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.

Designation: B229 – 12 (Reapproved 2017)

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

This standard is issued under the fixed designation B229; 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 concentric-lay-stranded conductors made from uncoated hard-drawn round copper wires in combination with hard-drawn round copper-clad steel wires for general use as overhead electrical conductors.

1.2 For the purpose of this specification, conductors are classified under the following type designations (see Fig. 1):

Type A	Type G
Type C	Type J
Type D	Type K
Type E	Type N
Type EK	Type P
Type F	Type V

1.3 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.

1.4 *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 *ASTM Standards:*[2]

B1 Specification for Hard-Drawn Copper Wire
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

2.2 *ANSI Standard:*

C 42 Definitions of Electrical Terms[3]

2.3 *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 type;

3.1.2 Conductor size: hard-drawn copper equivalent in circular-mil area or AWG (Section 7 and Table 1);

3.1.3 Type (see 1.2, Fig. 1, 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 section 8.2);

3.1.6 Package size (see 14.1);

3.1.7 Special package marking, if required (Section 15);

3.1.8 Lagging, if required (see 14.2); and

3.1.9 Place of inspection (Section 13).

4. Material for Wires

4.1 The purchaser shall designate the size and type of conductor to be furnished. The position of the hard-drawn copper wires and the copper-clad steel wires in the conductor cross section shall be as shown in Fig. 1.

4.2 Before stranding, the wire used shall meet the requirements of Specifications B1 and B227 that are applicable to its type.

5. Joints

5.1 *Copper*—Welds and brazes may be made in copper rods or in copper wires prior to final drawing. Joints may not be made in the finished copper wires composing concentric-lay-stranded composite conductors containing a total of seven wires or less. In other conductors, welds and brazes may be made in the finished individual copper wires composing the

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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.

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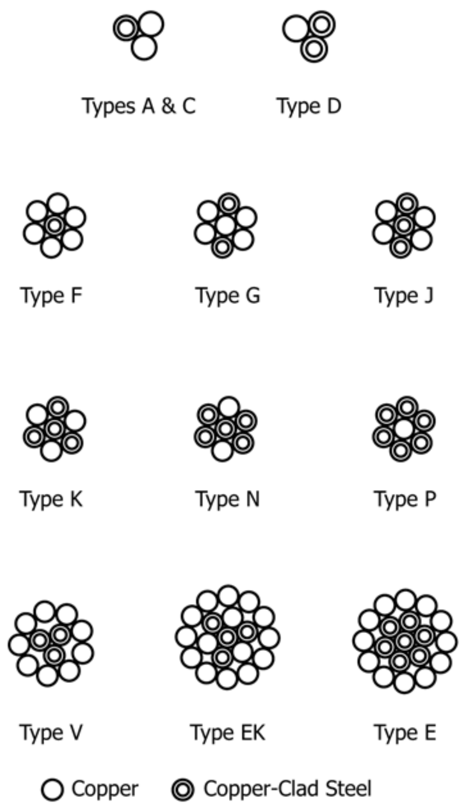

FIG. 1 Standard Types of Composite Conductors

conductor, but shall be not closer than 50 ft (15 m) to any other joint in the same layer in the conductor.

5.2 *Copper-Clad Steel*—Joints or splices may be made in the finished individual copper-clad steel wires composing concentric-lay-stranded conductors, 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 (Explanatory Note 1).

6. Lay

6.1 For Types A, C, and D conductors, the preferred lay is approximately 16.5 times the outside diameter of the completed conductor, but shall be not less than 13 nor more than 20 times this diameter.

6.2 For all other types, the preferred lay of a layer of wires is 13.5 times the outside diameter of that layer, but shall be not 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 successive 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 wires in the various types of concentric-lay-stranded composite conductors shall conform to the requirements prescribed in Table 1 (Explanatory Note 2).

8. Physical and Electrical Tests

8.1 Tests for the physical and electrical properties of wires composing concentric-lay-stranded composite conductors shall be made before but not after stranding.

