Designation: B 173 – 01

Standard Specification for Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members, for Electrical Conductors[1]

This standard is issued under the fixed designation B 173; 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.

1. Scope

1.1 This specification covers bare rope-lay-stranded conductors having concentric-stranded members made from round 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 Coated wires shall include only those wires with finished diameters and densities substantially equal to the respective diameters and densities of uncoated wires.

1.3 The values stated in inch-pound or SI units are to be regarded separately as standard. Each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. For conductor sizes designated by AWG or kcmil, the requirements in SI units have been numerically converted from corresponding values, stated or derived, in inch-pound units. For conductor sizes designated by SI units only, the requirements are stated or derived in SI units.

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

2. Referenced Documents

2.1 The following documents of the issue in effect at the time of reference form a part of this specification to the extent referenced herein:

2.2 *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 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]

2.3 *American National Standard:*

ANSI C42.35 Definitions of Electrical Terms[3]

3. Classification

3.1 For the purpose of this specification rope-lay-stranded conductors having concentric-stranded members are classified as follows:

3.1.1 *Class G*—Conductors consisting of 7 to 61 rope-lay-stranded members, each of which consists of 7 to 19 concentric-stranded wires, with total conductor sizes ranging from No. 14 AWG (2.08 mm^2) to 5 000 000 cmil (2534 mm^2). (Typical use is for rubber-sheathed conductor, apparatus conductor, portable conductor, and similar applications.)

3.1.2 *Class H*—Conductors consisting of 19 to 91 rope-lay-stranded members, each of which consists of 7 to 19 concentric-stranded wires, with total conductor sizes ranging from No. 9 AWG (6.63 mm^2) to 5 000 000 cmil (2534 mm^2). Class K construction produces a conductor with greater flexibility than class G. (Typical use is for rubber-sheathed cord and applications where flexibility is required such as on take-up reels over sheaves and extra-flexible apparatus conductor.)

4. Ordering Information

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

4.1.1 Quantity of each size and class,

4.1.2 Conductor size: circular-mil area or AWG (Section 7),

4.1.3 Class (Section 3 and Table 1),

4.1.4 Whether coated or uncoated; if coated, designate type of coating (see 11.1),

4.1.5 Details of special-purpose lays, if required (see 6.2 and 6.3) and (Explanatory Note 3),

4.1.6 Package size (see 14.1),

4.1.7 Special package marking, if required (Section 15),

4.1.8 Lagging, if required (see 14.2), and

4.1.9 Place of inspection (Section 13).

[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, 11 West 42nd St., 13th Floor, New York, NY 10036.

TABLE 1 Construction Requirements of Rope-Lay Stranded Copper Conductors Having Concentric-Stranded Members[A]

