Designation: B401 – 12 (Reapproved 2016)

Standard Specification for Compact Round Concentric-Lay-Stranded Aluminum Conductors, Steel-Reinforced (ACSR/COMP)[1]

This standard is issued under the fixed designation B401; 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 compact round concentric-lay-stranded conductors made from aluminum 1350-H19 (extra hard) wires and round zinc-coated, aluminum-coated, or aluminum-clad steel core wires usually used in overhead lines. These conductors shall be constructed with one steel core wire surrounded by one or more layers of helically-laid compacted or otherwise shaped aluminum wires (Explanatory Note 1 and Note 2).

1.2 Compact ACSR covered by this specification has five types of steel core wire which are designated by abbreviations as follows (Explanatory Note 2 and Note 7).

1.2.1 *ACSR/GA2/COMP*—Compact ACSR using Class A zinc-coated steel wire,

1.2.2 *ACSR/GC2/COMP*—Compact ACSR using Class C zinc-coated steel wire,

1.2.3 *ACSR/AW2/COMP*—Compact ACSR using aluminum-clad steel wire, AW2 (Normal Strength).

1.2.4 *ACSR/AW3/COMP*—Compact ACSR using aluminum-clad steel wire, AW3 (High Strength).

1.3 The SI values of density and resistivity are to be regarded as standard. For all other properties the inch-pound values are to be regarded as standard and the SI units may be approximate.

NOTE 1—Prior to 1975, aluminum 1350 was designated as EC aluminum.

NOTE 2—The aluminum and temper designations conform to ANSI H35.1. Aluminum 1350 corresponds to Unified Numbering System A91350 in accordance with Practice E527.

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

B230/B230M Specification for Aluminum 1350–H19 Wire for Electrical Purposes

B232/B232M Specification for Concentric-Lay-Stranded Aluminum Conductors, Coated-Steel Reinforced (ACSR)

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

B341/B341M Specification for Aluminum-Coated (Aluminized) Steel Core Wire for Aluminum Conductors, Steel Reinforced (ACSR/AZ) (Withdrawn 2007)[3]

B354 Terminology Relating to Uninsulated Metallic Electrical Conductors

B498/B498M Specification for Zinc-Coated (Galvanized) Steel Core Wire for Use in Overhead Electrical Conductors

B502 Specification for Aluminum-Clad Steel Core Wire for Use in Overhead Electrical Aluminum Conductors

B802M Specification for Zinc-5% Aluminum-Mischmetal Alloy-Coated Steel Core Wire for Aluminum Conductors, Steel Reinforced (ACSR)[Metric](Discontinued 1998-Replaced by B 802/B802M) (Withdrawn 1998)[3]

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 *Other Documents:*

ANSI H35.1 American National Standard Alloy and Temper Designation Systems For Aluminum[4]

NBS Handbook 100 —Copper Wire Tables of the National Bureau of Standards [5]

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

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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] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[5] Available from National Technical Information Service (NTIS), 5301 Shawnee Rd., Alexandria, VA 22312, http://www.ntis.gov.

3. Ordering Information

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

3.1.1 Quantity of each size and stranding (Table 1),

3.1.2 Conductor size: circular-mil area or AWG (Section 6, and Table 1),

3.1.3 Steel wire coating or aluminum-clad (see 11.3),

3.1.4 Special tension test, if required (see 15.3),

3.1.5 Place of inspection (Section 16), and

3.1.6 Packaging and Package Marking (Section 17).

4. Joints

4.1 Electric-butt welds, electric-butt, cold-upset welds, or cold-pressure welds in the individual round-drawn or shaped aluminum wires may be made during the stranding process. No weld shall occur within 50 ft (15 m) of a weld in the same wire or in any other wire of the completed conductor.

4.2 There shall be no joints of any kind made in the finished coated, or aluminum-clad steel wires.

5. Lay

5.1 The preferred lay of the aluminum wires of aluminum conductors, steel-reinforced, having a single wire steel core and one layer of aluminum wires is 14 times the outside diameter of the conductor but the lay shall be not less than 13 nor more than 16 times that diameter.

5.2 The preferred lay of the outside layer of aluminum wires of aluminum conductors, steel-reinforced, having multiple layers of aluminum wires is 12 times the outside diameter of the conductor but the lay shall be not less than 11 nor more than 14 times that diameter.

