be made of wire of the same type and temper as the concentric layers, unless otherwise specified.

6. Joints

6.1 Welds and brazes may be made in rods or in wires prior to final drawing. Welds and brazes may be made in the finished individual wires composing the conductor, but shall not be closer together than prescribed in Table 2.

TABLE 2 Minimum Distance Between Joints in Completed Conductor

Number of Wires in Conductor	Hard or Medium-Hard Temper	Soft Temper
3 to 19	50 ft	1 ft
20 to 36	50 ft	1 ft in a layer[A]
37 to 60	25 ft	1 ft in a layer[A]
61 and over	5 ft	1 ft in a layer[A]

[A] Except as indicated, the limitations apply to closeness of joints throughout the completed conductor.

7. Lay

7.1 For stranded conductors, the lay length of a layer of wires shall be not less than 8 nor more than 16 times the outer diameter of the finished conductor. For conductors of 37 wires or more, this requirement shall apply to the wires in the outer two layers only.

7.2 For stranded conductors, the direction of lay of the outer layer shall be left hand and may be reversed or unidirectional/unilay in successive layers, unless otherwise specified by the purchaser.

7.3 Other lays for special purposes shall be furnished by special agreement between the manufacturer and the purchaser (Explanatory Note 3).

8. Construction

8.1 The areas of cross section, minimum number of wires, and diameters of strands for SIW compressed stranded conductors shall conform to the requirements prescribed in Table 1 (Explanatory Note 2).

9. Physical and Electrical Tests of Conductors Stranded of Soft Wires

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

9.2 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 complete 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.

9.3 The physical properties of wire when tested before stranding shall conform to the applicable requirements of 5.2.

9.4 The physical properties of wires removed from the completed stranded conductor shall be permitted to vary from the applicable requirements of 5.2 by the following amounts (Explanatory Note 5):

9.4.1 *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.

9.4.2 *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 9.4.1), but in no case shall the elongation of any individual wire be less than 5 %.

9.5 In the event that the requirements prescribed in 9.4.2 are met but those prescribed in 9.4.1 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 9.4.

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

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

10. Physical and Electrical Tests of Conductors Stranded of Hard-Drawn or Medium-Hard-Drawn Wires

10.1 Tests for the physical and electrical properties of wires composing conductors made from hard-drawn or medium-hard-drawn wires, uncoated or coated, shall be made before but not after stranding.

10.2 At the option of the purchaser, tension and elongation tests on hard-drawn and medium-hard-drawn wires, uncoated or coated, before stranding may be waived, and the completed hard-drawn and medium-hard-drawn conductors may be tested as a unit. The breaking strength of the bare conductors so tested shall be at least 90 % of the total of the specified minimum breaking strengths of the component wires. The maximum breaking strength of conductors made from medium-hard-drawn wires, uncoated or coated, shall be not greater than the sum of the specified maximum breaking strengths of the component wires. The minimum breaking strength of wires shall be calculated using specified nominal diameters and specified minimum tensile strengths. The maximum breaking strengths of wires shall be calculated using nominal diameters and specified maximum tensile strengths. The free length between grips of the test specimen shall be not less than 24 in. (600 mm), and care shall be taken to ensure that the wires in the conductor are evenly gripped during the test (Explanatory Note 4).

10.3 When requested by the purchaser at the time of placing the order, tension tests on hard-drawn and medium-hard-drawn wires, uncoated or coated, before stranding or as a unit may be waived and tests made on wires removed from the completed conductor. The test limits, based on a 10-in. (250-mm) gage length, for such tests shall be specified by the purchaser in the placing of individual orders (Explanatory Note 5).

10.4 If a tinning test is required, it shall be made on the wires prior to stranding.

11. Density

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

12. Mass and Resistance

12.1 The mass and electrical resistance of a unit length of stranded unsealed conductor are a function of the length of lay. The approximate weight 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 (Explanatory Note 7).

