Designation: B 738 – 03

Standard Specification for Fine-Wire Bunch-Stranded and Rope-Lay Bunch-Stranded Copper Conductors for Use as Electrical Conductors[1]

This standard is issued under the fixed designation B 738; 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 bunch-stranded and rope-lay bunch-stranded conductors made from round copper wires finer than No. 40 AWG with diameters less than 0.0031 in. (.078 mm), either coated or uncoated with tin or silver, for use as electrical conductors. (Explanatory Note 1).

1.2 The values (SI units) for density and temperature 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

2.1 *ASTM Standards:*

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

B 49 Specification for Copper Rod Drawing Stock for Electrical Purposes[3]

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

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

B 193 Test Method for Resistivity of Electrical Conductor Materials[2]

B 258 Specification for Standard Nominal Diameters and Cross-Sectional Areas of AWG Sizes of Solid Round Wires Used as Electrical Conductors[2]

B 298 Specification for Silver-Coated Soft or Annealed Copper Wire[2]

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

3. Classification

3.1 For the purposes of this specification, the following classifications have been assigned (Explanatory Note 2):

3.1.1 *Type*:

3.1.1.1 *Type B*—Bunch-stranded conductors.

3.1.1.2 *Type R*—Rope-lay bunch-stranded conductors.

3.1.2 *Class*:

3.1.2.1 *Class R*—Stranded conductors using wire 42 AWG (0.0025).

3.1.2.2 *Class S*—Stranded conductors using wire 44 AWG (0.0020).

3.1.2.3 *Class T*—Stranded conductors using wire 46 AWG (0.00157).

3.1.2.4 *Class U*—Stranded conductors using wire 48 AWG (0.00124).

3.1.2.5 *Class V*—Stranded conductors using wire 50 AWG (0.00099).

3.2 Detailed information on Type B Conductors is found in Table 1 and Table 2. Detailed information on Type R Conductors is found in Table 3 and Table 2.

4. Ordering Information

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

4.1.1 Quantity of each size, class, and type,

4.1.2 *Conductor size*—circular-mil area, dc resistance (7.1) or AWG (5.2.1),

4.1.3 Class and type (Section 3),

4.1.4 Whether coated or uncoated; if coated, designate type of coating (6.1); if silver coated, the minimum thickness of silver (6.1.2), and whether tarnish protection is desired (11.3),

4.1.5 Maximum length of lay (5.2.4), if required,

4.1.6 Temper (6.2),

4.1.7 Separators, if required (5.2.2),

4.1.8 Package size (11.1),

4.1.9 Special package marking, if required (Section 10), and

4.1.10 Place of inspection (Section 9).

4.2 In addition, Supplementary Requirements shall apply only when specified by the purchaser in the inquiry, contract, or purchase order for direct procurement by agencies of the U.S. Government.

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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] *Annual Book of ASTM Standards*, Vol 02.01.

TABLE 1 Classification of Type B Bunch-Stranded Conductors

Class	Wire Diameter, in.[A]	Conductor Sizes, AWG
R	0.0025 (No. 42 AWG)	24,26,28,30,32,34
S	0.0020 (No. 44 AWG)	26,28,30,32,34,36
T	0.00157 (No. 46 AWG)	28,30,32,34,36,38
U	0.00124 (No. 48 AWG)	30,32,34,36,38,40
V	0.00099 (No. 50 AWG)	32,34,36,38,40

[A] Sufficient quantities of wires of these diameters shall be used to form conductors having cross-sectional areas approximately equal to the AWG conductor sizes listed.

5. Materials and Manufacture

5.1 The material shall be copper of such quality and purity that the finished product shall have the properties and characteristics described in this specification. Material meeting the requirements of Specification B 49 is such a material.

5.2 *Construction*:

5.2.1 *Cross-Sectional Area*—The cross-sectional area, number, and diameter of wires for a variety of strand constructions in general use are shown in Table 2.

5.2.2 *Separators*—If a separator is required to be furnished with the conductor, it shall be specified by the purchaser at the time of the order as to the requirements for the kind and thickness of material and its application details.

