Designation: B 399/B 399M – 99

Standard Specification for Concentric-Lay-Stranded Aluminum-Alloy 6201-T81 Conductors[1]

This standard is issued under the fixed designation B 399/B 399M; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers concentric-lay-stranded conductors, made from round aluminum-alloy 6201-T81 (hard: solution heat-treated, cold worked, and then artificially aged) wires, for use for electrical purposes. These conductors shall be constructed with a central core surrounded by one or more layers of helically laid wires (Explanatory Notes 1 and 2).

NOTE 1—The aluminum alloy and temper designations conform to ANSI H35.1/H35.1[M]. Aluminum-alloy 6201 corresponds to Unified Numbering System alloy A96201 in accordance with Practice E 527.

1.2 The values stated in inch-pound units 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 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:*

B 263 Test Method for Determination of Cross-Sectional Area of Stranded Conductors[2]

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

B 398/B 398M Specification for Aluminum-Alloy 6201-T81 Wire for Electrical Purposes[2]

B 682 Specification for Standard Metric Sizes of Electrical Conductors[2]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[3]

E 527 Practice for Numbering Metals and Alloys (UNS)[4]

2.3 *ANSI Standards:*

ANSI H35.1, American National Standard for Alloy and Temper Designation Systems for Aluminum[5]

ANSI H35.1[M] American National Standard Alloy and Temper Designation Systems for Aluminum [Metric][5]

2.4 *NIST Standards:*

NBS Handbook 100—Copper Wire Tables of the National Bureau of Standards[6]

2.5 *Aluminum Association Publication:*

Publication 50, Code Words for Overhead Aluminum Electrical Conductors[7]

3. Classification

3.1 For the purpose of this specification, conductors are classified as follows (Explanatory Notes 1 and 2):

3.1.1 *Class AA*—For bare conductors usually used in overhead lines.

3.1.2 *Class A*—For conductors to be covered with weather-resistant materials.

4. Ordering Information

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

4.1.1 Quantity of each size, stranding, and class,

4.1.2 Conductor size, area and aluminum 1350 equivalent size (if required) (Section 8 and Table 1, Table 2, or Table 3),

4.1.3 Number of wires (Table 1, Table 2 or Table 3),

4.1.4 Direction of lay of outer layer of aluminum wires if other than right-hand (see 7.4),

4.1.5 Compressed stranding, if required (see 8.2),

4.1.6 Special tension test, if required (see 9.2 and 14.2),

4.1.7 Place of inspection (see 15.2),

4.1.8 Special package marking, if required (Section 16),

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[1] This specification is under the jurisdiction of ASTM Committee B-1 on Electrical Conductors and is the direct responsibility of Subcommittee B01.07 on Conductors of Light Metals.

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

[3] *Annual Book of ASTM Standards*, Vol 14.02.

[4] *Annual Book of ASTM Standards*, Vol 01.01.

[5] Available from the American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

[6] Available from the National Technical Information Service, 5285 Port Royal Rd., Springfield, VA 22161.

[7] Available from the Aluminum Association, Inc., 900 19th Street NW, Suite 300, Washington, DC 20006.

TABLE 1 Construction Requirements of Concentric-Lay-Stranded Aluminum-Alloy 6201 Conductors Sized to Have Diameter Equal to ACSR, Class AA and Class A

NOTE 1—Metric values listed below represent a soft conversion and as such they may not be the same as those metric masses which are calculated from the basic metric density.

