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Standard Specification for Concentric-Lay-Stranded Aluminum-Alloy Conductors, Steel Reinforced (AACSR) (6201)[1]

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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 wire and round zinc-coated, Zn-5Al-MM coated, aluminum-coated, or aluminum-clad steel core wire for use as overhead electric conductors (Explanatory Note 1 and Note 2).

NOTE 1—All values are stated in SI units. No inch-pound equivalents are presented, nor is an inch-pound companion specification proposed.

NOTE 2—The alloy and temper designations conform to ANSI H35.1. Aluminum alloy 6201 corresponds to Unified Numbering System alloy A96201 in accordance with Practice E 527.

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 341 Specification for Aluminum-Coated (Aluminized) Steel Core Wire for Aluminum Conductors, Steel Reinforced (ACSR/AZ)[2]

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

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

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

B 498M Specification for Zinc-Coated (Galvanized) Steel Core Wire for Aluminum Conductors, Steel Reinforced (ACSR) [Metric][2]

B 500 Specification for Metallic Coated Stranded Steel Core for Aluminum Conductors, Steel Reinforced (ACSR)[2]

B 502 Specification for Aluminum-Clad Steel Core Wire for Aluminum Conductors, Aluminum-Clad Steel Reinforced[2]

B 606 Specification for High-Strength Zinc-Coated (Galvanized) Steel Core Wire for Aluminum and Aluminum-Alloy Conductors, Steel Reinforced[2]

B 802M Specification for Zinc-5% Aluminum-Mischmetal Alloy-Coated Steel Core Wire for Aluminum Conductors, Steel Reinforced (ACSR) [Metric][2]

B 803 Specification for High-Strength Zinc-5% Aluminum-Mischmetal Alloy-Coated Steel Core Wire for Aluminum and Aluminum-Alloy Conductors, Steel Reinforced[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 *American National Standards Institute Standard:*

H35.1M Alloy and Temper Designation Systems for Aluminum[5]

2.4 *Other Standard:*

NBS Handbook 100—Copper Wire Tables[6]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *AACSR*—covered by this specification has five types of coated steel and one type of aluminum-clad steel core wire which are designated by abbreviations as follows (Explanatory Note 2):

3.1.1.1 *AACSR/GA-AACSR*—using Class A zinc-coated steel wire (B 498).

3.1.1.2 *AACSR/GB-AACSR*—using Class B zinc-coated steel wire (B 498).

3.1.1.3 *AACSR/GC-AACSR*—using Class C zinc-coated steel wire (B 498).

3.1.1.4 *AACSR/AZ-AACSR*—using aluminum-coated (aluminized) steel wire (B 341).

3.1.1.5 *AACSR/HS-AACSR*—using extra high-strength steel wire (B 606).

3.1.1.6 *AACSR/AW-AACSR*—using aluminum-clad steel wire (B 502).

3.1.1.7 *AACSR/MA*—using Zn-5Al-MM coated steel core wire, coating Class A in accordance with Specification B B802M.

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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 American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036.

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

3.1.1.8 *AACSR/MB*—using Zn-5Al-MM coated steel core wire, coating Class B in accordance with Specification B 802M.

3.1.1.9 *AACSR/MC*—using Zn-5Al-MM coated steel core wire, coating Class C in accordance with Specification B 802M.

3.1.1.10 *AACSR/MC*—using high-strength Zn-5Al-MM coated steel core wire, coating Class A in accordance with Specification B 803.

4. Ordering Information

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

4.1.1 Quantity of each size and stranding,

4.1.2 Conductor size, square millimetres (Section 8 and Table 1),

4.1.3 Number of wires, aluminum and steel,

4.1.4 Type of steel core wire and, if galvanized or Zn-5Al-MM coated, class (A, B, or C) of coating (see 5.2),

4.1.5 Direction of lay of outer layer of aluminum wires if other than right-hand (see 7.2),

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

4.1.7 Place of inspection (Section 15),

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

4.1.9 Package size (see 17.1), and

4.1.10 Heavy wood lagging, if required (see 17.3).

5. Requirement for Wires

5.1 Before stranding, the aluminum-alloy wire shall meet the requirements of Specification B 398M.

5.2 Before stranding, the steel core wire shall meet the requirements of Specification B 341, B 498M, B 502, B 606, B 802M, or B 803, whichever is applicable.