5.2.3 *Joints*:

5.2.3.1 Necessary joints in wires shall be made in accordance with accepted commercial practice.

5.2.3.2 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 that the flexibility of the completed conductor is not adversely affected.

5.2.4 *Lay*:

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

5.2.4.2 The direction of the lay of bunch-stranded conductors shall be at the option of the manufacturer unless otherwise specified by the purchaser.

5.2.4.3 Unless otherwise specified by the purchaser, the length of the lay of bare or coated bunch-stranded conductors shall conform to the requirements of Table 4.

5.2.4.4 The direction of the lay of the outer layer of rope-lay stranded conductors shall be lefthand, unless otherwise specified by the purchaser.

5.2.4.5 The length of the lay of the outer layer of rope-lay stranded conductors shall be not less than 8 or more than 16 times the outside diameter of the completed conductor. The length of the lay of the wires composing the bunch-stranded members shall be not more than 30 times the diameter of the member.

6. Physical Properties

6.1 *Wire Coating*—When coated, the coating of the wires of the stranded conductor, before stranding, shall conform to the requirements of 6.1.1 or 6.1.2.

6.1.1 Tin coating shall conform to the coating requirements of Specification B 33.

6.1.2 Silver coating shall conform to the minimum thickness requirements of the purchase document. Minimum thickness shall be determined using the method for determining plating thickness described in Specification B 298.

6.1.3 The finished diameter and mass of the coated wires used shall be substantially equal to those of the uncoated wires of the same class.

6.2 *Temper*—Unless otherwise specified, all coated conductors shall be furnished in the annealed temper. Uncoated conductors may be furnished either annealed or unannealed as ordered (see 4.1.6).

NOTE 1—The term unannealed as used in this specification means cold-worked conductor as produced on commercial wire-drawing machines.

6.3 *Tensile Strength and Elongation*—The stranded conductor, in its finished form, shall conform to the following:

	Tensile Strength, min.		Elongation, min,
Finished State	psi	MPa	10 in. %
Unannealed	40 000	275	...
Annealed	...	...	10

7. Electrical Properties

7.1 *DC Resistance*—The dc resistance in Ω/1000 ft of the bunch-stranded conductor shall not exceed the appropriate values specified in Table 5. The dc resistance in Ω/1000 ft of the rope-lay bunch-stranded conductor shall not exceed the appropriate values specified in Table 6 (Explanatory Note 3 and Note 4).

8. Test Methods

8.1 *Coating*—Tests to determine conformance of the coating to the requirements of Specification B 33 or Specification B 298 shall be performed on the individual wires before stranding (see 6.1.1 to 6.1.3).

8.2 *Tensile Strength and Elongation*:

8.2.1 Tests to determine conformance to the tensile strength and elongation requirements of 6.3 shall be made on the finished stranded conductor.

8.2.2 Determine tensile strength, T_s, expressed in pounds per square inch as follows:

$$T_s = \frac{L}{A}$$

where:

L = maximum load on the stranded conductor during the tension test (see Explanatory Note 5), lbs, and

A = original cross-sectional area of the stranded conductor, in.^{2}/in. (see 8.2).

8.2.3 The original cross-sectional area of the stranded conductor shall be considered to be the cross-sectional area of the individual wire calculated from the nominal wire diameter (see Table 5) multiplied by the number of wires in the stranded conductor (Explanatory Note 6).

8.2.4 Determine the elongation of the specimen as the permanent increase in length, expressed in percent of the original length, due to the breaking of the specimen in tension, by measurements made between the jaws of testing machine. The zero length shall be the distance between the jaws at the start of the tension test, and shall be as near 10 in. (250 mm) as practicable. The final length shall be the distance between

TABLE 2 Construction Requirements of Bunch-Stranded and Rope-Lay Bunch-Stranded Conductors[A]