Area of Cross Section		Size AWG	Class G								Class H							
			Number of Wires	Diameter of Wires		Number of Wires in Each Member	Completed Conductor[B]				Number of Wires	Diameter of Wires		Number of Wires in Each Member	Completed Conductor[B]			
							Nominal Diameter		Nominal Mass						Nominal Diameter		Nominal Mass	
cmil	mm			in.	mm		in	mm	lb/1000 ft.	kg/km		in.	mm		in.	mm	lb/1000 ft.	kg/km
5 000 000	2534	...	1159	0.0657	1.67	19	2.957	75.1	16 052	23 888	1729	0.0538	1.37	19	2.959	75.2	16 057	23 896
4 500 000	2280	...	1159	0.0623	1.58	19	2.804	71.2	14 433	21 479	1729	0.0510	1.30	19	2.805	71.2	14 429	21 473
4 000 000	2027	...	1159	0.0587	1.49	19	2.642	67.1	12 814	19 069	1729	0.0481	1.22	19	2.646	67.2	12 835	19 101
3 500 000	1773	...	1159	0.0550	1.40	19	2.475	62.9	11 249	16 741	1729	0.0450	1.14	19	2.475	62.9	11 234	16 718
3 000 000	1520	...	1159	0.0509	1.29	19	2.291	58.2	9635	14 338	1729	0.0417	1.06	19	2.294	58.3	9647	14 356
2 500 000	1267	...	703	0.0596	1.51	19	2.086	53.0	8012	11 924	1159	0.0464	1.18	19	2.088	53.0	8006	11 915
2 000 000	1013	...	703	0.0533	1.35	19	1.866	47.4	6408	9536	1159	0.0415	1.05	19	1.868	47.4	6405	9531
1 900 000	963	...	703	0.0520	1.32	19	1.820	46.2	6099	9077	1159	0.0405	1.03	19	1.823	46.3	6100	9077
1 800 000	912	...	703	0.0506	1.29	19	1.771	45.0	5775	8594	1159	0.0394	1.00	19	1.773	45.0	5773	8591
1 750 000	887	...	703	0.0499	1.27	19	1.747	44.4	5617	8358	1159	0.0389	0.99	19	1.751	44.5	5627	8374
1 700 000	861	...	703	0.0492	1.25	19	1.722	43.7	5460	8125	1159	0.0383	0.97	19	1.724	43.8	5455	8118
1 600 000	811	...	703	0.0477	1.21	19	1.670	42.4	5132	7638	1159	0.0372	0.94	19	1.674	42.5	5146	7658
1 500 000	760	...	427	0.0593	1.51	7	1.601	40.7	4772	7102	703	0.0462	1.17	19	1.617	41.1	4815	7165
1 400 000	709	...	427	0.0573	1.46	7	1.547	39.3	4456	6631	703	0.0446	1.13	19	1.561	39.6	4487	6677
1 300 000	659	...	427	0.0552	1.40	7	1.490	37.8	4135	6154	703	0.0430	1.09	19	1.505	38.2	4171	6207
1 250 000	633	...	427	0.0541	1.37	7	1.461	37.1	3972	5911	703	0.0422	1.07	19	1.477	37.5	4017	5978
1 200 000	608	...	427	0.0530	1.35	7	1.431	36.3	3812	5673	703	0.0413	1.05	19	1.446	36.7	3847	5726
1 100 000	557	...	427	0.0508	1.29	7	1.372	34.8	3502	5212	703	0.0396	1.01	19	1.386	35.2	3537	5264
1 000 000	507	...	427	0.0484	1.23	7	1.307	33.2	3179	4731	703	0.0377	0.96	19	1.320	33.5	3206	4771
900 000	456	...	427	0.0459	1.17	7	1.239	31.5	2859	4255	703	0.0358	0.91	19	1.253	31.8	2891	4302
800 000	405	...	427	0.0433	1.10	7	1.169	29.7	2544	3787	703	0.0337	0.86	19	1.180	30.0	2562	3812
750 000	380	...	427	0.0419	1.06	7	1.131	28.7	2383	3546	703	0.0327	0.83	19	1.145	29.1	2412	3589
700 000	355	...	427	0.0405	1.03	7	1.094	27.8	2226	3313	703	0.0316	0.80	19	1.106	28.1	2252	3352
650 000	329	...	427	0.0390	0.99	7	1.053	26.7	2064	3072	703	0.0304	0.77	19	1.064	27.0	2085	3102
600 000	304	...	427	0.0375	0.95	7	1.013	25.7	1908	2840	703	0.0292	0.74	19	1.022	26.0	1923	2862
550 000	279	...	427	0.0359	0.91	7	0.969	24.6	1749	2603	703	0.0280	0.71	19	0.980	24.9	1768	2632
500 000	253	...	259	0.0439	1.12	7	0.922	23.4	1579	2350	427	0.0342	0.87	7	0.923	23.4	1587	2362
450 000	228	...	259	0.0417	1.06	7	0.876	22.3	1425	2120	427	0.0325	0.83	7	0.878	22.3	1433	2133
400 000	203	...	259	0.0393	1.00	7	0.825	21.0	1265	1883	427	0.0306	0.78	7	0.826	21.0	1271	1891
350 000	177	...	259	0.0368	0.93	7	0.773	19.6	1109	1651	427	0.0286	0.73	7	0.772	19.6	1110	1652
300 000	152	...	259	0.0340	0.86	7	0.714	18.1	947	1409	427	0.0265	0.67	7	0.716	18.2	953	1418
250 000	127	...	259	0.0311	0.79	7	0.653	16.6	792	1179	427	0.0242	0.61	7	0.653	16.6	795	1183
211 600	107	0000	133	0.0399	1.01	7	0.599	15.2	667	992	259	0.0286	0.73	7	0.601	15.3	670	997
167 800	85.0	000	133	0.0355	0.90	7	0.533	13.5	528	785	259	0.0255	0.65	7	0.536	13.6	533	793
133 100	67.4	00	133	0.0316	0.80	7	0.474	12.0	418	622	259	0.0227	0.58	7	0.477	12.1	422	628
105 600	53.5	0	133	0.0282	0.72	7	0.423	10.7	333	495	259	0.0202	0.51	7	0.424	10.8	334	497
83 690	42.4	1	133	0.0251	0.64	7	0.377	9.58	264	393	259	0.0180	0.46	7	0.378	9.60	265	395
66 360	33.6	2	49	0.0368	0.93	7	0.331	8.41	207	308	259	0.0160	0.41	7	0.335	8.51	210	312
52 620	26.7	3	49	0.0328	0.83	7	0.295	7.49	164	245	133	0.0199	0.51	7	0.299	7.59	166	247
41 740	21.1	4	49	0.0292	0.74	7	0.263	6.68	130	194	133	0.0177	0.45	7	0.266	6.76	131	195
33 090	16.8	5	49	0.0260	0.66	7	0.234	5.94	103	154	133	0.0158	0.40	7	0.237	6.02	105	156
26 240	13.3	6	49	0.0231	0.59	7	0.208	5.28	81.5	121	133	0.0140	0.36	7	0.210	5.33	82.1	122
20 820	10.5	7	49	0.0206	0.52	7	0.185	4.70	64.8	96.5	133	0.0125	0.32	7	0.188	4.78	65.4	97.4
16 510	8.37	8	49	0.0184	0.47	7	0.166	4.22	51.7	77.0	133	0.0111	0.28	7	0.167	4.24	51.6	76.8
13 090	6.63	9	49	0.0163	0.41	7	0.148	3.76	40.6	60.4	133	0.0099	0.25	7	0.149	3.78	41.0	61.1
10 380	5.26	10	49	0.0146	0.37	7	0.131	3.33	32.6	48.5								
6530	3.31	12	49	0.0115	0.29	7	0.104	2.64	20.2	30.1								
4110	2.08	14	49	0.0092	0.23	7	0.083	2.11	12.9	19.2								