5.3 Steel core supplied in a stranded construction shall meet the requirements of Specification B 500, if applicable.

TABLE 1 Construction Requirements of Aluminum-Alloy Conductors, Steel Reinforced, Concentric-Lay-Stranded

Conductor Area, mm^2			Stranding[A] and Wire Diameter				Diameter, mm		Rated Strength[B]	Mass[C]
Alloy Nominal	Steel	Total	Alloy		Steel		Conductor	Steel Core		
			Number	mm	Number	mm			kN	kg/km
1250	102	1352	84	4.35	19	2.61	47.8	13.0	490	4255
1120	91	1211	84	4.12	19	2.47	45.3	12.4	439	3816
1000	81	1081	84	3.89	19	2.33	42.8	11.6	391	3400
900	73	973	84	3.69	19	2.21	40.6	11.0	355	3060
800	101	901	54	4.34	19	2.60	39.0	13.0	363	3003
710	90	800	54	4.09	19	2.45	36.8	12.2	322	2664
630	80	710	54	3.85	19	2.31	34.6	11.6	286	2365
560	71	631	54	3.63	19	2.18	32.7	10.9	257	2104
500	63	563	54	3.43	19	2.06	30.9	10.3	229	1878
450	59	509	54	3.26	19	1.98	29.5	9.90	215	1706
400	91	491	30	4.12	19	2.47	28.8	12.4	237	1818
400	65	465	26	4.43	7	3.45	28.1	10.4	207	1616
355	81	436	30	3.88	19	2.33	27.2	11.6	211	1614
355	58	413	26	4.17	7	3.24	26.4	9.72	183	1430
315	72	387	30	3.66	19	2.20	25.6	11.0	190	1438
315	52	367	26	3.93	7	3.06	24.9	9.18	163	1272
280	65	345	30	3.45	7	3.45	24.2	10.4	171	1286
280	46	326	26	3.70	7	2.88	23.4	8.64	144	1127
250	58	308	30	3.26	7	3.26	22.8	9.78	156	1149
250	41	291	26	3.50	7	2.72	22.2	8.16	129	1008
224	52	276	30	3.08	7	3.08	21.6	9.24	139	1025
224	36	260	26	3.31	7	2.57	21.0	7.71	118	901
200	47	247	30	2.91	7	2.91	20.4	8.73	124	915
200	32	232	26	3.13	7	2.43	19.8	7.29	106	805
180	42	222	30	2.76	7	2.76	19.3	8.28	112	823
180	29	209	26	2.97	7	2.31	18.8	6.93	95.1	731
160	38	198	30	2.61	7	2.61	18.3	7.83	106	736
160	26	186	26	2.80	7	2.18	17.7	6.54	85.6	646
140	33	173	30	2.44	7	2.44	17.1	7.32	87.4	643
140	23	163	26	2.62	7	2.04	16.6	6.12	75.0	565

[A] Only those strandings with a relatively high steel content are listed. Other strandings are available by agreement between the purchaser and the producer.
[B] Rated strengths are for AACSR/GA and AACSR/MA conductors. Strengths were calculated in accordance with 9.1.
[C] Mass applies to AACSR/GA, AACSR/MA, and AACSR/AZ conductors.

6. Joints

6.1 Cold-pressure welds, electric-butt welds, and electric-butt, cold-upset welds in the finished individual aluminum alloy wires composing the conductor may be made during the stranding process. Following welding, electric-butt welds shall be annealed for a distance of at least 150 mm on each side of the weld. No weld shall occur within 15 m of a weld in the same wire or in any other wire of the completed conductor (Explanatory Note 3).

6.2 There shall be no joints made in the finished steel wires.

7. Lay Factors

7.1 The length of lay in the various layers of wire in a conductor shall conform to Table 2 (Explanatory Note 4).

7.2 The direction of lay of the outside layer of aluminum-alloy wires shall be right-hand unless otherwise specified in the purchase order. The direction of lay of the aluminum alloy and steel wires shall be reversed in successive layers.