5.3 The preferred lay of the layer immediately beneath the outside layer of aluminum wires of aluminum conductors, steel-reinforced, having multiple layers of aluminum wires is 14 times the outside diameter of such layer but the lay shall be not less than 11 nor more than 17.5 times that diameter.

5.4 The direction of lay of the outside layer of aluminum wires shall be right hand.

5.5 The direction of lay shall be reversed in successive layers.

6. Construction

6.1 The diameter of the steel core wire, the number of aluminum wires, the aluminum cross-sectional area, the diameter and weight of the compact round concentric-lay-stranded aluminum conductors, steel-reinforced, shall be as shown in Table 1.

7. Rated Strength of Conductor

7.1 The rated strength of a completed conductor shall be taken as the aggregate strength of the aluminum and steel components, calculated as follows: The strength contribution of the aluminum wires shall be taken as the percentage, according to the number of layers of aluminum wires, indicated in Table 2, of the sum of the strengths of the 1350-H19 wires, calculated on the basis of the nominal wire diameter for the corresponding noncompacted construction given in Specification B232/B232M and the appropriate specified minimum average tensile strength given in Specification B230/B230M. The strength contribution of the steel core shall be taken as 96 % of the strength of the steel wire calculated from its specified nominal diameter and the appropriate specified minimum stress at 1 % extension given in Specification B341/B341M, B498/B498M, B502, or B802M, whichever is applicable.

7.2 Rated strength and breaking strength values shall be rounded to three significant figures, in the final value only, in accordance with Practice E29.

7.3 Rated strength of conductors are given in Table 3.

8. Density

8.1 For the purpose of calculating mass, mass per unit length, cross sections, and so forth, the density of aluminum 1350 shall be taken as 2705 kg/m^3 (0.0975 lb/in.^{3}) at 20°C.

8.2 For the purpose of calculating mass, mass per unit length, cross sections, and so forth, the density of coated steel wire shall be taken as 7780 kg/m^3 (0.281 lb/in.^{3}) at 20°C.

TABLE 1 Construction Requirements for Compact Round Concentric-Lay-Stranded Aluminum Conductors, Steel Reinforced

Required Construction								Nominal Mass for Conductors With:			
Conductor Size (Aluminum Wires)			Number of Aluminum Wires	Steel Wire Diameter		Compact Conductor Diameter		Coated Steel Core Wire		Aluminum-Clad Steel Core Wire	
cmil	mm^2	AWG		in.	mm	in.	mm	lb/1000 ft	kg/km	lb/1000 ft	kg/km
336 400	170.2	...	18	0.1367	3.47	0.628	15.95	364.8	543.3	357.2	531.1
266 800	135.0	...	18	0.1217	3.09	0.559	14.20	289.1	430.8	283.1	421.1
211 600	107.2	0000	6	0.1878	4.77	0.517	13.13	290.8	433.4	276.5	412.1
167 800	85.1	000	6	0.1672	4.25	0.461	11.71	230.5	343.9.0	219.2	327.1
133 100	67.3	00	6	0.1489	3.78	0.410	10.41	182.8	272.3	173.8	258.9
105 600	53.5	0	6	0.1327	3.37	0.365	9.27	145.2	216.4	138.1	205.8
83 690	42.4	1	6	0.1181	3.00	0.326	8.28	115.0	171.4	109.4	163.0
66 360	33.6	2	7	0.1299	3.30	0.298	7.57	106.6	158.6	99.8	148.4
66 360	33.6	2	6	0.1052	2.67	0.290	7.37	91.2	135.9	86.8	129.2
52 620	26.7	3	6	0.0937	2.38	0.258	6.55	72.4	107.9	68.8	102.6
41 740	21.1	4	7	0.1029	2.61	0.236	5.99	67.0	99.7	62.7	93.4
41 740	21.2	4	6	0.0834	2.12	0.229	5.82	57.3	85.6	54.5	81.4
26 240	13.3	6	6	0.0661	1.68	0.182	4.62	36.0	53.7	...	...

