Designation: B941 – 16

Standard Specification for Heat Resistant Aluminum-Zirconium Alloy Wire for Electrical Purposes[1]

This standard is issued under the fixed designation B941; 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 heat resistant aluminum-zirconium alloy round wire for electrical purposes. There is a family of aluminum-zirconium alloys that are used for heat-resistance (that is, resist annealing), which differ by zirconium content, tensile strength, electrical conductivity, and maximum use temperature. This standard covers one currently commercially applicable alloy from this family.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 The following documents of the issue in effect on the 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

B557 Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products

B830 Specification for Uniform Test Methods and Frequency

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *lot*—a group of production units, up to 30 000 1b [15 000 kg] of mass, of one type and size of wire, which was produced during the same time period, under similar production conditions, and. is presented for acceptance at the same time (Explanatory Notes 1 and 2).

3.1.2 *production unit*—a coil, reel, spool, or other package of wire that represents a single usable length.

3.1.3 *sample*—the production unit(s) from which a test specimen(s) has been removed, and which is considered to have properties representative of the lot.

3.1.4 *specimen*—a length of wire removed for test purposes.

4. Ordering Information

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

4.1.1 Quantity of each size,
4.1.2 Wire size (see 11.1 and 11.2),
4.1.3 Special tension test, if required (see 6.1, 6.2 and 7.1),
4.1.4 Frequency of bending test (see 8.1 and 14.7),
4.1.5 Special jointing procedures, if permitted (see 12.1),
4.1.6 Place of inspection (see 16.2),
4.1.7 Package size and type (see 17.1),
4.1.8 Special package marking, if required (see 17.4).

5. Materials and Manufacture

5.1 The aluminum wire shall be made from drawing stock. The rod shall have properties such that once drawn into wire, the wire properties set forth in Table 1 are met.

5.2 The wire shall be aluminum-zirconium alloy of such quality and purity that the finished product shall have the properties and characteristics prescribed in this specification, including tensile, elongation, heat resistance properties, bending properties, and electrical resistivity. Chemical analysis of a specific alloy is not a requirement of this specification unless definite agreement is reached between the manufacturer and the purchaser on individual orders.

6. Tensile Properties

6.1 *Tensile Strength and Elongation*—The wire shall conform to the tensile strength and elongation requirements set forth in Table 1 (Explanatory Note 3).

[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.

TABLE 1 Tensile Strength and Elongation Requirements

Diameter		Tensile Strength		Heat Resistance	Elongation in 10 in. (250 mm)
in.	(mm)	min ksi	min (MPa)	(%)	min (%)
0.050-0.128	(1.25-3.25)	24.0	(165)	90 % of Minimum	2 %
0.128-0.154	(3.25-3.91)	23.5	(162)	90 %	2 %
0.154-0.185	(3.91-4.70)	23.0	(159)	90 %	2 %
> 0.185	(> 4.70)	22.5	(155)	90 %	2 %

6.2 When requested by the purchaser, tension tests shall be made of specimens of wire containing joints made in the drawing stock or in the wire prior to final drawing. Such tests shall indicate tensile strengths not less than 90 % of the values for individual tests shown in Section 6.1.

7. Heat Resistance

7.1 Heat resistance tests (see section 14.4) shall indicate strengths not less than 90 % of the values for individual tests shown in Table 1. For the smallest size group, heat resistance values shall not be less than 90 % of the minimum strength specification. (Explanatory Note 5).

8. Wrap Test

8.1 The wire shall be free of brittleness as evidenced by its ability to be coiled or looped at least six times around its own diameter in a close helix, with or without a mandrel (see section 14.7). No fracture shall occur. Slight surface checks shall not constitute cause for rejection.

9. Resistivity

9.1 Electrical resistivity, determined on samples of drawn wire selected and tested in accordance with Test Method B193, shall not exceed 17.28 Ω.cmil/ft (0.02873 Ω.mm^2/m) at 20°C (68°F) (Explanatory Note 4).

9.2 Equivalent conductivity; the wire shall meet or exceed 60.0 % IACS at 20°C (68°F).

9.3 When resistance measurements are made at temperatures other than 20°C (68°F), corrections shall be based on a temperature coefficient of resistance of 0.0040/°C (0.0022/°F) (see Table 2).

10. Density

10.1 For the purpose of calculating mass, cross-section, and so forth, the density of aluminum-zirconium alloy shall be taken as 2700 kg/m^3 [0.0970 Ib/in.^{3}] at 20°C [68°F].

11. Diameter

11.1 The diameter of the wire shall be specified in inches to the nearest 0.0001 in. or the diameter of the wire shall be specified in millimeters to the nearest 0.001 mm for wires less than 1.000 mm in diameter, and to the nearest 0.01 mm for wires 1.00 mm in diameter and larger.