8.2 At the option of the purchaser or his representative, tension and elongation tests on wires before stranding may be waived, and the completed conductor may be tested as a unit. The breaking strength of the conductors so tested shall be not less than the rated strength values shown in Table 2. The free length between grips of the test specimen shall be not less than 24 in. (0.61 m), and care shall be taken to ensure that the wires in the conductor are evenly gripped during the test (Explanatory Note 3).

9. Density

9.1 For the purpose of calculating weights, cross sections, and so forth, the density of the copper shall be taken as 8.89 g/cm^3 at 20°C (Explanatory Note 4 and Table 2).

9.2 The density of both types of copper-clad-steel wire shall be taken as stated 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 (Explanatory Note 6). Reference information is shown in Table X1.1 in Appendix X1.

11. Variation in Area

11.1 The area of cross section of the completed conductor shall be not less than 97 % of the nominal area. 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 point when measured perpendicularly to their axes (Explanatory Note 8). For the purposes of determining conformance to this standard, a measured or calculated value for cross sectional area shall be rounded to four significant figures in accordance with the rounding method of Practice E29.

12. Finish

12.1 The conductor shall be free of all imperfections not consistent with the best commercial practice.

13. Inspection

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

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

NOTE 1—*Metric Equivalents*—For conductor size, 1 cmil = 0.0005067 mm^2 (round to four significant figures); for diameter 1 mil = 0.02540 mm (round to four significant figures); for breaking strength, 1 lb = 0.45359 kg (round to four significant figures).

Conductor Size, Hard-Drawn Copper Equivalent[A]		Type	Grade 30 EHS Copper-Clad Steel Wires		Hard-Drawn Copper Wires		Rated Breaking Strength, min, lb[B]
cmil	AWG		Number of Wires	Diameter of Wires, mils	Number of Wires	Diameter of Wires, mils	
350 000	. . .	E	7	157.6	12	157.6	32 420
350 000	. . .	EK	4	147.0	15	147.0	23 850
350 000	. . .	V	3	175.1	9	189.3	23 480
300 000	. . .	E	7	145.9	12	145.9	27 770
300 000	. . .	EK	4	136.1	15	136.1	20 960
300 000	. . .	V	3	162.1	9	175.2	20 730
250 000	. . .	E	7	133.2	12	133.2	23 920
250 000	. . .	EK	4	124.2	15	124.2	17 840
250 000	. . .	V	3	148.0	9	160.0	17 420
211 600	0000	E	7	122.5	12	122.5	20 730
211 600	0000	G	2	194.4	5	194.4	15 640
211 600	0000	EK	4	114.3	15	114.3	15 370
211 600	0000	V	3	136.1	9	147.2	15 000
211 600	0000	F	1	183.3	6	183.3	12 290
167 800	000	E	7	109.1	12	109.1	16 800
167 800	000	J	3	185.1	4	185.1	16 170
167 800	000	G	2	173.1	5	173.1	12 860
167 800	000	EK	4	101.8	15	101.8	12 370
167 800	000	V	3	121.2	9	131.1	12 200
167 800	000	F	1	163.2	6	163.2	9980
133 100	00	K	4	178.0	3	178.0	17 600
133 100	00	J	3	164.8	4	164.8	13 430
133 100	00	G	2	154.2	5	154.2	10 510
133 100	00	V	3	108.0	9	116.7	9846
133 100	00	F	1	145.4	6	145.4	8094
105 600	0	K	4	158.5	3	158.5	14 490
105 600	0	J	3	146.7	4	146.7	10 970
105 600	0	G	2	137.3	5	137.3	8563
105 600	0	F	1	129.4	6	129.4	6536
83 690	1	N	5	154.6	2	154.6	15 410
83 690	1	K	4	141.2	3	141.2	11 900
83 690	1	J	3	130.7	4	130.7	9000
83 690	1	G	2	122.2	5	122.2	6956
83 690	1	F	1	115.3	6	115.3	5266
66 360	2	P	6	154.0	1	154.0	16 870
66 360	2	N	5	137.7	2	137.7	12 680
66 360	2	K	4	125.7	3	125.7	9730
66 360	2	J	3	116.4	4	116.4	7322
66 360	2	A	1	169.9	2	169.9	5876
66 360	2	G	2	108.9	5	108.9	5626
66 360	2	F	1	102.6	6	102.6	4233
52 620	3	P	6	137.1	1	137.1	13 910
52 620	3	N	5	122.6	2	122.6	10 390
52 620	3	K	4	112.0	3	112.0	7910
52 620	3	J	3	103.6	4	103.6	5955
52 620	3	A	1	151.3	2	151.3	4810
41 740	4	P	6	122.1	1	122.1	11 420
41 740	4	N	5	109.2	2	109.2	8460
41 740	4	D	2	161.5	1	161.5	7340
41 740	4	A	1	134.7	2	134.7	3938
33 090	5	P	6	108.7	1	108.7	9311
33 090	5	D	2	143.8	1	143.8	6035
33 090	5	A	1	120.0	2	120.0	3193
26 240	6	D	2	128.1	1	128.1	4942
26 240	6	A	1	106.8	2	106.8	2585
26 240	6	C	1	104.6[C]	2	104.6	2143
20 820	7	D	2	114.1	1	114.1	4022
20 820	7	A	1	126.6	2	89.5	2754

