Designation: B399/B399M – 04 (Reapproved 2021)

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

This standard is issued under the fixed designation B399/B399M; 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 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 E527.

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.

1.3 *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 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:*[2]

B193 Test Method for Resistivity of Electrical Conductor Materials

B263 Test Method for Determination of Cross-Sectional Area of Stranded Conductors

B354 Terminology Relating to Uninsulated Metallic Electrical Conductors

B398/B398M Specification for Aluminum-Alloy 6201-T81 and 6201-T83 Wire for Electrical Purposes

B682 Specification for Standard Metric Sizes of Electrical Conductors

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

2.3 *ANSI Standards:*[3]

ANSI H35.1 American National Standard for Alloy and Temper Designation Systems for Aluminum

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

2.4 *NIST Standards:*[4]

NBS Handbook 100 Copper Wire Tables of the National Bureau of Standards

2.5 *Aluminum Association Publication:*[5]

Publication 50 Code Words for Overhead Aluminum Electrical Conductors

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,

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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.

[5] Available from Aluminum Association, Inc., 1525 Wilson Blvd., Suite 600, Arlington, VA 22209, http://www.aluminum.org.

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),
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 B398/B398M.

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.

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		Nominal dc Resistance @ 20°C	
			Size					Strand-ing	Number of Wires	Diameter of Wires		Class					
cmil	mm²		cmil[B]	AWG	mm²	cmil[B]	AWG	mm²			in.	mm		lb per 1000 ft	kg per	kips	kN	ohm per 1000 ft	ohm per
1 439 200	729	—	1 272 000	...	644.5	1 272 000	...	644.5	54/7	61	0.1536	3.90	AA	1342	1999	46.8	207	0.01400	0.04597
1 348 800	685	—	1 192 500	...	604.2	1 192 500	...	604.2	54/7	61	0.1487	3.78	AA	1258	1878	43.9	194	0.01494	0.04893
1 259 600	638	—	1 113 000	...	564.0	1 113 000	...	564.0	54/7	61	0.1437	3.65	AA	1175	1751	41.0	181	0.01600	0.05248
1 165 100	590	—	1 033 500	...	523.7	1 033 500	...	523.7	54/7	61	0.1382	3.51	AA	1086	1620	37.9	167	0.01730	0.05675
1 077 400	547	—	954 000	...	483.4	954 000	...	483.4	54/7	61	0.1329	3.38	AA	1005	1502	35.0	156	0.01870	0.06120
927 200	470	Greeley	795 000	...	402.8	795 000	...	402.8	26/7	37	0.1583	4.02	AA	864.6	1289	30.5	135	0.02173	0.07133
740 800	375	Flint	636 000	...	322.3	636 000	...	322.3	26/7	37	0.1415	3.59	AA	690.8	1028	24.4	107	0.02720	0.08944
652 400	331	Elgin	556 500	...	282.0	556 500	...	282.0	26/7	19	0.1853	4.71	AA	608.3	908.3	21.9	97.0	0.03089	0.1012
559 500	284	Darien	477 000	...	241.7	477 000	...	241.7	26/7	19	0.1716	4.36	AA	521.7	778.3	18.8	83.1	0.03602	0.1181
465 400	236	Cairo	397 500	...	201.4	397 500	...	201.4	26/7	19	0.1565	3.98	AA	433.9	648.6	15.6	69.2	0.04330	0.1417
394 500	200	Canton	336 400	...	170.5	336 400	...	170.5	26/7	19	0.1441	3.66	AA, A	367.9	548.5	13.3	58.6	0.05107	0.1676
312 800	159	Butte	266 800	...	135.2	266 800	...	135.2	26/7	19	0.1283	3.26	A	291.6	435.1	10.5	46.5	0.06443	0.2112
246 900	125	Alliance	211 600	0000	107.2	211 600	0000	107.2	6/1	7	0.1878	4.77	AA	230.2	343.2	8.56	37.8	0.08162	0.2678
195 700	99.3	Am-herst	167 800	000	85.0	167 800	000	85.0	6/1	7	0.1672	4.25	AA, A	182.5	272.5	6.79	30.0	0.1030	0.3373
155 400	78.6	Ana-heim	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	23.8	0.1297	0.4264
123 300	62.4	Azusa	105 600	0	53.5	105 600	0	53.5	6/1	7	0.1327	3.37	AA, A	114.9	171.3	4.27	18.9	0.1635	0.5365
77 470	39.2	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	12.4	0.2601	0.8547
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	67.80	1.76	7.83	0.4139	1.356
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	42.58	1.11	4.92	0.6588	2.159

[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 mm²
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

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 B682.

