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Standard Specification for Concentric-Lay-Stranded Aluminum Conductors, Composite Reinforced (ACCR)[1]

This standard is issued under the fixed designation B978/B978M; 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-zirconium alloy wires and an aluminum matrix composite (AMC) core wire(s) for use as overhead electrical conductors (Explanatory Note 1 and Explanatory Note 2).

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

2. Referenced Documents

2.1 The following documents form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards:*[2]

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

B354 Terminology Relating to Uninsulated Metallic Electrical Conductors

B682 Specification for Metric Sizes of Electrical Conductors

B941 Specification for Heat Resistant Aluminum-Zirconium Alloy Wire for Electrical Purposes

B976 Specification for Fiber Reinforced Aluminum Matrix Composite (AMC) Core Wire for Aluminum Conductors, Composite Reinforced (ACCR)

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

2.3 *NIST Document:*[3]

NBS Handbook 100 —Copper Wire Tables

2.4 *Aluminum Association Documents:*[4]

Publication 50 Code Words for Overhead Aluminum Electrical Conductors

Aluminum Association Guideline A Method of Stress-Strain Testing of Aluminum Conductors and ACSR and a Test Method for Determining the Long Time Creep of Aluminum Conductors in Overhead Lines

3. Terminology

3.1 *Acronyms:*

3.1.1 *ACCR*—aluminum conductor, composite reinforced

3.1.2 *AMC*—aluminum matrix composite

3.1.3 *Al-Zr*—aluminum zirconium

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 (Section 8 and Table 1 and Table 2),

4.1.3 Number of wires, aluminum-zirconium alloy and AMC (see Table 1 and Table 2),

4.1.4 Type of AMC core wires (see 5.3),

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

4.1.6 Special tension test, if desired (see 14.3),

4.1.7 Place of inspection (Section 16),

4.1.8 Package size and type (see 17.1),

4.1.9 Heavy wood lagging, if required (see 17.3), and

4.1.10 Special package marking, if required (see 17.4).

5. Requirement for Wires

5.1 Tests for mechanical and electrical properties of aluminum-zirconium alloy and core wires shall be made before stranding.

5.2 Before stranding, the aluminum-zirconium alloy wire used shall meet the requirements of Specification B941.

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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 National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, http://www.nist.gov.

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

TABLE 1 Construction Requirements of Aluminum Conductors, Composite Reinforced (ACCR)

Designation	Nominal, kcmil	Stranding, Aluminum-Zirconium Alloy/AMC	Rated Strength, lb	Cross Sectional Area, in.^{2}		Layers of Aluminum-Zirconium Alloy	Diameter				Total Mass (lb)/1000 ft
							Individual Wires				
				Aluminum-Zirconium Alloy	Total		Aluminum-Zirconium Alloy, in.	AMC, in.	AMC Core, in.	Complete Cable, in.	
300-T16	297	26/7	12100	0.233	0.271	2	0.107	0.083	0.249	0.677	337
336-T16	340	26/7	13900	0.267	0.310	2	0.114	0.089	0.267	0.724	385
477-T16	470	26/7	19200	0.369	0.429	2	0.134	0.105	0.314	0.852	533
557-T16	573	26/7	23100	0.450	0.524	2	0.149	0.116	0.347	0.941	650
636-T16	656	26/19	25600	0.516	0.598	2	0.159	0.074	0.371	1.006	740
795-T16	824	26/19	32200	0.648	0.751	2	0.178	0.083	0.416	1.128	930
954-T13	967	54/19	33200	0.760	0.856	3	0.134	0.080	0.402	1.205	1059
1033-T13	1036	54/19	35600	0.814	0.917	3	0.139	0.083	0.416	1.247	1134
1272-T11	1236	51/19	38500	0.972	1.075	3	0.156	0.083	0.416	1.350	1.325
1351-T13	1334	54/19	45300	1.048	1.180	3	0.157	0.094	0.472	1.415	1460
1590-T11	1594	51/19	49500	1.252	1.385	3	0.094	0.177	0.472	1.532	1.706