TABLE 2 Strength Rating Factors

Stranding				Rating Factor, %	
Number of Wires		Number of Layers		Aluminum	Steel
Aluminum	Steel	Aluminum	Steel		
6	1	1	[A]	96	96
7	1	1	[A]	96	96
18	1	2	[A]	93	96

[A] Central steel wire only: the 96 % Rating Factor is applied to the single steel wire core in the event it contains a weld (made prior to drawing).

8.3 For the purpose of calculating mass, mass per unit length, cross sections, and so forth, the density of aluminum-clad steel wire shall be taken as 6590 kg/m^3 (0.2381 lb/in.^{3}) at 20°C.

9. Mass and Electrical Resistance

9.1 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 an increment of 1.5 % for conductors composed of 1 steel and 6 or 7 aluminum wires and an increment of 2 % for conductors composed of 1 steel and 18 aluminum wires. When greater accuracy is desired, the increment based on the specific lay of the conductor may be calculated (Explanatory Note 4).

9.2 In the calculation of the electrical resistance of a completed conductor, coated steel wires may be included.

9.3 The maximum electrical resistance of a unit length of stranded conductor shall not exceed 102 % of the nominal dc resistance shown in Table 4 (Explanatory Note 6). When the dc resistance is measured at other than 20°C, it is to be corrected by using the multiplying factor given in Table 5.

9.4 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.

10. Workmanship, Finish, and Appearance

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

11. Requirements for Wires

11.1 Before stranding and compacting, the round aluminum wire used shall conform to the requirements of Specification B230/B230M.

11.2 Aluminum wires shaped before stranding shall meet the requirements of Specification B230/B230M, except for shape, tensile and elongation requirements, and diameter tolerances. The minimum tensile and elongation requirements shall be 96 % of those for round wires of the same nominal area, provided the completed conductor is capable of meeting the requirements of Section 7. The area tolerances for the shaped wires shall be such that the finished conductor conforms to Section 12.

11.3 Before stranding, the steel core wire used shall conform to the requirements of Specification B341/B341M, B498/B498M, B502, or B802M, whichever is applicable.

12. Variation in Area

12.1 The cross-sectional area of the aluminum in wires of a compact round ACSR shall be not less than 98 % of the cross-sectional area as specified in column 1 of Table 1. The manufacturer shall determine the cross-sectional area by Test Method B263. In applying this method, the increment in weight resulting from stranding may be the applicable value specified in 9.1 or may be calculated from the measured dimensions of the sample under test. In case of question regarding area compliance, the actual mass increment due to stranding shall be calculated.

13. Variation in Diameter

13.1 The diameter of the compact round ACSR shall vary by not more than +1 –2 % from the diameter specified in Table 1.

14. Sampling

14.1 The aluminum cross-sectional area (Section 12) and the conductor diameter (Section 13) shall be measured on a sample of completed conductor. At least one sample shall be tested for each size of conductor on each order of quantities from 5000 to 100 000 ft (1500 to 30 000 m) and one additional sample tested from each 100 000 ft thereafter.

15. Mechanical and Electrical Tests

15.1 Tests for mechanical and electrical properties of aluminum wires composing the conductors shall be made before stranding (Explanatory Note 5).

15.2 Tests for the mechanical and electrical properties of the steel core wire shall be made before, but not after stranding, unless otherwise agreed by the manufacturer and the purchaser as provided in 15.3 (Explanatory Note 5).

15.3 At the option of the purchaser, at the time of placing the order, tension and elongation tests of wire before stranding may be waived, and the completed conductor may be tested as a unit. The minimum breaking strength of conductors so tested 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. of the end of, either gripping device. The free length between grips of the test specimen shall be not less than 24 in. (600 mm), and care shall be taken to ensure that the wires in the conductor are evenly gripped during the test (Explanatory Note 3).

16. Inspection

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

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

16.3 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.