Nominal Area, cmil	Size, AWG	CLASS R		CLASS S		CLASS T		CLASS U		CLASS V	
		Minimum Number of Wires 0.0025 in. in Diameter (No. 42 AWG)		Minimum Number of Wires 0.0020 in. in Diameter (No. 44 AWG)		Minimum Number of Wires 0.00157 in. in Diameter (No. 46 AWG)		Minimum Number of Wires 0.00124 in. in Diameter (No. 48 AWG)		Minimum Number of Wires 0.00099 in. in Diameter (No. 50 AWG)	
		Type[B] B	Type[C] R	Type B	Type R	Type B	Type R	Type B	Type R	Type B	Type R
2580	16	...	...	...	665	...	...	...	...	...	...
1620	18	...	...	...	413	...	...	...	...	...	...
1020	20	...	168	...	259	...	...	...	...	...	...
640	22	...	105	...	168	...	...	...	...	...	...
404	24	65	...	...	105	...	168	...	...	...	...
253	26	41	...	65	...	...	105	...	168	...	...
159	28	26	...	40	...	65	...	...	105	...	168
100	30	16	...	25	...	40	...	65	...	...	105
64	32	10	...	16	...	25	...	40	...	65	...
40	34	7	...	10	...	16	...	25	...	40	...
25	36	...	...	7	...	10	...	16	...	25	...
16	38	...	...	...	...	7	...	10	...	16	...
10	40	...	...	...	...	...	...	7	...	10	...

[A] This table shows a variety of strand constructions useful and generally adequate to meet the needs encountered. It is not intended that the constructions listed in this table be exclusive of other constructions that may appear durable in certain applications employing the same number of wires. The constructions shown in this table provide for a finished, noncovered, stranded conductor approximately of the area indicated. When specified by the purchaser, usually to provide additional area to compensate for draw-down during subsequent processing, the number or size of wires composing the uncovered conductor may be increased as required.

[B] Type B Bunch-Stranded Conductors.

[C] Type R Rope-Lay Bunch-Stranded Conductors.

TABLE 3 Classification of Type R Rope-Lay Bunch-Stranded Conductors[A]

Class	Wire Diameter, in.[B]	Conductor Sizes, AWG
R	0.0025 (No. 42 AWG)	20,22
S	0.0020 (No. 44 AWG)	16,18,20,22,24
T	0.00157 (No. 46 AWG)	24,26
U	0.00124 (No. 48 AWG)	26,28
V	0.00099 (No. 50 AWG)	28,30

[A] Rope-lay bunch-stranded conductors 7 by bunch-stranded members.

[B] Sufficient quantities of wires of these diameters shall be used to form conductors having cross-sectional areas approximately equal to the AWG conductor sizes listed.

the jaws at the time of rupture. The fracture shall be between the jaws of the testing machine and not closer than 1 in. (25 mm) to either jaw.

8.3 *Electrical*—Tests to determine conformance to the electrical resistance requirements of 7.1 shall be made on the finished stranded conductor in accordance with Test Method B 193 (Explanatory Note 3).

8.4 *Other Requirements*—For the purpose of calculating mass, cross-sectional area, and so forth, the density of the coated copper shall be taken as 8.89 g/cm^3(0.32117 lb/in.^{3}) at 20°C (Explanatory Note 5).

8.5 *Examination for Workmanship of Finished Uninsulated Stranded Conductor*—A visual inspection with the unaided eye shall be performed on the outer layer of the conductor on the supplied package. Use a white card (as a background) to ascertain if any base metal is exposed through a break in the coating. Detection of any base metal constitutes rejection.

8.6 *Examination for Workmanship of Finished Uninsulated Stranded Conductor*—A visual inspection with 10× magnification and a white background shall be performed on a conductor sample taken from the top of the supplied spool. The sample shall be a minimum of 12 in. (30 cm) in length. The outer surface of all stranded constructions shall be examined.

Detection of excessive exposed base metal due to the stranding process, such as indications along one side of the sample due to excessive localized abrasion during stranding, constitutes rejection. Continuous lines or patterns of exposed base metals constitute rejection. Small, random point failures shall not be cause for rejection.

9. Inspection

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

9.2 All inspection 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.

9.3 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.

10. Product Marking

10.1 The net mass, length (or lengths, and number of lengths, if more than one length is included in the package), size designation, type of conductor, purchase order number, and any other marks required by the purchase order shall be marked on a tag attached to the reel and, optionally, 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.