8. Construction

8.1 The number and diameter of aluminum alloy and steel wires and the areas of cross section of aluminum alloy wires shall conform to the requirements prescribed in Table 1.

9. Rated Strength of Conductor

9.1 The rated strength of a conductor shall be taken as the aggregate strength of the aluminum alloy and steel components, calculated as follows: The strength contribution of the aluminum-alloy wires shall be taken as the percentage, according to the number of layers of aluminum-alloy wires indicated in Table 3, of the sum of the strengths of the 6201 wires, calculated from their specified nominal wire diameter and the appropriate specified minimum average tensile strength given in Specification B 398M. The strength contribution of the steel core wires shall be taken as the percentage, according to the number of layers of steel wires, indicated in Table 3, of the sum of the strengths of the steel wires, calculated from their specified nominal wire diameter and the appropriate specified ultimate tensile strength given in Specification B 498M, B 341, B 502, B 606, B 802M, or B 803, whichever is applicable.

9.1.1 The rated strengths of conductors calculated in accordance with 9.1 and 9.3 and using steel wires in accordance with Specification B 498M or B 802M, Class A coating are shown in Table 1.

9.2 Tests for demonstration of rated 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. If tested, the breaking strength of the conductor shall be not less than the rated strength if failure occurs in the free length at least 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 25 mm of the end of, either gripping device (Explanatory Note 5).

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 of Practice E 29.

TABLE 3 Rating Factors

Stranding					
Number of Wires		Number of Layers		Rating Factor, %	
Aluminum Alloy	Steel	Aluminum Alloy	Steel	Aluminum Alloy	Steel
12	7	1	1	96	96
24	7	2	1	93	96
26	7	2	1	93	96
30	7	2	1	93	96
42	7	3	1	91	96
45	7	3	1	91	96
48	7	3	1	91	96
54	7	3	1	91	96
72	7	4	1	90	96
16	19	1	2	96	93
30	19	2	2	93	93
54	19	3	2	91	93
76	19	4	2	90	93
84	19	4	2	90	93

10. Density

10.1 For the purpose of calculating mass, cross sections, etc., the density of aluminum-alloy 6201 shall be taken as 2690 kg/m^3 at 20°C.

10.2 For the purpose of calculating mass, cross sections, etc., the density of coated steel wire shall be taken as 7780 kg/m^3 at 20°C.

10.3 For the purpose of calculating mass, cross sections, etc., the density of aluminum-clad steel wire shall be taken as 6590 kg/m^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 approximate mass and electrical resistance may be determined using the standard increments shown in Table 4. When greater

TABLE 2 Lay Factors of Aluminum-Alloy Conductors Steel Reinforced

Stranding	Ratio of Length of Lay of a Layer to Nominal Outside Diameter of That Layer															
	Aluminum-Alloy Wire Layers										Steel Wire Layers					
	First (Outside)			Second			Third		Fourth		12-Wire			6-Wire		
	Min	Pref[A]	Max	Min	Pref	Max	Min	Max	Min	Max	Min	Pref	Max	Min	Pref	Max
84/19	10	11	13	10	13	16	10	17	10	17	16	20	24	18	25	30
76/19	10	11	13	10	13	16	10	17	10	17	16	20	24	18	25	30
54/19	10	11	13	10	13	16	10	17	...	...	16	20	24	18	25	30
54/7	10	11	13	10	13	16	10	17	...	...	...	...	...	18	25	30
30/7	10	11	13	10	13	16	...	...	...	...	...	...	...	18	25	30
26/7	10	11	13	10	13	16	...	...	...	...	...	...	...	18	25	30

[A] Preferred (Pref).

TABLE 4 Standard Increments Due to Stranding

Stranding of AACSR Number of Wires		Increment (Increase), %		
		Mass		
Aluminum Alloy	Steel	Aluminum Alloy	Steel	Electrical Resistance
12	7	2.5	0.4	2.5
24	7	2.5	0.4	2.5
26	7	2.5	0.4	2.5
30	7	2.75	0.4	2.75
42	7	2.5	0.4	2.5
45	7	2.5	0.4	2.5
48	7	2.5	0.4	2.5
54	7	2.5	0.4	2.5
72	7	3.0	0.4	3.0
16	19	2.5	0.6	2.5
30	19	2.75	0.6	2.75
54	19	3.0	0.6	3.0
76	19	3.0	0.6	3.0
84	19	3.0	0.6	3.0

accuracy is desired, the increment based on the specific lay of the conductor may be calculated (Explanatory Note 6).