Conductor Size		Code Words[A]	Approximate Aluminum 1350 Size Having Equivalent Resistance			Size and Stranding of ACSR with Equal Diameter			Required Construction					Mass		Rated Strength	
cmil	mm^2		Size			cmil[B]	AWG	mm^2	Stranding	Number of Wires	Diameter of Wires		Class	Per 1000 ft, lb	Per km, kg	kips	kN
			cmil[B]	AWG	mm^2						in.	mm					
1 439 200	729.2	—	1 272 000	. . .	644.5	1 272 000	. . .	644.5	54/7	61	0.1536	3.90	AA	1342	1997	46.8	208
1 348 800	683.4	—	1 192 500	. . .	604.2	1 192 500	. . .	604.2	54/7	61	0.1487	3.78	AA	1258	1872	43.9	195
1 259 600	638.2	—	1 113 000	. . .	564.0	1 113 000	. . .	564.0	54/7	61	0.1437	3.65	AA	1175	1748	41.0	182
1 165 100	590.3	—	1 033 500	. . .	523.7	1 033 500	. . .	523.7	54/7	61	0.1382	3.51	AA	1086	1617	37.9	169
1 077 400	545.9	—	954 000	. . .	483.4	954 000	. . .	483.4	54/7	61	0.1329	3.38	AA	1005	1495	35.0	156
927 200	469.8	Greeley	795 000	. . .	402.8	795 000	. . .	402.8	26/7	37	0.1583	4.02	AA	864.6	1287	30.5	136
740 800	375.4	Flint	636 000	. . .	322.3	636 000	. . .	322.3	26/7	37	0.1415	3.59	AA	690.8	1028	24.4	108
652 400	330.6	Elgin	556 500	. . .	282.0	556 500	. . .	282.0	26/7	19	0.1853	4.71	AA	608.3	905.2	21.9	97.5
559 500	283.5	Darien	477 000	. . .	241.7	477 000	. . .	241.7	26/7	19	0.1716	4.36	AA	521.7	776.3	18.8	83.6
465 400	235.8	Cairo	397 500	. . .	201.4	397 500	. . .	201.4	26/7	19	0.1565	3.98	AA	433.9	645.7	15.6	69.6
394 500	199.9	Canton	336 400	. . .	170.5	336 400	. . .	170.5	26/7	19	0.1441	3.66	AA, A	367.9	547.4	13.3	59.0
312 800	158.5	Butte	266 800	. . .	135.2	266 800	. . .	135.2	26/7	19	0.1283	3.26	A	291.6	434.0	10.5	46.7
246 900	125.1	Alliance	211 600	0000	107.2	211 600	0000	107.2	6/1	7	0.1878	4.77	AA	230.2	342.6	8.56	38.1
195 700	99.2	Amherst	167 800	000	85.0	167 800	000	85.0	6/1	7	0.1672	4.25	AA, A	182.5	271.5	6.79	30.2
155 400	78.7	Anaheim	133 100	00	67.4	133 100	00	67.4	6/1	7	0.1490	3.78	AA, A	144.9	215.6	5.39	24.0
123 300	62.5	Azusa	105 600	0	53.5	105 600	0	53.5	6/1	7	0.1327	3.37	AA, A	114.9	171.0	4.27	19.0
77 470	39.3	Ames	66 360	2	33.6	66 360	2	33.6	6/1	7	0.1052	2.67	AA, A	72.24	107.5	2.80	12.5
48 690	24.7	Alton	41 740	4	21.1	41 740	4	21.1	6/1	7	0.0834	2.12	A	45.40	67.56	1.76	7.84
30 580	15.5	Akron	26 240	6	13.3	26 240	6	13.3	6/1	7	0.0661	1.68	A	28.52	42.44	1.11	4.92

[A]Code words shown in this column are obtained from, "Publication 50, Code Words for Overhead Aluminum Electrical Conductors", by the Aluminum Association. They are provided here for information only.

[B]Conversion factors: 1 mil = 2.54 E-02 mm
1 cmil = 5.067 E-04 mm^2
1 in. = 25.4 mm
1 lb/1000 ft = 1.488 E + 00 kg/km
1 ft = 3.048 E-01 m
1 lb = 4.536 E-01 kg
1 lbf = 4.448 E-03 kN

4.1.9 Package size and type (see 16.1), and

4.1.10 Heavy wood lagging, if required (see 16.4).

5. Requirements of Wires

5.1 The aluminum-alloy wire used shall conform to the requirements of Specification B 398/B 398M.

6. Joints

6.1 In conductors composed of seven wires, only cold-pressure joints or electric-butt, cold-upset joints are permitted in the six outer finished wires; no joints are permitted in the center wire. In other conductors, cold-pressure welds, electric-butt, cold-upset welds, or electric-butt welds may be made in the finished wires composing conductors, but such joints shall be not closer than prescribed in Table 4. Following welding, electric-butt welds shall be annealed for a distance of at least 6 in. [150 mm] on each side of the weld.