TABLE 3 Rated Strengths for Compact Round Concentric-Lay-Stranded Aluminum Conductors, Steel-Reinforced

Conductor Size				Rated Strength For Conductors With:									
				Aluminum-Coated Steel Core Wire		Aluminum-Clad Steel Core Wire		Coated Steel Core Wire:					
								Class A		Class B		Class C	
cmil	mm^2	AWG	Number of Aluminum Wires	kips	kN	kips	kN	kips	kN	kips	kN	kips	kN
336 400	170.2	...	18	8.26	36.3	8.54	37.6	8.68	38.2	8.54	37.5	8.40	36.9
266 800	135.0	...	18	6.54	28.81	6.82	30.0	6.88	30.3	6.77	29.8	6.66	29.3
211 600	107.2	0000	6	7.42	32.9	7.69	34.1	8.35	37.1	8.08	35.9	7.95	35.3
167 800	85.1	000	6	5.88	26.1	6.30	28.0	6.62	29.4	6.41	28.5	6.30	28.1
133 100	67.3	00	6	4.88	21.4	5.13	22.5	5.30	23.3	5.13	22.5	5.05	22.2
105 600	53.5	0	6	3.98	17.6	4.25	18.8	4.38	19.4	4.25	18.8	4.12	18.2
83 690	42.4	1	6	3.29	14.4	3.45	15.1	3.55	15.6	3.45	15.1	3.34	14.7
66 360	33.6	2	7	3.26	14.4	3.51	15.6	3.64	16.1	3.51	15.6	3.39	15.0
66 360	33.7	2	6	2.64	11.7	2.76	12.3	2.85	12.7	2.76	12.3	2.68	11.9
52 620	26.7	3	6	2.13	9.44	2.23	9.89	2.29	10.2	2.23	9.91	2.17	9.61
41 740	21.1	4	7	2.16	9.60	2.28	10.1	2.36	10.5	2.28	10.2	2.20	9.81
41 740	21.2	4	6	1.76	7.83	1.78	7.95	1.86	8.30	1.81	8.07	1.76	7.83
26 240	13.3	6	6	1.12	4.98	Not Standard	Not Standard	1.19	5.28	1.16	5.13	1.12	4.98

TABLE 4 Nominal dc Resistance Values

Required Construction						Nominal dc Resistance @ 20°C for Conductors With:			
Conductor Size (Aluminum Wires)			Number of Aluminum Wires	Steel Wire Diameter		Coated Steel Core Wire		Aluminum-Clad Steel Core Wire	
cmil	mm^2	AWG		in.	mm	ohm/1000 ft	ohm/km	ohm/1000 ft	ohm/km
336 400	170.2	...	18	0.1367	3.472	0.05113	0.1680	0.05060	0.1662
266 800	135.0	...	18	0.1217	3.091	0.06451	0.2118	0.06384	0.2096
211 600	107.2	0000	6	0.1878	4.770	0.07956	0.2611	0.07720	0.2533
167 800	85.1	000	6	0.1672	4.247	0.1004	0.3288	0.09739	0.3191
133 100	67.3	00	6	0.1489	3.782	0.1266	0.4157	0.1228	0.4033
105 600	53.5	0	6	0.1327	3.371	0.1594	0.5230	0.1546	0.5074
83 690	42.4	1	6	0.1181	3.000	0.2012	0.6600	0.1952	0.6403
66 360	33.6	2	7	0.1299	3.299	0.2503	0.8239	0.2393	0.7874
66 360	33.6	2	6	0.1052	2.672	0.2536	0.8332	0.2460	0.8084
52 620	26.7	3	6	0.0937	2.380	0.3203	1.049	0.3107	1.017
41 740	21.1	4	7	0.1029	2.614	0.3985	1.309	0.3809	1.251
41 740	21.2	4	6	0.0834	2.118	0.4034	1.322	0.3914	1.282
26 240	13.3	6	6	0.0661	1.679	0.6423	2.104	...	...

17. Packaging and Package Marking

17.1 Package sizes and kind of package, reels, or coils shall be agreed upon between the manufacturer and the purchaser.

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

17.3 There shall be only one length of conductor on a reel.

17.4 The net mass, length, size, kind of conductor, stranding, kind of coating, class of zinc coating (if used), and any other necessary identification shall be marked on a tag attached to the end of the conductor inside the package. This 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 the package.