Conversion factors:
1 cmil = 5.067 E – 4.0 mm^2
1 in. = 2.54 E + 01 mm
1lb/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 N

TABLE 2 Construction Requirements of Aluminum Conductors, Composite Reinforced (ACCR) – Metric

Designation	Nominal, mm^2	Stranding Aluminum-Zirconium Alloy/AMC	Rated Strength, kN	Cross Sectional Area, mm^2		Layers of Aluminum-Zirconium Alloy	Diameter				Total Mass kg/m
							Individual Wires				
				Aluminum-Zirconium Alloy	Total		Aluminum-Zirconium Alloy, mm	AMC, mm	AMC Core, mm	Complete Cable, mm	
300-T16	150	26/7	53.8	150	175	2	2.7	2.1	6.3	17.2	0.501
336-T16	172	26/7	61.8	172	200	2	2.9	2.3	6.8	18.4	0.573
477-T16	238	26/7	85.4	238	277	2	3.4	2.7	8.0	21.6	0.793
556-T16	291	26/7	102.8	291	338	2	3.8	2.9	8.8	23.9	0.967
636-T16	333	26/19	113.9	332	385	2	4.0	1.9	9.4	25.5	1.101
795-T16	418	26/19	143.2	418	484	2	4.5	2.1	10.6	28.6	1.384
954-T13	490	54/19	147.7	490	552	3	3.4	2.0	10.2	30.6	1.576
1033-T13	525	54/19	158.4	525	591	3	3.5	2.1	10.6	31.7	1.687
1272-T11	627	51/19	171.3	627	694	3	4.0	2.1	10.6	34.3	1.972
1351-T13	676	54/19	201.5	676	761	3	4.0	2.4	12.0	35.9	2.172
1590-T11	806	51/19	220.2	808	894	3	4.5	2.4	12.0	38.9	2.539

Conversion factors:
1 cmil = 5.067 E – 4.0 mm^2
1 in. = 2.54 E + 01 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 N

5.3 Before stranding, the AMC core wire used shall meet the requirements of Specification B976.

6. Joints

6.1 Electric-butt welds, cold-pressure welds, and electric-butt, cold-upset welds in the finished individual aluminum-zirconium alloy wires composing the conductor may be made during the stranding process. No weld shall occur within 50 ft [15 m] of any weld in the completed conductor (Explanatory Note 3).

6.2 There shall be no joints of any kind made in the finished AMC core wires.

7. Lay

7.1 The length of lay of the various layers of wires in a conductor shall conform to Table 3 (see Explanatory Note 4). These are expressed in values of lay ratio.

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

7.3 The direction of lay of the core wires shall preferably be unidirectional in successive layers. Use of core wires reversed

TABLE 3 Lay Factors for Aluminum Conductors, Composite-Reinforced, Concentric-Lay-Stranded

Standing Class	Stranding	Ratio of Length of Lay of a Layer to Nominal Outside Diameter of That Layer														
		Aluminum-Zirconium Alloy Wire Layers									AMC Layers					
		First (Outside)			Second			Third			12 Wire			6 Wire		
		Min	Preferred	Max	Min	Preferred	Max	Min	Preferred	Max	Min	Preferred	Max	Min	Preferred	Max
AA	26/7	10	11.5	13	10	13	16	—	—	—	—	—	—	58	66	80
	26/19	10	11.5	13	10	13	16	—	—	—	58	66	80	58	66	80
	54/19	10	11.5	13	10	13	16	10	13.5	17	58	66	80	58	66	80

in successive layers may be acceptable upon agreement between the supplier and the purchaser.

7.4 The direction of lay of the inner Al-Zr alloy wires may be either unidirectional or reversed relative to the direction of lay of the outside layer of the core wires.

8. Construction

8.1 The number and diameter of aluminum-zirconium alloy and AMC wires and the area of cross section of aluminum-zirconium alloy wires shall conform to the requirements prescribed in Table 1 and Table 2.