[A] The constructions shown in this table are typical of those used in the industry. It is not intended that this table preclude other constructions using the same total number of wires which may be desirable for specific applications. The constructions shown provide for a finished, non-covered, stranded conductor approximately of the area indicated. When specified by the purchaser, the number or size of wires may be increased to provide additional area to compensate for draw-down during subsequent processing.

[B] Values for the nominal diameter and mass of the completed conductor are approximate. The mass values are based upon the standard stranding increments listed in Explanatory Note 6.

5. Joints

5.1 Necessary joints in wires or in groups of wires shall be made in accordance with accepted commerical practice, taking into account the size of the wire or group of wires as related to the size of the entire conductor.

5.2 Concentric-stranded members forming the completed conductor may be joined as a unit by soldering, brazing, or welding.

5.3 Joints shall be so constructed and so disposed throughout the conductor that the diameter or configuration of the completed conductor is not substantially affected, and so that the flexibility of the completed conductor is not adversely affected.

6. Lay (Explanatory Note 3)

6.1 Conductors of the same size and description furnished on one order shall have the same lay.

6.2 The length of lay of the outer layer of the rope-lay stranded conductor shall be not less than 8 nor more than 16 times the outside diameter of the completed conductor. The

length of lay of the other layers shall be at the option of the manufacturer unless specifically agreed upon. The direction of lay of the outer layer shall be left-hand, unless the direction of lay is specified otherwise by the purchaser. The direction of lay of the other layers shall be reversed in successive layers, unless otherwise agreed upon between the manufacturer and the purchaser.

6.3 The length of lay of the individual wires composing the stranded members shall be not less than 8 nor more than 16 times the outside diameter of that layer. Unless otherwise specified, the direction of lay of the outer layer of wires shall be at the option of the manufacturer. The direction of lay shall be reversed in successive layers, unless otherwise agreed upon between the manufacturer and the purchaser.

7. Construction

7.1 The area of cross section and the number and diameter of wires for a variety of strand constructions in general use are shown in Table 1.

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 conductors, but need not be made upon both. Care shall be taken to avoid mechanical injury and stretching when removing wires 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 11.1.

8.4 The physical properties of wires removed from the completed stranded conductor shall be permitted to vary from the applicable requirements of 11.1 by the following amounts: (Explanatory Note 4):

8.4.1 *Average of Results Obtained on All Wires Tested*—The percent minimum elongation may be reduced by the value of 5 % from the values required for unstranded wires as specified by Specifications B 3, B 33, or B 189, as applicable. For example, where the unstranded wire specification requires minimum elongation of 30 %, wire of that material removed from Specification B 173 stranded conductor shall meet a minimum elongation value of 25 %, a value 5 % reduction.

8.4.2 *Results Obtained on Individual Wires*—The percent minimum elongation may be reduced by the value of 15 % from the values required for unstranded wires as specified by Specifications B 3, B 33, or B 189, as applicable. For example, where the unstranded wire specification requires minimum elongation of 30 %, wire of that material removed from Specification B 173 stranded conductor shall meet a minimum elongation value of 15 %. If the reduction results in minimum elongation of less than 5 %, a minimum of 5 % shall apply.