TABLE 1 *Continued*

Conductor Size, Hard-Drawn Copper Equivalent[A] cmil	AWG	Type	Grade 30 EHS Copper-Clad Steel Wires: Number of Wires	Diameter of Wires, mils	Hard-Drawn Copper Wires: Number of Wires	Diameter of Wires, mils	Rated Breaking Strength, min, lb[B]
16 510	8	D	2	101.6	1	101.6	3256
16 510	8	A	1	112.7	2	79.7	2233
16 510	8	C	1	80.8[C]	2	83.4	1100
11 750	9½	D	2	80.8[C]	1	80.8	1330

[A] See Explanatory Note 7.
[B] See Explanatory Note 11.
[C] Grade 40 HS (all of the other CCS wire is Grade 30 EHS).

TABLE 2 Density of Copper and Copper-Clad Steel

Units	Density at 20°C		
	Copper	30 % Copper-Clad Steel	40 % Copper-Clad Steel
Grams per cubic centimetre	8.89	8.15	8.24
Pounds per cubic inch	0.3212	0.2944	0.2975
Pounds per circular mil-foot	0.0000030270	0.0000027750	0.0000028039

TABLE 3 Standard Increments Due to Stranding

Type of Conductor	Increment (Increase) of Resistance and Weight, %
A, C, and D	0.8
F, G, J, K, N, and P	1.0
V	1.2
E and EK	1.4

13.2 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.

13.3 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.

14. Packaging and Shipping

14.1 Package sizes for conductors shall be agreed upon by the manufacturer and the purchaser in the placing of individual orders (Explanatory Note 9).

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, and number of lengths, if more than one length is included in the package), size, type 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 composite conductors; concentric-lay-stranded copper conductor; copper-clad steel conductor; copper electrical conductor; electrical conductor; electrical conductor—copper; stranded copper conductor

EXPLANATORY NOTES

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 then is protected from corrosion with one of two approaches:

(1) A snug-fitting seamless copper sleeve that extends at least ⅜ in. (9.5 mm) on each side of the weld and that 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 silver solder that extends at least ⅜ in. (9.5 mm) on each side of the weld.

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 only slightly larger than the wire itself and is applicable for 7-wire composite conductors (except Types F and G) and for 12- and 19-wire composite 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 wire size. Their use is usually limited to 3-wire conductors where the relatively large diameter is not objectionable although they may be used also in Type F conductors. This joint develops the full strength of the wire.

NOTE 2—For definitions of terms relating to conductors, reference should be made to (*1*) ANSI C42.35- latest revision and (*2*) Terminology B354.

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 conductors 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 (13.6 Mg) 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—The value of density of copper is in accordance with the International Annealed Copper Standard. As pointed out in the discussion of this subject in *NBS Handbook 100* of the National Institute of Standards and Technology,[4] there is no appreciable difference in values of density of hard-drawn and annealed copper wire. Equivalent expressions of density at 20°C are given in Table 3.