Conductor Size, mm²	Required Construction			Mass, kg per 1000 m	Rated Strength 6201-T81, kN	Nominal dc Resistance @ 20°C, ohm per 1000 m
	Number of Wires	Diameter of Wires, mm	Class			
630	37	4.66	AA	1731	181	0.05308
560	37	4.39	AA	1537	161	0.05981
500	37	4.15	AA	1373	143	0.06693
450	37	3.94	AA	1238	129	0.07426
400	37	3.71	AA	1097	115	0.08375
355	37	3.50	AA	976.7	102	0.09410
315	37	3.29	AA	863.0	90.2	0.10650
280	37	3.10	AA	766.2	83.9	0.11995
250	19	4.09	AA	684.9	73.1	0.13419
224	19	3.87	AA	613.2	65.5	0.14988
200	19	3.66	AA, A	548.5	58.6	0.16758
180	19	3.47	AA, A	493.0	52.6	0.18643
160	19	3.27	AA, A	437.8	46.7	0.20993
140	19	3.06	AA, A	383.4	42.9	0.23973
125	19	2.89	AA, A	342.0	38.3	0.26877
112	7	4.51	AA	306.8	33.8	0.29955
100	7	4.26	AA, A	273.8	30.2	0.33574
80.0	7	3.81	AA, A	219.0	24.1	0.41974
63.0	7	3.39	AA, A	173.4	19.1	0.53019
50.0	7	3.02	AA, A	137.6	15.9	0.66806
40.0	7	2.70	AA, A	110.0	12.7	0.83580
31.5	7	2.39	A	86.2	9.95	1.0667
25.0	7	2.13	A	68.4	7.90	1.3430
20.0	7	1.91	A	55.0	6.35	1.6702
16.0	7	1.71	A	44.1	5.09	2.0837

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.

TABLE 5 Rating Factors

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

the increment based on the specific lay of the conductor may be calculated (Explanatory Note 4).

11.2 The maximum electrical resistance of a unit length of stranded conductor shall not exceed 102 % of the nominal dc resistance shown in Table 1, Table 2, and Table 3 (Explanatory Note 7). When the dc resistance is measured at other than 20°C, it is to be corrected by using the multiplying factor given in Table 6.

TABLE 6 Temperature Correction Factors for Conductor Resistance

Temperature, °C	Multiplying Factor for Conversion to 20°C
0	1.075
5	1.055
10	1.036
15	1.018
20	1.000
25	0.983
30	0.966
35	0.951
40	0.935
45	0.920
50	0.906
55	0.892
60	0.878
65	0.865
70	0.852
75	0.840
80	0.828
85	0.816
90	0.805

11.3 For conductors to be used in covered or insulated wires or cables dc resistance measurements may be used in lieu of the method outlined in Section 12.

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 B263. 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 B398/B398M 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 B354.

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, and so forth, 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 dc 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 dc resistance at 20°C.

NOTE 7—The dc resistance on a given construction shall be calculated using the following formula:

Inch-Pound Units:

$$R = \left(\frac{k}{100} + 1\right) \times \frac{\rho}{A} \tag{3}$$

or Metric Units:

$$R = \left[\left(\frac{k}{100} + 1\right) \times \frac{\rho}{A}\right] \times 1000 \tag{4}$$

where:

R = conductor resistance in Ω/1000 ft (Ω/km),
k = increment due to stranding = 2 (from Section 11) and Explanatory Note 4,
ρ = volume resistivity in ohms-cmil/ft (Ω-mm^2/m), determined in accordance with Test Method B193, and
A = cross-sectional area of conductor in kcmil (mm^2) determined in accordance with Section 12 of this specification.