Designation: B 787/B 787M – 0~~0~~1

Standard Specification for 19 Wire Combination Unilay-Stranded Copper Conductors for Subsequent Insulation[1]

This standard is issued under the fixed designation B 787/B 787M; 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 combination unilay-stranded conductors made from round copper wires, either uncoated or coated with tin or lead alloy for insulated conductors for electrical purposes. These conductors shall be constructed with a central core wire surrounded by two layers of helically laid wires, resulting in an outer diameter equal to the compressed-stranded equivalent conductor. (See Explanatory Note 1 and Note 2).

NOTE 1—For the purpose of this specification, combination unilay conductor is defined as follows: a central core wire surrounded by a layer of six helically laid wires of the same diameter as the core wire with a helically laid outer layer containing six smaller wires alternated between six wires of the same diameter as the wires in the layer underneath. Both layers have a common length and direction of lay (see Fig. 1).

1.2 For the purpose of this specification, normal conductor classification (Class AA, A, B, C) is not applicable as these conductors are intended for subsequent insulation. The descriptive term combination unilay-stranded shall be used in place of conductor classification.

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 on date of material purchase form a part of this specification to the extent referenced herein.

2.2 *ASTM Standards:*

[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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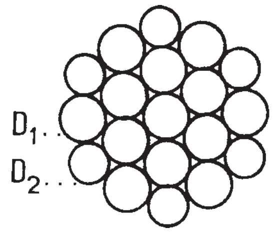

FIG. 1 Cross Section of Conductor

B 1 Specification for Hard-Drawn Copper Wire[2]
B 2 Specification for Medium-Hard-Drawn Copper Wire[2]
B 3 Specification for Soft or Annealed Copper Wire[2]
B 33 Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes[2]
B 189 Specification for Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes[2]
B 246 Specification for Tinned Hard-Drawn and Medium-Hard-Drawn 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 *Other Standard:*

NBS Handbook 100—Copper Wire Tables of the National Bureau of Standards[3]

3. Ordering Information

3.1 Orders for materials under this specification shall include the following information:

3.1.1 Quantity of each size,

3.1.2 Conductor Size: Circular-mil area or American Wire Gage, AWG (Section 7 and Table 1),

3.1.3 Stranding (see Explanatory Note 3),

3.1.4 Temper (see 4.2),

3.1.5 Whether coated or uncoated; if coated, designate type of coating (see 4.1 and 4.2),

3.1.6 Details of special-purpose lays, if required (see 6.2),

3.1.7 When physical tests shall be made (see 9.2 and 9.3),

3.1.8 Package size (see 15.1),

3.1.9 Lagging, if required (see 15.2),

3.1.10 Special package marking, if required (Section 15), and

3.1.11 Place of inspection (Section 13).

4. Requirements for Wires

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

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

4.2.1 Specification B 3

4.2.2 Specification B 33

4.2.3 Specification B 2

4.2.4 Specification B 1

4.2.5 Specification B 189

4.2.6 Specification B 246.

4.3 In combination unilay stranded conductors the central core wire shall be made of the same type and temper as the layers, unless otherwise specified.

5. Joints

5.1 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 50 ft (15.24 m) for hard and medium-hard conductors, and 1 ft in a layer for soft conductors.

6. Lay

6.1 For combination unilay conductors the lay of a layer of wires shall be not less than 8 nor more than 16 times the outside diameter of the outer layer.

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[2] *Annual Book of ASTM Standards*, Vols 02.03.

[3] Available from National Institute of Standards and Technology, (NIST), Gaithersburg, MD 20899.

TABLE 1 Construction Requirements for 19-Wire Combination Unilay Stranded Copper Conductors