9. Rated Strength of Conductor

9.1 The rated strength of a completed conductor shall be taken as the sum of the aluminum-zirconium alloy load rating and the AMC load rating, calculated as follows.

9.1.1 The strength contribution of the aluminum alloy wires shall be taken as:

$$\text{Aluminum zirconium alloy load} = (\text{min wire strength} \times \text{nominal wire area}) \times (0.967) \times \text{number strands} \times \text{stranding derating factor}$$

(See Explanatory Note 5) for more information.)

9.1.2 The minimum aluminum-zirconium alloy wire strength and nominal diameter may be obtained from Specification B941. The number of strands is found in Table 1 and Table 2, and the stranding derating factor is found in Table 4. The strength contribution of the AMC core wires shall be taken as:

$$\text{Core load} = \text{min wire load} \times \text{number strands} \times \text{stranding factor}$$

9.1.3 The minimum core wire strength may be obtained from Specification B976. The number of strands is found in Table 1 and Table 2, and the stranding factor is found in Table 4.

9.2 Rated strengths of various constructions are given in Table 1 and Table 2.

10. Density

10.1 For the purpose of calculating mass per unit length, cross sections, etc., the density of the aluminum-zirconium alloy shall be taken as 2698 kg/m^3 [0.0975 lb/in.^{3}] at 20°C.

10.2 For the purpose of calculating mass per unit length, cross sections, etc., the density of the AMC wire shall be taken as 3370 kg/m^3 [0.122 lb/in.^{3}] at 20°C.

TABLE 4 Standard Increments and Rating Factors for Mass Per Unit Length, Resistivity, and Rated Strength Determination

Stranding Design	Standard Increments Due to Stranding (for mass per unit length and resistivity) Increase		Stranding Derating Factors (for rated strength)	
Aluminum-Zirconium Alloy/AMC	Aluminum-Zirconium Alloy (%)	Core (%)	Aluminum-Zirconium Alloy (%)	Core (%)
Round Wires				
26/7	2.5	0	93	96
26/19	2.5	0	93	92
54/19	3.0	0	91	92

11. Mass Per Unit Length and Electrical Resistance

11.1 The mass per unit length 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 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 conductor, the AMC core wires may be included. The electrical resistance of the AMC core wires shall be taken as 39.88 Ω·cmil/ft [0.0642 Ω·mm^2/m] at 68°F [20°C]. The electrical resistance of aluminum-zirconium wires shall be taken as 17.28 Ω·cmil/ft [0.02873 Ω·mm^2/m] at 68°F [20°C]. These are typical DC resistance values, not minimum values.

12. Cross-sectional Area

12.1 The area of cross section of the aluminum-zirconium 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 four decimal places for inches or three decimal places for millimeters, of the component aluminum-zirconium alloy wires at any point when measured perpendicularly to their axes.

12.1.2 The area of cross section of the aluminum-zirconium alloy wires of a conductor may be determined by Test Method B263. In applying that test method the increment in mass per unit length 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 questions regarding area compliance, the actual mass per unit length 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, Electrical and Dimensional Tests

14.1 *Classification of Tests:*

14.1.1 *Type Tests*—Type tests are intended to verify the main characteristics of a conductor which depend mainly on its design. They are carried out once for a new design or manufacturing process of conductor and then subsequently repeated only when the design or manufacturing process is changed.

14.1.2 *Production Sample Tests*—Production sample tests are intended to guarantee the quality of conductors and compliance with the requirements of this standard.

14.2 *Type Test Requirements:*

14.2.1 Type tests require measurement of (*a*) the breaking strength of the conductor, and (*b*) measurement of the stress-strain curves.

14.2.1.1 The breaking load of the conductor may be measured by terminating a length of conductor at least 2.5 m [9.5 ft] in length with suitable termination fittings. The conductor is placed in a tensile test frame and loaded with a steadily increasing load until failure occurs. The test should be performed at a rate of 1 % strain per minute (typically less than 2 minutes per test). The breaking load should be recorded. If failure of the specimen occurs within 150 mm [6 in.] of the end terminations, and if the failure load does not exceed the rated strength of the specimen, then the test result may be discarded and the test should be repeated with a new specimen.