NOTE 5—The value of density of copper-clad steel is an average value that has been found to be in accordance with usual values encountered in practice. Equivalent expressions of density at 20°C are given in Table 3.

NOTE 6—The increment of mass or electrical resistance of a completed concentric-lay-stranded conductor (k) in percent is calculated as follows:

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

where m is the lay 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 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 calculated as follows:

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

where:

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

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

NOTE 7—Hard-drawn copper equivalent is the area of a hard-drawn copper cable having the same dc resistance at 20°C as that of the composite cable.

NOTE 8—For the convenience of the users of this specification, Appendix X1 has been prepared giving the approximate diameters, areas, resistances per 1000 ft, and mass per 1000 ft and per mile, of the various constructions referred to in Table 1.

NOTE 9—It is of some importance that hard-drawn conductors be placed on reels having drum diameters sufficiently large that the bending will not unduly modify the physical properties of the completed conductor.

NOTE 10—The term "mass per unit length" is used in this specification as being more technically correct, replacing the term "weight."

NOTE 11—Identified Minimum Rated Breaking Strength in Table 1 are determined by: Breaking load of 7-wire, 12-wire and 19-wire strands are taken as 90 % of the sum of the breaking loads of the individual wires at the minimum tensile and nominal diameter; breaking load of 3-wire strand is taken as 95 % of the sum of the breaking loads of the individual wires at the minimum tensile and nominal diameter.

APPENDIX

(Nonmandatory Information)

X1. Diameters, Areas, Mass, and Resistances of Concentric-Lay-Stranded Composite Conductors

TABLE X1.1

NOTE 1—*Metric Equivalents*—For conductor size, 1 cmil = 0.0005067 mm^2 (round to four significant figures): for nominal diameter, 1 in. = 25.40 mm (round to four significant figures); for area, 1 in.^{2} = 645.16 mm^2 (round to four significant figures); for mass, 1 lb/1000 ft = 1.48816 kg/km (round to four significant figures); for resistance 1 ohm/1000 ft = 3.281 ohm/km (round to four significant figures).

Conductor Size, Hard-Drawn Copper Equivalent[A]		Type	Nominal Diameter of Conductor, in.	Actual Area of Conductor		Mass Unit Length, lb		DC Resistance ohms/1000 ft at 20°C
cmil	AWG			cmil	in.^{2}	per 1000 ft	per mile	
350 000	. . .	E	0.788	471 900	0.3706	1404	7414	0.03143
350 000	. . .	EK	0.735	410 600	0.3225	1238	6537	0.03143
350 000	. . .	V	0.754	414 500	0.3255	1246	6581	0.03143
300 000	. . .	E	0.729	404 400	0.3177	1203	6354	0.03667
300 000	. . .	EK	0.680	351 900	0.2764	1061	5604	0.03667
300 000	. . .	V	0.698	355 100	0.2789	1068	5637	0.03667
250 000	. . .	E	0.666	337 100	0.2648	1003	5296	0.04400
250 000	. . .	EK	0.621	293 100	0.2302	883.9	4667	0.04400
250 000	. . .	V	0.637	296 100	0.2326	890.4	4701	0.04400
211 600	0000	E	0.613	285 100	0.2239	848.3	4479	0.05199
211 600	0000	G	0.583	264 500	0.2078	789.6	4169	0.05199
211 600	0000	EK	0.571	248 200	0.1950	748.6	3952	0.05199
211 600	0000	V	0.586	250 600	0.1968	753.5	3978	0.05199
211 600	0000	F	0.550	235 200	0.1847	710.5	3752	0.05199
167 800	000	E	0.545	226 200	0.1776	672.9	3553	0.06556
167 800	000	J	0.555	239 800	0.1884	707.1	3733	0.06556
167 800	000	G	0.519	209 700	0.1647	626.0	3305	0.06556
167 800	000	EK	0.509	196 900	0.1546	593.8	3135	0.06556
167 800	000	V	0.522	198 800	0.1561	597.6	3155	0.06556
167 800	000	F	0.490	186 400	0.1464	563.2	2974	0.06556
133 100	00	K	0.534	221 800	0.1742	645.8	3410	0.08265
133 100	00	J	0.494	190 100	0.1493	560.5	2959	0.08265
133 100	00	G	0.463	166 400	0.1307	496.8	2623	0.08265