~~Area ofCrossSection~~ Cross-Sectional Area		~~Size, American (or Brown and Sharpe)~~ Size, American (or Brown and Sharpe)	~~Wire D_1~~[A] ~~Diameter,~~ Wire D_1[A] Diameter,		~~Wire D_2~~[B] ~~Diameter,~~ Wire D_2[B] Diameter,	
cmil	sq mm	Wire Gage	mils	mm	mils	mm
500 000	253.4		175.6	4.5	128.5	3.3
450 000	228.0		166.6	4.2	121.9	3.1
400 000	202.7		157.1	4.0	115.0	2.9
350 000	177.3		146.9	3.7	107.5	2.7
300 000	152.0		136.0	3.5	99.6	2.5
250 000	126.7		124.2	3.2	90.9	2.3
~~211 600~~	~~107.2~~	~~0000~~	~~144.2~~	~~3.7~~	~~83.6~~	~~2.1~~
211 600	107.2	0000	114.2	2.4	83.6	2.1
167 800	85.0	000	101.7	2.6	74.5	1.9
133 100	67.4	00	90.6	2.3	66.3	1.7
105 600	53.5	0	80.7	2.0	59.1	1.5
83 690	42.4	1	71.8	1.8	52.6	1.3
66 360	33.6	2	64.0	1.6	46.8	1.2
52 620	26.7	3	57.0	1.4	41.7	1.1
41 740	21.1	4	50.7	1.3	37.1	0.9
33 090	16.8	5	45.2	1.1	33.1	0.8
26 240	13.3	6	40.2	1.0	29.4	0.7
~~30 820~~	~~15.6~~	~~7~~	~~35.8~~	~~0.9~~	~~26.2~~	~~0.7~~
20 820	10.5	7	35.8	0.9	26.2	0.7
16 510	8.4	8	31.9	0.8	23.4	0.6
13 090	6.6	9	28.4	0.7	20.8	0.5
10 380	5.3	10	25.3	0.6	18.5	0.5
6 530	3.3	12	20.1	0.5	14.7	0.4
4 110	2.1	14	15.9	0.4	11.7	0.3
2 580	1.3	16	12.6	0.3	9.2	0.2
1 620	0.8	18	10.0	0.3	7.3	0.2
1 020	0.5	20	7.9	0.2	5.8	0.1
640	0.3	22	6.3	0.2	4.6	0.1
404	0.2	24	5.0	0.1	3.7	0.1

[A] Equation to calculate D_1:

(~~Area of Cross-Section (cmil)~~)

$$\sqrt{\frac{\text{Cross-Sectional Area}}{16.2149}}$$

[B] Equation to calculate D_2: $= D_1 \times 0.732$.

6.2 Other lays for special purposes shall be furnished by special agreement between the manufacturer and the purchaser (Explanatory Note 4).

6.3 The direction of lay shall be left-hand unless the direction of lay is specified otherwise by the purchaser.

7. Construction (Explanatory Note 3)

7.1 The ~~areas of cross section,~~ cross-sectional areas, numbers, and diameters of wires in the various conductors shall conform to the requirements prescribed in Table 1.

7.2 The diameters of the wires listed in Table 2 are nominal. In order to produce an essentially round 19-wire construction, the outer 12-wire layer in the combination unilay product is comprised of 6 wires of the same diameter as the wires in the 7-wire core, and 6 wires approximately 25 % smaller. The 2-wire sizes are alternated around the 7-wire core (Fig. 1).

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

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 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.

8.3 The physical properties of wire when tested before stranding shall conform to the applicable requirements of 4.2.

8.4 The physical properties of wires removed from the completed stranded conductor shall be permitted to vary from the applicable requirements of 4.2 by the amounts as follows (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 %.

TABLE 2 Diameters, Areas, and Masses of 19-Wire Combination Unilay Stranded Copper Conductors