11.2 In the calculation of the electrical resistance of a completed conductor, the resistivity of coated steel core wires shall be taken as 0.19157 Ω-mm^2/m at 20°C, and the resistivity of aluminum-clad steel core wires shall be taken as 0.0848 Ω-mm^2/m at 20°C.

12. Variation in Area

12.1 The area of cross section of the aluminum-alloy wires of a 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 may be determined by calculations from diameter measurements, expressed to three decimal places, of the component aluminum wires at any point when measured perpendicularly to their axes.

12.1.2 The area of cross section of the aluminum-alloy wires of a conductor may be determined by Test Method B 263. In applying that method the increment in linear density 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 linear density increment due to stranding shall be calculated.

13. Finish

13.1 The conductor shall be 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 wires shall be made before stranding (Explanatory Note 7).

14.2 All aluminum-alloy wires composing the conductors shall be capable of meeting the bending properties stated in Specification B 398 after stranding. Routine production testing after stranding is not required.

14.3 Routine production testing after stranding is not required. However, when such tests are requested by the purchaser and agreed upon by the manufacturer at the time of ordering (or made for other reasons), aluminum wires removed from the completed conductor shall have tensile strengths of not less than 95 % of the minimum tensile strength specified for the wire before stranding. The electrical resistivity shall meet the minimum resistivity specified for wire before stranding. Elongation tests may be made for information purposes only and no minimum values are assigned (Explanatory Note 7). The frequency of these tests shall be decided upon between the purchaser and the manufacturer.

14.4 Tests for all properties of steel wire shall be made before stranding (Explanatory Note 7).

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 manufacturer's facilities to satisfy him that the material is being furnished in accordance with this specification.

16. Product Marking

16.1 The net mass, length, size, kind of conductor, stranding, type of coating, class of 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.

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 (Explanatory Note 8).

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

17.3 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 placing the purchaser order.

18. Keywords

18.1 aluminum conductor; aluminum-alloy conductor; aluminum-allow conductor—steel reinforced; electrical conductor; electrical conductor—aluminum; stranded aluminum conductor; stranded electrical conductor

EXPLANATORY NOTES

NOTE 1—In this specification only concentric-lay-stranded aluminum-alloy conductor, steel-reinforced, are specifically designated.

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

NOTE 3—The behavior of properly spaced wire joints in stranded conductors is related to both their tensile strength and elongation. Because of its higher elongation properties, the lower-strength electric-butt weld gives equivalent over-all performance to that of a cold-pressure weld or an electric-butt, cold-upset weld in stranded conductors.

NOTE 4—The preferred ratio of the lay with respect to the outside diameter of a layer of wires varies for different layers and for different diameters of the conductor, being larger for the inside layers than for the outside layer, and larger for conductors of small diameter than for those of larger diameter.

NOTE 5—To test AACSR for breaking strength successfully as a unit requires special devices for gripping the ends of the aluminum-alloy and steel wires without causing damage that may result in failure below the actual strength of the conductor. Various special dead-end devices are available such as compression sleeves and split sleeves, but ordinary jaws or clamping devices usually are not suitable.

NOTE 6—The increment of mass 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:

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

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

The factors k and m for composite conductors are to be determined separately for each different material involved.

NOTE 7—Wires unlaid from conductor may have different mechanical properties from those of the wire when prepared for stranding because of the deformation brought about by stranding and by straightening for test. If tests on steel wires are to be made after stranding, the purchaser and the manufacturer at the time of placing the order should agree on the properties to be met.

NOTE 8—Owing to the variation in coil masses, etc., it is common practice to allow a permissible variation in length of ±5 % for sizes larger than 40 mm^2 and a tolerance of ±10 % on sizes 40 mm^2 and smaller. It is also common practice to allow an amount not exceeding 10 % of the total weight of any one order to be shipped in random lengths but no piece shorter than 50 % of the standard length ordered.