11. Packaging

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

11.2 The conductors shall be protected against damage in ordinary handling and shipping.

11.3 When specified, silver-plated wire shall be protected from tarnish.

TABLE 4 Maximum Length of Lay for Bunch-Stranded Conductors

Size, AWG	Nominal Diameter		Nominal Area		Maximum Length of Lay	
	in.	(mm)	cmil	(mm^2)	in.	(mm)
24	0.024	(0.61)	404	(0.20)	0.70	(18)
26	0.019	(0.48)	253	(0.13)	0.60	(15)
28	0.015	(0.38)	159	(0.081)	0.50	(13)
30	0.012	(0.30)	100	(0.051)	0.40	(10)
32	0.009	(0.23)	64	(0.032)	0.30	(7.6)
34	0.007	(0.18)	40	(0.020)	0.25	(6.4)
36	0.006	(0.15)	25	(0.013)	0.20	(5.1)
38	0.005	(0.13)	16	(0.0081)	0.15	(3.8)
40	0.004	(0.10)	10	(0.0051)	0.13	(3.3)

TABLE 5 DC Ohmic Resistance Per 1000 Ft. of Type B Bunch-Stranded Conductors

Size Designations	Conductor Construction[A]		Calculated Total Cross-Sectional Area cmil	DC Resistance at 20°C, Ω/1000 ft, max.[B]		
	Number of Wires[C]	Nominal Diameter of Each Wire, in.		Annealed Bare or Silver Coated[D]	Annealed Tin Coated[E]	Unannealed Bare
24-65	65	0.0025	406	28.3	30.4	29.4
26-41	41	0.0025	256	44.9	48.2	46.7
26-65	65	0.0020	260	45.2	48.5	47.0
28-26	26	0.0025	163	70.8	76.0	73.6
28-40	40	0.0020	160	73.5	78.9	76.4
28-65	65	0.00157	160	71.8	...	74.6
30-16	16	0.0025	100	115.0	123.4	119.6
30-25	25	0.0020	100	117.5	126.2	122.2
30-40	40	0.00157	98.6	116.6	...	121.3
30-65	65	0.00124	99.9	115.0	...	119.6
32-10[C]	10	0.0025	62.5[C]	184.0	197.5	191.3
32-16	16	0.0020	64	183.7	197.2	191.0
32-25[C]	25	0.00157	61.6[C]	186.6	...	194.0
32-40[C]	40	0.00124	61.5[C]	187.0	...	194.4
32-65	65	0.00099	63.7	180.5	...	187.7
34-7	7	0.0025	43.8	262.8	281.8	273.3
34-10	10	0.0020	40	293.8	315.5	305.6
34-16	16	0.00157	39.4	291.6	...	303.2
34-25[C]	25	0.00124	38.4[C]	299.1	...	311.1
34-40	40	0.00099	39.2	293.3	...	305.0
36-7	7	0.0020	28	419.8	450.6	436.5
36-10	10	0.00157	24.6	466.5	...	485.1
36-16	16	0.00124	24.6	467.4	...	486.0
36-25	25	0.00099	24.5	469.3	...	488.0
38-7	7	0.00157	17.3	666.4	...	693.0
38-10[C]	10	0.00124	15.4[C]	747.8	...	777.7
38-16	16	0.00099	15.7	733.2	...	762.5
40-7	7	0.00124	10.8	1068.3	...	1111.0
40-10	10	0.00099	9.8	1173.2	...	1220.0

[A] See Table 2 for construction requirements or bunch-stranded conductors.
[B] See Explanatory Note 4.
[C] Bunch.
[D] The cross-sectional areas of these conductor-size designations deviate by more than 2 % from the nominal areas of the standard AWG sizes as defined in Specification B 258.
[E] Tin-coated wire is not available at this time on wire diameters smaller than .0020 (44 AWG).