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 a conductor of 100 wires or less, or 100 wires selected at random throughout a conductor of more than 100 wires shall be tested for the purpose of final determination for 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 the wires prior to stranding.

9. Density

9.1 For the purpose of calculating mass, cross sections, etc., the density of copper shall be taken as 8.89 g/cm ^{3} (0.32117 lb/in.^{3}) at 20°C (Explanatory Note 5).

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 Explanatory Note 6. When greater accuracy is desired, the increment based on the specific lay of the conductor may be calculated (Explanatory Note 7).

11. Requirements for Wires

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

11.1.1 Before stranding, uncoated wire shall meet the requirements of Specification B 3.

11.1.2 Before stranding, tinned wire shall meet the requirements of Specification B 33.

11.1.3 Before stranding, lead coated and lead-alloy coated wire shall meet the requirements of Specification B 189.

11.2 These requirements shall not prohibit the manufacture of conductors from uncoated hard-drawn wires which are annealed after stranding.

12. Variation in Area

12.1 The calculated area of cross section of a stranded conductor expressed in circular mils shall be the product of the square of the specified diameter in mils of the individual wires times the number of wires prescribed (Note 1).

NOTE 1—The calculated area of such cables as may incorporate more than one size of component wires should be the sum of the areas of the different sizes of wires.

12.2 The area of cross section of a completed stranded conductor designated as an AWG size shall be not less than 98 % of the area indicated in Column 1 of Table 1 for sizes 211 600 cmil (107 mm^2) and smaller. The area of cross section of a completed stranded conductor not designated as an AWG size shall be not less than 98 % of a calculated value obtained as prescribed in 10.1

12.3 The area of cross section of a conductor shall be determined by Test Method B 263. In applying this method, the increment of linear density resulting from stranding may be the applicable value listed in Explanatory Note 6 or may be calculated from the measured component dimensions of the sample under test. In case of question regarding area compliance, the actual linear density increment due to stranding shall be calculated

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, without charge, 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 purchase.

15. Marking

15.1 The net mass, length (or 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.

16. Keywords

16.1 copper electrical conductor; electrical conductor—copper; rope-lay-stranded copper conductors; stranded copper conductor

EXPLANATORY NOTES

NOTE 1—In this specification only rope-lay-stranded conductors constructed with concentric-stranded members are designated. Requirements for rope-lay-stranded conductors constructed with *bunch-stranded* members will be found in Specification B 172. Requirements for concentric-lay-stranded conductors will be found in Specification B 8.

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

NOTE 3—Certain types of insulated conductors may require a shorter lay than other conductors. It is expected that departures from the provisions of this specification because of special requirements relative to length of lay, direction of lay, and direction of lay of successive layers will be agreed upon by the manufacturer and the purchaser.

NOTE 4—Wires removed from stranded conductors and straightened for tests will have altered physical properties due to cold working of the material. The reduced elongation requirement for wires removed from stranded conductors reflects this condition.

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}). Density calculations involving coated wire should consider the variation of coated wire density from the density of uncoated copper wire. The relative affect of the coating density on the overall wire density becomes greater as wire diameters decrease.

NOTE 6—The following values approximate the incremental increase in mass and the incremental decrease in resistance of rope-lay stranded conductor as a result of stranding. The values are sufficiently accurate for most purposes and may be used when more precise values are not available. They are as follows:

Construction	Increment of Linear Density and Resistance, %
Rope-lay-stranded conductors (Classes G and H):	
49 wires or less	3
133 wires	4
259 wires	4.5
427 wires	5
Over 427 wires	6

NOTE 7—Any calculation of the increment of mass or electrical resistance, *k*, of a rope-lay-stranded conductor involves two independent calculations:

(1) Determination of the increment due to stranding of the individual members, and

(2) Determination of the increment due to twisting these members to form the completed conductor.

In the case of a rope-lay-stranded conductor having concentric-stranded members, the increment *k*, in percent, may be expressed as:

$$k = k_m + k_a + k_m k_a /100$$

where:

k_m = is the increment of mass or electrical resistance, in percent, of an individual concentric-stranded member before twisting into the completed conductor, calculated as described in Specification B 8, Note 9

k_a = is the increment of mass or electrical resistance, in percent, due to twisting the concentric-stranded members into the completed conductor, calculated as described in Specification B 8, Note 9, with each member considered as an individual wire.