Size of Conductor				Nominal Area		Mass		
cmil or AWG	sq mm	Nominal Diameter, in.[A]	Conductor, mm	in.^{2}	mm^2	lbs/1000 ft	lbs/mile	~~k~~g/m
~~500 000~~	~~253.4~~	~~0.784~~	~~19.9~~	~~0.392700~~	~~253.4~~	~~1544~~	~~8151~~	~~2.297~~
500 000	253.4	0.784	19.9	0.392700	253.4	1544	8151	2297
~~450 000~~	~~228.0~~	~~0.744~~	~~18.9~~	~~0.353400~~	~~228.0~~	~~1389~~	~~7336~~	~~2.067~~
450 000	228.0	0.744	18.9	0.353400	228.0	1389	7336	2067
~~400 000~~	~~202.7~~	~~0.701~~	~~17.8~~	~~0.314000~~	~~202.6~~	~~1235~~	~~6521~~	~~1.838~~
400 000	202.7	0.701	17.8	0.314000	202.6	1235	6521	1838
~~350 000~~	~~177.3~~	~~0.656~~	~~16.7~~	~~0.274900~~	~~177.4~~	~~1081~~	~~5706~~	~~1.609~~
350 000	177.3	0.656	16.7	0.274900	177.4	1081	5706	1609
~~300 000~~	~~152.0~~	~~0.607~~	~~15.4~~	~~0.235600~~	~~152.0~~	~~926.3~~	~~4891~~	~~1.378~~
300 000	152.0	0.607	15.4	0.235600	152.0	926.3	4891	1378
~~250 000~~	~~126.7~~	~~0.554~~	~~14.1~~	~~0.196300~~	~~126.7~~	~~771.9~~	~~4076~~	~~1.149~~
250 000	126.7	0.554	14.1	0.196300	126.7	771.9	4076	1149
~~0000~~	~~107.2~~	~~0.510~~	~~13.0~~	~~0.166200~~	~~107.2~~	~~653.3~~	~~3450~~	~~0.972~~
0000	107.2	0.510	13.0	0.166200	107.2	653.3	3450	972.1
~~000~~	~~85.0~~	~~0.454~~	~~11.5~~	~~0.131800~~	~~85.0~~	~~518.1~~	~~2736~~	~~0.771~~
000	85.0	0.454	11.5	0.131800	85.0	518.1	2736	770.9
~~00~~	~~67.4~~	~~0.404~~	~~10.3~~	~~0.104500~~	~~67.4~~	~~410.9~~	~~2169~~	~~0.611~~
00	67.4	0.404	10.3	0.104500	67.4	410.9	2169	611.4
~~0~~	~~53.5~~	~~0.360~~	~~9.1~~	~~0.082910~~	~~53.5~~	~~325.8~~	~~1720~~	~~0.485~~
0	53.5	0.360	9.1	0.082910	53.5	325.8	1720	684.8
~~1~~	~~42.4~~	~~0.321~~	~~8.2~~	~~0.065730~~	~~42.4~~	~~258.4~~	~~1364~~	~~0.384~~
1	42.4	0.321	8.2	0.065730	42.4	258.4	1364	384.5
~~2~~	~~33.6~~	~~0.286~~	~~7.3~~	~~0.052120~~	~~33.6~~	~~204.9~~	~~1082~~	~~0.305~~
2	33.6	0.286	7.3	0.052120	33.6	204.9	1082	304.9
~~3~~	~~26.7~~	~~0.254~~	~~6.5~~	~~0.041330~~	~~26.7~~	~~162.5~~	~~858.1~~	~~0.242~~
3	26.7	0.254	6.5	0.041330	26.7	162.5	858.1	241.8
~~4~~	~~21.1~~	~~0.226~~	~~5.7~~	~~0.032780~~	~~21.1~~	~~128.9~~	~~680.5~~	~~0.192~~
4	21.1	0.226	5.7	0.032780	21.1	128.9	680.5	191.8
~~5~~	~~16.8~~	~~0.202~~	~~5.1~~	~~0.025990~~	~~16.8~~	~~102.2~~	~~539.6~~	~~0.152~~
5	16.8	0.202	5.1	0.025990	16.8	102.2	539.6	152.1
~~6~~	~~13.3~~	~~0.179~~	~~4.5~~	~~0.020610~~	~~13.3~~	~~81.05~~	~~428.0~~	~~0.121~~
6	13.3	0.179	4.5	0.020610	13.3	81.05	428.0	120.6
~~7~~	~~15.6~~	~~0.160~~	~~4.1~~	~~0.016350~~	~~10.5~~	~~64.28~~	~~339.4~~	~~0.096~~
7	15.6	0.160	4.1	0.016350	10.5	64.28	339.4	95.65
~~8~~	~~8.4~~	~~0.143~~	~~3.6~~	~~0.012970~~	~~8.4~~	~~50.97~~	~~269.1~~	~~0.076~~
8	8.4	0.143	3.6	0.012970	8.4	50.97	269.1	75.84
~~9~~	~~6.6~~	~~0.127~~	~~3.2~~	~~0.010280~~	~~6.6~~	~~40.42~~	~~213.4~~	~~0.060~~
9	6.6	0.127	3.2	0.010280	6.6	40.42	213.4	60.14
~~10~~	~~5.3~~	~~0.113~~	~~2.9~~	~~0.008155~~	~~5.3~~	~~32.06~~	~~169.3~~	~~0.048~~
10	5.3	0.113	2.9	0.008155	5.3	32.06	169.3	47.71
~~12~~	~~3.3~~	~~0.090~~	~~2.3~~	~~0.005130~~	~~3.3~~	~~20.16~~	~~106.5~~	~~0.030~~
12	3.3	0.090	2.3	0.005130	3.3	20.16	106.5	30.00
~~14~~	~~2.1~~	~~0.071~~	~~1.8~~	~~0.003230~~	~~2.1~~	~~12.68~~	~~66.95~~	~~0.019~~
14	2.1	0.071	1.8	0.003230	2.1	12.68	66.95	18.87
~~16~~	~~1.3~~	~~0.056~~	~~1.4~~	~~0.002030~~	~~1.3~~	~~7.974~~	~~42.10~~	~~0.012~~
16	1.3	0.056	1.4	0.002030	1.3	7.974	42.10	11.87
~~18~~	~~0.8~~	~~0.045~~	~~1.1~~	~~0.001280~~	~~0.8~~	~~5.015~~	~~26.48~~	~~0.007~~
18	0.8	0.045	1.1	0.001280	0.8	5.015	26.48	7.462
~~20~~	~~0.5~~	~~0.035~~	~~0.9~~	~~0.000804~~	~~0.5~~	~~3.154~~	~~16.65~~	~~0.005~~
20	0.5	0.035	0.9	0.000804	0.5	3.154	16.65	4.693
~~22~~	~~0.3~~	~~0.028~~	~~0.7~~	~~0.000503~~	~~0.3~~	~~1.992~~	~~10.52~~	~~0.003~~
22	0.3	0.028	0.7	0.000503	0.3	1.992	10.52	2.964
~~24~~	~~0.2~~	~~0.022~~	~~0.6~~	~~0.000317~~	~~0.2~~	~~1.249~~	~~6.59~~	~~0.002~~
24	0.2	0.022	0.6	0.000317	0.2	1.249	6.59	1.859