14.2.1.2 The stress-strain measurements should follow the test procedure in the Aluminum Association Guideline, "A Method of Stress-Strain Testing of Aluminum Conductors and ACSR and A Test Method for Determining the Long Time Creep of Aluminum Conductors in Overhead Lines."

14.3 *Production Sample Test Requirements:*

14.3.1 Tests for all properties of aluminum-zirconium alloy wires shall be made before stranding (Explanatory Note 7).

14.3.2 Tests on aluminum-zirconium alloy wires should follow the requirements of Specification B941. These require measurement of diameter, electrical resistivity, tensile strength, tensile elongation, heat resistance (only the 280°C/1 hr test is required), and wrapping.

14.3.3 Tests for all properties of AMC wires shall be made before stranding (Explanatory Note 7).

14.3.4 Tests on AMC wires should follow the requirements of Specification B976. This requires measurement of diameter, electrical resistivity, and tensile breaking load.

14.3.5 Routine production testing of wires after stranding is not required. However, when such tests are requested by the purchaser and agreed to by the manufacturer at the time of placing the order (or made for other reasons) aluminum-zirconium alloy and AMC 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 maximum resistivity specified for the wire before stranding. Elongation tests may be made for information purposes only and no minimum values are assigned (Explanatory Note 7).

14.3.6 Routine production testing of conductor after stranding is required. Tests shall be conducted for diameter, mass per unit length, lay ratio and lay direction. Specimens for these tests shall be taken at random from the outer end of 10 % of the reels of conductor.

14.3.7 Tests for demonstration of rated strength of the completed 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 completed conductor shall be not less than the rated strength if failure occurs in the free length at least 150 mm [6 in.] beyond the end of either gripping device, or shall be not less than 95 % of the rated strength if failure occurs within 150 mm [6 in.] of the end of either gripping device.

14.3.8 Conductor diameter shall be measured preferably using a micrometer with 75 mm [3 in.] long parallel platens or by using calipers. The diameter shall be the average of two readings rounded to the nearest 0.01 mm [0.005 in.], and taken 90° from each other at the same location. The conductor diameter shall be measured between the closing die and the capstan on the stranding machine. The diameter of the conductor shall not vary by more than ±2 % from the specified diameters of Table 1 and Table 2.

14.3.9 Mass per unit length shall be measured using an apparatus capable of an accuracy of ±0.1 %. The mass per unit length of the conductor shall not vary by more than ±4 % from the specified nominal values in Table 1 and Table 2.

14.3.10 Lay ratio and direction of lay shall conform to the requirements of Section 7.

14.3.11 Testing frequencies are summarized in Table 5.

15. Tests and Retests

15.1 If upon testing a sample from any reel or coil of conductor the results do not conform to the requirements of Section 9 and Section 10, at least one more additional sample shall be tested, and the average of the tests shall determine the acceptance of the reel or coil.

15.2 If any of the lot is rejected, the manufacturer shall have the right to test all individual reels of conductors in the lot and submit those which meet the requirements for acceptance.

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 especially agreed upon between the manufacturer and the purchaser at the time of the purchase.

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

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 at the time of placing the order. Recommended package sizes are shown in Table 6 or Table 7. Drum sizes of reels for ACCR shall be a minimum of 1067 mm [42 in.]. RMT 84.36, 90.45, 84.45, 96.60 all have a standard 1067 mm [42 in.] drum

TABLE 5 Production Sample Testing Frequency

Constituent	Sampling Frequency	Testing Location	Required Properties Tested
Aluminum-zirconium wires	see Specification B941	by strander	strength, diameter, elongation, resistivity, heat resistance, ductility (wrap) test
AMC wires	see Specification B976	by core wire supplier	diameter, strength, resistivity/ conductivity
Conductor	10 % of produced reels	by strander	diameter, lay lengths, lay directions, mass per unit length