12. Keywords

12.1 copper electrical conductor; electrical conductor; electrical conductor—copper; fine-wire bunch-stranded conductor; rope-lay bunch-stranded conductor; stranded conductor

TABLE 6 D-C Ohmic Resistance Per 1000 Ft. of Type R Rope-Lay Bunch-Stranded Conductor

Size Designation	Conductor Construction[A]		Calculated Total Cross-Sectional Area cmil	D-C Resistance of 20°C, Ohms/1000 ft. max.[B]		
	Number of Wires[C]	Nominal Diameter of Each Wire, in.		Annealed Bare or Silver Coated[B]	Annealed Tin Coated[D]	Unannealed Bare
16-665	665	0.0020	2660	4.51	4.84	4.69
18-413	413	0.0020	1652	7.25	7.79	7.54
20-168	168	0.0025	1050	11.2	12.0	11.6
20-259	259	0.0020	1036	11.6	12.4	12.0
22-105	105	0.0025	656	17.9	19.2	18.6
22-168	168	0.0020	672	17.8	19.1	18.5
24-105	105	0.0020	420	28.5	30.6	29.7
24-168	168	0.00157	414	28.3	...	29.4
26-105	105	0.00157	259	45.3	...	47.1
26-168	168	0.00124	258	45.4	...	47.2
28-105	105	0.00124	161	72.6	...	75.5
28-168	168	0.00099	165	71.2	...	74.0
30-105	105	0.00099	103	113.9	...	118.5

[A] See Table 2 Construction Requirements of Rope-Lay Bunch-Stranded Conductors.
[B] See Explanatory Note 3.
[C] Seven Member Ropes.
[D] Tin coated wire is not available at this time on wire diameters smaller than .0020 (44 AWG).

EXPLANATORY NOTES

NOTE 1—In this specification, only bunch-stranded and rope-lay bunch-stranded conductors made from coated or uncoated round copper wires finer than No. 40 AWG are defined. Requirements for rope-lay stranded copper conductors having bunch-stranded members made from round copper wires either coated or uncoated, No. 34 AWG or heavier will be found in Specification B 172. Requirements for bunch-stranded copper conductors made from round copper wires either coated or uncoated, No. 40 AWG or heavier will be found in Specification B 174.

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

NOTE 3—Because of the difficulties encountered in determining correctly the cross-sectional area of stranded conductors, this requirement has been superseded by the dc ohmic resistance/1000 ft length of conductors. Since this specification describes uninsulated conductors usually intended for ultimate use as insulated conductors in various electrical and electronic applications, maximum resistance values are shown for the conductors before insulating to serve as the minimum acceptance requirement for the conductor. Since some increase of resistance may occur during the insulating process due to stretching, an allowance in the maximum resistance is recommended. The values appearing in Table 5 and Table 6 under the heading "Annealed Silver Coated" are applicable to silver-coated conductors whether annealed or unannealed prior to insulating.

NOTE 4—The method used to calculate the dc resistance values appearing in the tables is as follows:

DC resistance at 20°C for the conductors (Table 5 and Table 6) expressed in maximum Ω/1000 ft =

$$\frac{10.371 \times K}{(1000\,NC \times d^2 f)}$$

where:

K = stranding factor: for Type B, bunch-stranded conductors, the factor is 1.02; and for Type R, Rope-lay bunch-stranded conductors, the factor is 1.04,
N = the number of wires in the stranded conductor,
C = minimum wire conductivity divided by 100 as shown in the following:

Type of Wire	Range of Wire Sizes	C
Annealed silver coated	all	1.00
Annealed bare	all	1.00
Annealed tin coated	all	0.9315
Unannealed bare	all	0.9616

d = single wire nominal diameter, in., and
f = diameter factor (minimum wire diameter) for all sizes except No 44 AWG is 0.92 and for No 44 AWG (0.0020) it is 0.90.

NOTE 5—The value of the density of copper is in accordance with the International Annealed Copper Standard.

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—It is known that the rate of loading during tension testing of copper affects the performance of the sample to a greater or lesser extent, depending upon many factors. In general, tested values of tensile strength are increased and tested values of elongation are reduced with increase of speed of the moving head of the testing machine. These effects are pronounced when the speed of the moving head is excessive in the testing of hard-drawn wires. It is suggested that tests be made at speeds of moving heads that, under no-load conditions, are not greater than 3 in./min (75 mm/min) but in no case at a speed greater than that at which correct readings can be made.