7. Lay

7.1 For Class AA conductors, the preferred lay of a layer of wires is 13.5 times the outside diameter of that layer, but the lay shall be not less than 10 nor more than 16 times this diameter.

7.2 For Class A conductors, the lay of a layer of wires shall be not less than 8 nor more than 16 times the outside diameter of that layer, except that for conductors composed of 37 wires or more, this requirement shall apply only to the two outer layers. The lay of the layers other than the two outer layers shall be at the option of the manufacturer, unless otherwise agreed upon.

7.3 Other lays for special purposes shall be furnished by agreement between the manufacturer and the purchaser.

7.4 The direction of lay of the outer layer shall be right-hand unless specified otherwise by the purchaser.

7.5 The direction of lay shall be reversed in successive layers, unless otherwise specified by the purchaser.

8. Construction

8.1 The cross-sectional areas and the numbers and diameters of wires in the concentric-lay-stranded conductors shall conform to the requirements prescribed in Table 1, Table 2, or Table 3 as applicable (Explanatory Notes 2 and 6).

8.2 Where compressed stranding is required in order that the conductor may be properly insulated, one or more layers of any stranded conductor consisting of 7 wires or more may be slightly compressed, thereby reducing the outside diameter of

TABLE 2 Construction Requirements of Concentric-Lay-Stranded Aluminum-Alloy 6201 Conductors Sized by Standard Areas, Class AA and Class A

NOTE 1—Metric values listed below represent a soft conversion and as such they may not be the same as those metric masses which are calculated from the basic metric density.

Conductor Size			Required Construction				Mass		Rated Strength	
cmil[A]	AWG	mm^2	Number of Wires	Diameter of Wires		Class	Per 1000 ft, lb	Per km, kg	kips	kN
				in.	mm					
1 750 000	. . .	886.7	61	0.1694	4.30	AA	1632	2429	56.9	253
1 500 000	. . .	760.0	61	0.1568	3.98	AA	1399	2081	48.8	217
1 250 000	. . .	633.3	61	0.1431	3.63	AA	1165	1733	40.6	180
1 000 000	. . .	506.7	37	0.1644	4.18	AA	932.5	1388	32.9	146
900 000	. . .	456.0	37	0.1560	3.96	AA	839.7	1249	29.6	132
800 000	. . .	405.4	37	0.1470	3.73	AA	745.6	1109	26.3	117
750 000	. . .	380.0	37	0.1424	3.62	AA	699.6	1041	24.7	110
700 000	. . .	354.7	37	0.1375	3.49	AA	652.3	970.6	23.0	102
650 000	. . .	329.4	37	0.1325	3.37	AA	605.7	901.3	21.4	95.0
600 000	. . .	304.0	37	0.1273	3.23	AA, A	559.1	832.0	20.6	91.5
550 000	. . .	278.7	37	0.1219	3.10	AA, A	512.7	762.9	18.9	83.9
500 000	. . .	253.4	19	0.1622	4.12	AA	466.1	693.6	16.8	74.7
450 000	. . .	228.0	19	0.1539	3.91	AA	419.6	624.4	15.1	67.3
400 000	. . .	202.7	19	0.1451	3.69	AA, A	373.0	555.1	13.4	59.8
350 000	. . .	177.3	19	0.1357	3.45	A	326.3	485.5	11.8	52.3
300 000	. . .	152.0	19	0.1257	3.19	A	280.0	416.6	10.5	46.8
250 000	. . .	126.7	19	0.1147	2.91	A	233.1	346.9	8.76	39.0
211 600	0000	107.2	7	0.1739	4.42	AA, A	197.4	293.7	7.34	32.7
167 800	000	85.0	7	0.1548	3.93	AA, A	156.4	232.7	5.82	25.9
133 100	00	67.4	7	0.1379	3.50	AA, A	124.1	184.7	4.62	20.5
105 600	0	53.5	7	0.1228	3.12	AA, A	98.43	146.5	3.82	17.0
66 360	2	33.6	7	0.0974	2.47	AA, A	61.92	92.14	2.40	10.7
41 740	4	21.1	7	0.0772	1.96	A	38.90	57.89	1.51	6.72
26 240	6	13.3	7	0.0612	1.55	A	24.49	36.44	0.949	4.22