TABLE 6 Packaging Information: Recommended Reel Sizes, Shipping Lengths, and Net Masses

Designation	Conductor Size, kcmil	Stranding Design Aluminum-Zirconium Alloy/AMC	Reel Type RMT[A] Reel Size[B]	Reel Type RMT[A] Max Length on Reel, ft	Reel Type RMT[A] Net Mass, lb
Round Wires					
300-T16	297.0	26/7	84.36	20 000	8450
336-T16	340.0	26/7	84.36	16 390	7200
477-T16	470.0	26/7	84.36	11 560	7050
556-T16	573.0	26/7	84.36	9140	6850
636-T16	656.0	26/19	84.36	8000	6800
795-T16	824.0	26/19	84.36	6940	7350
954-T13	967.0	54/19	90.45	9600	11 050
1033-T13	1036.0	54/19	90.45	8870	10 950
1272-T11	1238	51/19	90.45	7175	10 400
1351-T13	1334.0	54/19	90.45	6755	10 750
1590-T11	1594	51/19	90.45	5740	10 700

[A] Prefix “RMT” metal returnable reel with I-beam tires.
[B] Reels are not designed to withstand the forces required for braking during tension stringing operations.

TABLE 7 Packaging Information: Recommended Reel Sizes, Shipping Lengths, and Net Masses (Metric)

Designation	Conductor Size, mm^2	Stranding Design Aluminum-Zirconium Alloy/AMC	Reel Type RMT[A] Reel Size[B]	Reel Type RMT[A] Max Length on Reel, m	Reel Type RMT[A] Net Mass, kg
Round Wires					
300-T16	150	26/7	84.36	6100	3835
336-T16	172	26/7	84.36	5000	3280
477-T16	238	26/7	84.36	3525	3210
556-T16	291	26/7	84.36	2785	3110
636-T16	333	26/19	84.36	2440	3100
795-T16	418	26/19	84.36	2115	3340
954-T13	490	54/19	90.45	2925	5030
1033-T13	525	54/19	90.45	2700	4980
1272-T11	627	51/19	90.45	2190	4720
1351-T13	676	54/19	90.45	2060	4890
1590-T11	806	51/19	90.45	1750	4850

[A] Prefix “RMT” metal returnable reel with I-beam tires.
[B] Reels are not designed to withstand the forces required for braking during tension stringing operations.

diameter. Reel type RMT is the recommended reel type for all ACCR conductors. Wood lagging is also recommended for conductor protection.

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 purchase order.

17.4 The net mass, length, size, kind of conductor, reel identification, and order number shall be marked on a tag attached to the end of the conductor inside the package. Any other information required shall be agreed upon between the purchaser and the supplier.

18. Keywords

18.1 ACCR; aluminum conductor, composite reinforced; aluminum matrix composite; electrical conductors; HTLS – high temperature low sag conductors

EXPLANATORY NOTES

NOTE 1—In this specification only concentric-lay-stranded aluminum conductors, composite-reinforced, are specifically designated. Conductor constructions not included in this specification should be 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—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 overall 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 length with respect to the outside diameter of a layer of wires varies for different layers and for different diameters of the conductors, being larger for the inside layers than for the outside layer, and larger for conductors of small diameter than for those of large diameter.

NOTE 5—The strength derating factor for 0.64 % strain recognizes that the aluminum-zirconium alloy does not reach the ultimate strength before the core fails. This strength derating factor is taken as 0.967.

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 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 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 =

$$\frac{\text{length of lay}}{\text{diameter of helical path of the wire}}$$

The derivation of the above is given in *NBS Handbook 100* Copper Wire Tables. The factors k and m are to be determined separately for the AMC wires (Section 8).

NOTE 7—Wires unlaid from conductors may have different physical properties from those of the wire prior to stranding because of the deformation caused by stranding and straightening for test. If tests on either core or aluminum-zirconium alloy wires are to be made after stranding, the properties shall reflect the adjustment stated in 14.3.5.