TABLE 5 Temperature Correction Factors for Conductor Resistance

Temperature, °C	Multiplying Factor for Conversion to 20°C
0	1.088
5	1.064
10	1.042
15	1.02
20	1.00
25	0.98
30	0.961
35	0.943
40	0.925

NOTE 1—Although the temperature coefficient of aluminum is different from steel, the approximate temperature correction factor is given in the above chart. For a more accurate conductor resistance calculation the individual resistance temperature coefficient for the aluminum and for the steel must be included in the dc resistance equations shown in Explanatory Note 6. As per ASTM B193, the 20°C temperature coefficient of resistance for 1350 aluminium at 61.0 % IACS is 0.00403. The 20°C temperature coefficient of resistance for aluminum clad steel at 20.3 %IACS is 0.00306. The 20°C temperature coefficient of resistance for zinc or aluminum coated steel is not defined in ASTM B193, however a approximated value of 0.005 has been used.

18. Keywords

18.1 aluminum conductors; aluminum conductors; steel-reinforced; aluminum electrical conductor; compact round stranded conductors; concentric-lay-stranded conductors; electrical conductor; electrical conductor-aluminum; steel-reinforced conductors; stranded conductors

EXPLANATORY NOTES

NOTE 1—In this specification, only compact round concentric-lay-stranded aluminum conductors, steel-reinforced, are specially designated. Conductor constructions not included in this specification should be specifically agreed upon between the manufacturer and the purchaser at the time of purchase.

NOTE 2—For definitions and terms relating to conductors, reference should be made to Terminology B354.

NOTE 3—To test stranded conductors for breaking strength successfully as a unit requires 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 means 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, mass per unit length, or electrical resistance of a completed concentric-lay-stranded conductor, k, in percent is:

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

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 stranding, that is, all wires parallel to the conductor axis. The stranding factor m for the completed stranded 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:

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

$$\text{where } n = \frac{\text{length of lay}}{\text{diameter of helical path of wire}}$$

The derivation of the above as given in *NBS Handbook 100* is based on the round-wire constructions which are applicable to compacted wire constructions.

NOTE 5—Individual wires are not to be unlaid from compact round conductors for testing purposes. Some physical properties of the individual wires may be altered by the deformation brought about by compacting, unlaying, and straightening for test. If tests on steel wires are to be made after stranding, the purchaser and the manufacturer should agree on the properties to be met at the time of placing the order.

NOTE 6—The dc resistance on a given construction shall be calculated using the following formula:

$$R = \left(\frac{1}{\left[\frac{1}{Ra} + \frac{1}{Rc} \right]} \right)$$

where:

Ra = dc resistance at 20°C for the aluminum strand wires, and
Rc = dc resistance at 20°C for the steel core.

Inch-Pound Units:

$$R_a = \left(\frac{k}{100} + 1 \right) \times \frac{\rho_a}{A_a}$$

$$R_c = \left(\frac{k}{100} + 1 \right) \times \frac{\rho_c}{A_c}$$

Metric Units:

$$R_a = \left(\frac{k}{100} + 1 \right) \times \frac{\rho_a}{A_a} \times 1000$$

$$R_c = \left(\frac{k}{100} + 1 \right) \times \frac{\rho_c}{A_c} \times 1000$$

where:

R = conductor dc resistance in Ω/1000 ft (Ω/km) at 20°C,
R_a = aluminum strand wire dc resistance in Ω/1000 ft (Ω/km) at 20°C,
R_c = steel core wire dc resistance in Ω/1000 ft (Ω/km) at 20°C,
k = increment due to stranding = 2 (from Section 11) and Explanatory Note 4,
ρ_a = volume resistivity in ohms-cmil/ft (Ω-mm^2/m), for the aluminum strand wires determined in accordance with Test Method B193,
ρ_c = volume resistivity in ohms-cmil/ft (Ω-mm^2/m), for the steel core wire determined in accordance with Test Method B193,
A_a = cross-sectional area of aluminum strand wires in the conductor in kcmil (mm^2) determined in accordance with Section 12 of this specification, and
A_c = cross-sectional area of the steel core wire in kcmil (mm^2) determined in accordance with Section 12 of this specification.

NOTE 7—Some of the abbreviations for standard aluminum conductors with steel core have changed. The following tabulation shows the new designations and the prior designations:
ACSR/GA2/COMP—was ACSR/GA/COMP
ACSR/GC2/COMP—was ACSR/GC/COMP
ACSR/AW2/COMP—was ACSR/AW/COMP
ACSR/AW3/COMP—none