TABLE 3 Construction Requirements and Rated Strengths of Concentric-Lay-Stranded Aluminum-Alloy 6201-T81 Conductors Sized by Standard Areas, Class AA and Class A

NOTE 1—Sizes were selected from Specification B 682.

Conductor Size, mm^2	Required Construction			Rated Strength 6201-T81, kN
	Number of Wires	Diameter of Wires, mm	Class	
630	37	4.66	AA	181
560	37	4.39	AA	161
500	37	4.15	AA	143
450	37	3.94	AA	129
400	37	3.71	AA	115
355	37	3.50	AA	102
315	37	3.29	AA	90.2
280	37	3.10	AA	83.9
250	19	4.09	AA	73.1
224	19	3.87	AA	65.5
200	19	3.66	AA, A	58.6
180	19	3.47	AA, A	52.6
160	19	3.27	AA, A	46.7
140	19	3.06	AA, A	42.9
125	19	2.89	AA, A	38.3
112	7	4.51	AA	33.8
100	7	4.26	AA, A	30.2
80.0	7	3.81	AA, A	24.1
63.0	7	3.39	AA, A	19.1
50.0	7	3.02	AA, A	15.9
40.0	7	2.70	AA, A	12.7
31.5	7	2.39	A	9.95
25.0	7	2.13	A	7.90
20.0	7	1.91	A	6.35
16.0	7	1.71	A	5.09

TABLE 4 Minimum Distance Between Joints in the Completed Conductor

Number of Wires in Conductor	Distance Between Joints, min. ft (m)
7	50 (15)[A]
19	50 (15)
37	25 (7.5)
61	25 (7.5)

[A] Only cold-pressure welds and electric-butt, cold-upset welds are permitted in the six outer wires of conductors composed of seven wires; no welds are permitted in the center or core wire.

the conductor by not more than 3 %, provided that the area of cross section after compressing is in accordance with Section 12.

NOTE 2—The user's attention is called to the claim that certain compressed strand constructions may be subject to patent rights, for example: Patents 3,383,704 and 3,444,684.

9. Rated Strength of Conductor

9.1 The rated strength of a conductor shall be taken as that percentage, indicated in Table 5 of the sum of the strengths of the 6201 wires, calculated on the basis of the nominal wire diameter and the specified minimum average tensile strength given in Specification B 398/B 398M.

9.2 Tests for determining the breaking strength of a conductor are not required by this specification but may be made if agreed upon between the manufacturer and the purchaser at the time of placing an order. When tested, the breaking strength of

TABLE 5 Rating Factors

Stranding		Rating Factor, %
Number of Wires in Conductor	Number of Layers	
7	1	96
19	2	93
37	3	91
61	4	90

a conductor shall be not less than the rated strength if failure occurs in the free length at least 1 in. [25 mm] beyond the end of either gripping device, or shall be not less than 95 % of the rated strength if failure occurs inside, or within 1 in. [25 mm] of the end of, either gripping device (Explanatory Note 3).

9.3 Rated strength and breaking strength values shall be rounded to three significant figures, in the final value only, in accordance with the rounding method in Practice E 29.

10. Density

10.1 For the purpose of calculating, mass, mass per unit length, cross sections, etc., the density of aluminum-alloy 6201 shall be taken as 2690 kg/m^3 (0.097 lb/in.^{3}) at 20°C.

11. Mass and Electrical Resistance

11.1 The mass and electrical resistance of a unit length of stranded conductor are a function of the length of lay. The appropriate mass and electrical resistance may be determined using an increment of 2 %. When greater accuracy is desired, the increment based on the specific lay of the conductor may be calculated (Explanatory Note 4).