[A] To calculate the diameter, multiply the large wire diameter in Table 1 times 3 and add two times the small wire diameter.
Example: AWG 4/0 diameter = [(3(114.2) + 2 (83.6)] = 509.8

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

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

9.1 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.

9.2 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 strengths 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. (61 c0 mm), and care shall be taken to ensure that the wires in the conductor are evenly gripped during the test (Explanatory Note 6).

9.3 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. (25.4 c mm) gage length, for such tests shall be specified by the purchaser in the placing of individual orders (Explanatory Note 5).

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

10. Density

10.1 For the purpose of calculating masses, cross sections, etc., the density of the copper shall be taken as 8.89 g/cm^3(0.32117 lb/in.^{3}) at 20°C (Explanatory Note 7).

11. Mass and Resistance

11.1 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 increment of 2 %. When greater accuracy is desired, the increment based on the specific lay of the conductor may be calculated (Explanatory Note 8).

12. Variance in Area

12.1 The cross-sectional 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 shall determine the cross-sectional area by the following method:

12.1.1 The cross-sectional area of cross section of a conductor may be determined by Test Method B 263. In applying this method, the increment in mass resulting from stranding may be the applicable value specified in 11.1 or may be calculated from the measured component dimensions of the sample under test. In case of question regarding area compliance, the actual mass increment due to stranding shall be calculated.

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.

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

13.3 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.

14. Product Marking

14.1 The net weight, 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.

15. Packaging and Package Marking

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

15.2 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.

EXPLANATORY NOTES

NOTE 1—In this specification only combination unilay stranded conductor constructions are specifically designated. Conductor constructions not included in any of these specifications should be specifically agreed upon between the manufacturer and the purchaser when placing the order.

NOTE 2—For definitions of terms relating to conductors, refer to Terminology B 354.

NOTE 3—The construction details in 7.1, and 7.2 are considered typical and are not intended to restrict other constructions that otherwise meet physical, electrical and mechanical requirements of this specification.