TABLE X1.1 *Continued*

Conductor Size, Hard-Drawn Copper Equivalent[A] cmil	AWG	Type	Nominal Diameter of Conductor, in.	Actual Area of Conductor cmil	in.^{2}	Mass Unit Length, lb per 1000 ft	per mile	DC Resistance ohms/1000 ft at 20°C
133 100	00	V	0.465	157 600	0.1237	473.8	2501	0.08265
133 100	00	F	0.436	148 000	0.1162	447.1	2361	0.08265
105 600	0	K	0.475	175 900	0.1381	512.0	2704	0.1043
105 600	0	J	0.440	150 600	0.1183	444.1	2345	0.1043
105 600	0	G	0.412	132 000	0.1036	393.8	2080	0.1043
105 600	0	F	0.388	117 200	0.09206	354.1	1870	0.1043
83 690	1	N	0.464	167 300	0.1314	481.1	2540	0.1315
83 690	1	K	0.423	139 600	0.1096	406.4	2146	0.1315
83 690	1	J	0.392	119 600	0.09392	352.5	1861	0.1315
83 690	1	G	0.367	104 500	0.08210	312.0	1647	0.1315
83 690	1	F	0.346	93 060	0.07309	281.1	1484	0.1315
66 360	2	P	0.462	166 000	0.1304	471.3	2488	0.1658
66 360	2	N	0.413	132 700	0.1042	381.6	2015	0.1658
66 360	2	K	0.377	110 600	0.08687	322.0	1700	0.1658
66 360	2	J	0.349	94 840	0.07449	279.6	1476	0.1658
66 360	2	A	0.366	86 600	0.06801	256.9	1356	0.1658
66 360	2	G	0.327	83 010	0.06520	247.6	1308	0.1658
66 360	2	F	0.308	73 690	0.05787	222.6	1175	0.1658
52 620	3	P	0.411	131 600	0.1033	373.5	1972	0.2090
52 620	3	N	0.368	105 200	0.08264	302.5	1597	0.2090
52 620	3	K	0.336	87 810	0.06896	255.7	1350	0.2090
52 620	3	J	0.311	75 130	0.05901	221.5	1170	0.2090
52 620	3	A	0.326	68 680	0.05394	203.7	1076	0.2090
41 740	4	P	0.366	104 400	0.08196	296.3	1564	0.2636
41 740	4	N	0.328	83 470	0.06556	240.0	1267	0.2636
41 740	4	D	0.348	78 250	0.06145	225.9	1193	0.2636
41 740	4	A	0.290	54 430	0.04275	161.5	852.6	0.2636
33 090	5	P	0.326	82 710	0.06496	234.8	1240	0.3291
33 090	5	D	0.310	62 040	0.04872	179.1	945.8	0.3291
33 090	5	A	0.258	43 200	0.03393	128.2	676.7	0.3291
26 240	6	D	0.276	49 230	0.03866	142.1	750.5	0.4150
26 240	6	A	0.230	34 220	0.02688	101.5	536.0	0.4150
26 240	6	C[B]	0.225	32 820	0.02578	97.89	516.9	0.4150
20 820	7	D	0.246	39 060	0.03067	112.8	595.4	0.5232
20 820	7	A	0.223	32 040	0.02517	93.71	494.8	0.5232
16 510	8	D	0.219	30 970	0.02432	89.42	472.1	0.6598
16 510	8	A	0.199	25 400	0.01995	74.29	392.3	0.6598
16 510	8	C[B]	0.179	20 430	0.01604	61.02	322.2	0.6598
11 750	9½	D[B]	0.174	19 590	0.01539	56.94	300.6	0.9170

[A] See Explanatory Note 7.
[B] Grade 40 HS (all other CCS wires are Grade 30 EHS). Also noted below Table 1.

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