12. Variation in Area

12.1 The area of cross section of the conductor shall be not less than 98 % of the area specified. 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 question regarding area compliance, the method of 12.1.2 shall be used.

12.1.1 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.

12.1.2 The area of cross section of the wires 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. Workmanship, Finish and Appearance

13.1 The conductor shall be clean and free of imperfections not consistent with good commercial practice.

14. Mechanical and Electrical Tests

14.1 Tests for mechanical and electrical properties of aluminum alloy 6201 wires shall be made before stranding (Explanatory Note 5).

14.2 When requested by the purchaser at the time of purchase, tension tests of wires before stranding or of the conductor as a unit may be waived and tests made of aluminum wires removed from the conductor. When so tested, individual wires shall have minimum tensile strengths not less than 95 % of the tensile strength prescribed.

14.3 All wires composing the conductors shall be capable of meeting the bending properties stated in Specification B 398/B 398M after stranding. Routine production testing after stranding is not required unless agreed to between the manufacturer and the purchaser at the time of purchase.

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 to between the manufacturer and the purchaser at the time of the purchase.

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

16. Packaging and Package Marking

16.1 The net mass, length (and number of lengths if more than one is included in a package), size, kind of conductor, stranding, and any other necessary identification shall be marked on a tag attached to the end of the conductor inside the package. The same information, together with the purchase order number, the manufacturer's serial number (if any), and all shipping marks and other information required by the purchaser shall appear on the outside of each package.

NOTE 3—Multiple lengths per package are allowable only when the bare conductor is intended for remanufacture, such as adding a covering or insulation. In such cases the position of each end of a length is to be clearly marked and the length of each portion shall be shown on the tag attached to the end of the conductor.

16.2 Package sizes, and kind of package, reels, or coils shall be agreed upon between the manufacturer and the purchaser at the time of placing the order.

16.3 There shall be only one length of conductor on a reel when the conductor on the reel will not undergo further manufacturing processes.

16.4 The conductor 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.

17. Keywords

17.1 aluminum alloy conductors; aluminum electrical conductor; concentric-lay-stranded conductors; electrical conductor; electrical conductor-aluminum; stranded conductors

EXPLANATORY NOTES

NOTE 1—In this specification only concentric-lay-stranded conductor constructions manufactured from round aluminum-alloy 6201 wires are specifically designated. Conductor constructions not included in this specification 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—To test aluminum-alloy conductors for breaking strength successfully as a unit requires an adequate means of gripping the ends of the test specimen without causing damage that may result in failure below the actual strength of the conductor. Various special devices are available, such as compression sleeves, split sleeves, and preformed grips, but ordinary jaws or clamping devices usually are not suitable.

NOTE 4—The increment of mass or electrical resistance of a 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 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 stranding factor m for a standard conductor is the *numerical average* 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). The stranding factor ($m$ind) for any given wire in a concentric-lay-stranded conductor is:

$$m_{\text{ind}} = \sqrt{1 + 9.8696/n^2} \tag{2}$$

where n = length of lay per diameter of helical path of the wire. The derivation of the above is given in *NBS Handbook 100*.

NOTE 5—Wires unlaid from conductors may have different physical properties from those of the wire prior to stranding because of the deformation brought about by stranding and by straightening for test.

NOTE 6—The electrical characteristics of any conductor in service are influenced by conductivity, physical size, power frequency, temperature coefficient of resistance, etc., and it is not likely that one type of conductor may be stated to be the exact equivalent of another type except on a closely defined basis. For example, a conductor made of high-strength aluminum alloy may be designed to be the equivalent of a conductor made of aluminum 1350 on the basis of d-c resistance at 20°C, but it may not be an exact equivalent in other ways. The constructions shown in Table 1 were designed to have physical diameters the same as those of standard sizes and strandings of ACSR as shown, for which suitable accessories and fittings are readily available. The approximate aluminum 1350 equivalent sizes shown in Table 2 are those standard sizes of 26/7 and 6/1 ACSR having approximately the same d-c resistance at 20°C.