NOTE 4—Certain types of insulated conductors may require 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 5—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 6—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 (13 600 kg) 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 7—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 8—The increment of mass or electrical resistance of a completed concentric-lay-stranded conductor~~,~~ (*k*~~,~~) in percent is as follows:

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

where *m* is the stranding factor, and is also the ratio of the ~~mass~~ 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 ~~stranding,~~ lay, that is, all wires parallel to the conductor axis. ~~The~~ For combination unilay conductors, the stranding factor *m* for the completed stranded conductor is the numerical average ~~of~~ 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). ~~T~~

$$m = \frac{W}{W'} = \frac{[1m_1 + 6m_2 + 6m_3 + (6 \times 0.732^2)m_4]\times\left[\delta \times 12 \times \frac{\pi}{4} \times D_1^2\right]}{[1 + 6 + 6\,(6 \times 0.732^2)]\times\left[\delta \times 12 \times \frac{\pi}{4} \times D_1^2\right]} = \frac{[1m_1 + 6m_2 + 6m_3 + (3.215)m_4]}{[16.215]} \tag{2}$$

where:

W = weight of all the strand components in the twisted conductor (lb/ft)
W' = equivalent weight of all the strand components if they were untwisted (lb/ft)
D_1 = diameter of larger strand component (refer to Fig. 1) (inches)
D_2 = diameter of smaller strand component (refer to Fig. 1) (inches) = $0.732 \times D_1$
δ = density of metal (lb/in^3)
12 = number of inches in 1 foot
m_1 = ratio increase for the center wire = 1
m_2 = ratio increase for the wires in the inner layer = $\sqrt{1 + \frac{\pi^2 \times (2 \times D_1)^2}{LOL^2}}$
m_3 = ratio increase for the wires of diameter D_1 the outer layer = $\sqrt{1 + \frac{\pi^2 \times (3.464 \times D_1)^2}{LOL^2}}$
m_4 = ratio increase for the wires of diameter D_2 the outer layer = $\sqrt{1 + \frac{\pi^2 \times (3.732 \times D_1)^2}{LOL^2}}$
LOL = length of lay (inches)

The above equations for m_2, m_3 and m_4 may be simplified using the following approximation:

$$y = \sqrt{1 + x^2} \cong 1 + \frac{x^2}{2} \tag{3}$$

where:
$x \leq 0.125$
The simplified ratio increase equations then become:

$$m_2 \cong 1 + \frac{\pi^2 \times (2 \times D_1)^2}{2 \times (LOL^2)} = 1 + \frac{19.7392 \times D_1^2}{LOL^2} \tag{4}$$

$$m_3 \cong 1 + \frac{\pi^2 \times (3.464 \times D_1)^2}{2 \times (LOL^2)} = 1 + \frac{59.2141 \times D_1^2}{LOL^2} \tag{5}$$

$$m_4 \cong 1 + \frac{\pi^2 \times (3.732 \times D_1)^2}{2 \times (LOL^2)} = 1 + \frac{68.7310 \times D_1^2}{LOL^2} \quad (6)$$

Combining the terms, the combined m value for the conductor becomes:

$$m = \frac{[1m_1 + 6m_2 + 6m_3 + (3.215)m_4}{[16.215]} \quad (7)$$

$$= \frac{\left[1 + 6 \times \left(1 + 19.7392 \times \left(\frac{D^2}{LOL^2}\right)\right) + 6 \times \left(1 + 59.2141 \times \left(\frac{D^2}{LOL^2}\right)\right) + (6 \times 0.732^2) \times \left(1 + 68.7310 \times \left(\frac{D^2}{LOL^2}\right)\right)\right]}{[16.215]}$$

$$= \frac{16.215 + 694.686 \frac{D^2}{LOL^2}}{16.215}$$

$$= 1 + 42.8422 \frac{D^2}{LOL^2}$$

The stranding factor (m_{ind}) for any given wire in a concentric-lay-stranded conductor is as follows:

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

when combination unilay conductors are made up of two wire sizes in the outer layer, the value of n is calculated as follows: (Refer to Fig. 1.)

$$\text{Core wire: } n = \infty \quad (8)$$

$$\text{First layer: } n = \frac{\text{Length of lay}}{2\,D,} \quad (9)$$

$$\text{Second layer strand diameter } D_1\text{: } n = \frac{\text{Length of lay}}{3.464 D_1} \quad (10)$$

$$\text{Second layer strand diameter } D_2\text{: } n = \frac{\text{Length of lay}}{3.732\, D_1}$$

The derivation is given in *NBS Handbook 100*.

NOTE 9—To cooperate with the manufacturer in avoiding the accumulation of excessive amount of scrap wire, it is suggested that package sizes permit ordinary variations of plus and minus 10 % in package lengths, and that occasional short lengths be permitted, and such packages to be distinctly marked.