12.2 The maximum electrical resistance of a unit length of bare stranded conductor shall not exceed 2 % over the nominal

TABLE 3 Standard Increments Due to Stranding

SIW Compressed Conductor	Increment of Resistance and Mass %
Classes AA[A], B, C, and D, 2000 cmil and under	2
Over 2000 to 3000 cmil	3
Over 3000 to 4000 cmil	4
Over 4000 to 5000 cmil	5

[A] No. 0 AWG and larger.

dc resistance shown in Table 1 (Explanatory Note 8). When dc resistance is measured at other than 20°C, it is to be corrected by using the multiplying factor given in Table 4.

12.3 For conductors to be used in covered or insulated wires or cables, dc resistance measurement may be used in lieu of the method outlined in Section 13 to determine compliance with this specification; however, the referee method shall be that outlined in Section 13.

13. Variation in Area

13.1 The area of cross section of the completed conductor shall be not less than 98 % of the area indicated in Column 1 of Table 1. Unless otherwise specified by the purchaser, the manufacturer may have the option of determining the cross-sectional area by either of the following methods, except that in case of a question regarding area compliance, the method of 13.1.2 shall be used.

13.1.1 The area of cross section of a conductor may be determined by calculations from diameter measurements, expressed to four decimal places, of its component wires at any point when measured perpendicularly to their axes.

13.1.2 The area of cross section of a conductor may be determined by Test Method B 263. In applying that test method, the increment in mass resulting from stranding may be the applicable value specified in 12.1 or may be calculated from the measured component dimensions of the sample under test. In case of questions regarding area compliance, the actual mass increment due to stranding shall be calculated.

TABLE 4 Temperature Correction Factors for Conductor Resistance

Temperature, °C	Resistance Correction Factor 20°C
0	1.085
5	1.063
10	1.041
15	1.020
20	1.000
25	0.981
30	0.962
35	0.944
40	0.927
45	0.911
50	0.895
55	0.879
60	0.864
65	0.850
70	0.836
75	0.822
80	0.809
85	0.797
90	0.784

14. Variation in Diameter

14.1 The average diameter of the conductor shall vary by not more than +1 to –2 % from the nominal diameter specified in Table 1.

15. Inspection

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

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

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

16. Packaging and Package Marking

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

16.2 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 purchase.

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

17. Keywords

17.1 compressed; concentric lay stranded conductors; copper; electrical conductors; reverse concentric lay; single input wire; SIW; SIW compressed; stranded copper conductors; unilay

EXPLANATORY NOTES

NOTE 1—For definitions of terms relating to conductors, refer to Terminology B 354.

NOTE 2—Certain types of insulated conductors may require a shorter lay than other conductors. It is expected that special requirements regarding length of lay will be specified by the purchaser in such instances.

NOTE 3—To test stranded conductors for tensile strength successfully as a unit requires an adequate means of gripping the ends of the test specimen. Various means are available, such as a long tube or socket into which the conductor may be soldered, or in which, after insertion, the conductor may be swaged or pressed without serious distortion. Ordinary jaws or clamping devices usually are not suitable. The conductor testing facilities of many commercial laboratories are limited to a breaking strength of 30 000 lb (133 kN), or less. Consequently, it may not be feasible to test the very large-sized conductors as a unit. Where such is imperative, special arrangements for the testing shall be agreed upon between the manufacturer and the purchaser.

NOTE 4—Wires unlaid from conductors manifestly will have different physical and electrical properties from those of the wire when prepared for cabling on account of the deformation brought about by laying and again straightening for test.

NOTE 5—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 hard-drawn 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 6—The increment of mass or electrical resistance of a complete concentric-lay-stranded conductor, k, in percent is calculated as follows:

$$k = 100\,(m - 1) \tag{1}$$

where:

m = the lay factor and is the ratio of the weight 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 lay 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 lay factor is unity). The lay factor, m_{ind}, for any given wire in a concentric-lay-stranded conductor is

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

where:

n = length of lay/diameter of helical path of wire.

The derivation of the above is given in *NBS Handbook 100*.

NOTE 7—The dc resistance on a given construction shall be calculated using the following formula:

$$R = \left(\frac{k}{100} + 1\right) p/A \tag{3}$$

where:

R = conductor resistance in ohms/1000 ft
k = increment due to stranding from Table 3
p = volume resistivity in ohms.cmil/ft determined in accordance with Test Method B 193
A = cross-sectional area of conductor in kcmil determined in accordance with Section 12 of this specification.