11.2 The actual wire diameter shall not vary from the specified diameter by more than the values shown in Table 3.

TABLE 2 Temperature Correction Factors for Electrical Resistance

Resistance Temperature (°C)	Multiplying Factor for the conversion to 20°C
0	1.080
5	1.060
10	1.040
15	1.020
20	1.000
25	0.980
30	0.960
35	0.940
40	0.920
45	0.900
50	0.880
55	0.860
60	0.840
65	0.820
70	0.800
75	0.780
80	0.760
85	0.740
90	0.720
95	0.700
100	0.680
105	0.660
110	0.640
115	0.620
120	0.600
125	0.580
130	0.560
135	0.540
140	0.520
145	0.500
150	0.480
155	0.460
160	0.440
165	0.420
170	0.400
175	0.380
180	0.360
185	0.340
190	0.320
195	0.300
200	0.280
205	0.260
210	0.240
215	0.220
220	0.200
225	0.180
230	0.160
235	0.140
240	0.120

TABLE 3 Diameter Tolerances

Nominal Diameter	Permissible Variations in Diameter
0.0105 to 0.0359 in. (up to 0.99 mm)	±0.0005 in. (±0.010 mm)
0.0360 to 0.0999 in. (1.00 to 2.99 mm)	±0.0010 in. (±0.030 mm)
0.1000 to 0.2600 in. (3.00 mm and over)	±1 % in. (±1 % mm)

12. Joints

12.1 Unless otherwise specified at the time of placing the order, wire shall be supplied in one continuous length of reel, coil, or spool. Joints may be made in the drawing stock or wire prior to final drawing by electric-butt welding, cold-pressure welding, or by electric-butt, cold-upset welding.

12.2 If agreed upon between the manufacturer and the purchaser, joints may be made during the final drawing or in

the finished wire by electric-butt welding, cold-pressure welding, or electric-butt, cold-upset welding, subject to the following limitations.

12.2.1 For wire sizes from 0.0100 to 0.0555 in. [0.225 to 1.25 mm] in diameter not more than three such joints shall be present in any coil, reel, or spool of the specified nominal mass.

12.2.2 For wire sizes greater than 0.0500 in. [1.25 mm] diameter, not more than 10 % of the coils, reels, or spools shall contain such joints, and no such joint shall be closer than 50 ft [15 m] to another joint or to either end of the wire. Not more than two such joints shall be present in any coil, reel or spool of the specified nominal mass.

13. Sampling

13.1 *Sampling*—For each use of a coil of redraw rod, four test specimens shall be obtained from the resulting drawn wire and tested to determine compliance with sections 6 – 9, and 11.

14. Test Methods

14.1 *Diameter*—Dimensional measurements shall be made with equipment capable of measuring to a graduation of 0.0001 in. or 0.001 mm. Take two measurements at one location, the second rotated 90° from the first. Average the two measurements to obtain the specimen diameter.

14.2 *Finish*—Make a visual surface finish inspection with the unaided eye (corrective lenses excepted). The surface finish shall be free of surface marks. Should any specimen be found unacceptable, the lot shall be considered to not meet surface finish requirements.

14.3 *Tensile Strength and Elongation*—These may be determined simultaneously. Obtain the tensile strength, in accordance with Test Methods B557, by dividing the maximum load resisted by the tensile specimen by the original cross-sectional area of the specimen, with the tensile stress to be expressed in ksi [MPa]. Elongation is the percent increase in length of the tensile test specimen as measured between gage marks originally spaced 10 in. [250 mm] apart on the specimen. Elongation measurements are not required for wires <0.0500 in. [<1.25 mm] in diameter. Should any part of the fracture take place outside the elongation gage lines, or if examination of the tensile specimen indicates a flaw, the values obtained may not be representative and a test on another section of the specimen may be run.

14.4 *Heat Resistance*—Cut wire samples from a continuous section of drawn wire, and then heat treat test samples in a uniformly heated oven or furnace at 536 ± 9°F (280 ± 5°C) for one hour, remove and air cool, and then measure the tensile strength at room temperature as in Section 14.3.

14.5 Determine the electrical resistivity in accordance with Test Method B193.

14.6 *Test Results*—All measured values shall meet or exceed the minimum sample requirements.

14.7 *Wrap test (Brittleness)*—Specimens from any production unit may be tested, with the frequency of sampling and testing to be agreed upon by the manufacturer and the purchaser. Slowly wrap the test specimen in an open helix around a wire or mandrel of it's own diameter. Take care not to stretch the specimen during the wrapping operation. The spacing of consecutive turns shall be approximately equal to the diameter of the wire. Use helical turns for the test.

15. Conformance Criteria

15.1 The test results of each specimen shall meet the minimum individual test requirements in Sections 6 – 9, 11, unless otherwise specified.

15.2 If one or more of the test samples fail any test, the non-conforming production unit will be rejected. Additional tests shall be required as follows:

15.2.1 One additional test specimen shall be obtained from each production unit on either side of the non-conforming production unit. Tests shall be run on the additional units.

15.2.2 If all of the additional individual specimen results are in conformance, the lot shall be considered in conformance.

15.2.3 If one or more of the additional tested specimens fail any test, the lot shall be considered not in conformance and rejected.

15.2.4 In the event a lot is rejected in accordance with 15.2.3, production units making up that lot may be individually tested. Acceptance of individual production units from a rejected lot shall be dependent on the individual specimen test results meeting the minimum property requirements of Sections 6 – 9, and 11.

16. Inspection

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

16.2 All tests and inspections shall be made at the place of manufacture unless otherwise agreed upon by the manufacturer and the purchaser.

16.3 The manufacturer shall afford the purchaser reasonable access to the manufacturer's facilities consistent with the purchaser's need to ensure compliance with this specification.

16.4 Unless otherwise agreed upon by the manufacturer and the purchaser, conformance of the wire to the requirements specified in Sections 6 – 9, and 11, shall be determined by sampling in accordance with Sections 14, 15, and 16 of each lot of wire presented for acceptance.

17. Packaging and Package Marking

17.1 Package sizes and types shall be as agreed upon by the manufacturer and the purchaser at the time of placing the individual orders.

17.2 Unless otherwise specified, each coil, reel, or spool shall contain one continuous length of wire.

17.3 The wire shall be protected against damage in ordinary handling and shipping.

17.4 Each coil, reel, spool, or other package shall bear a tag showing the manufacturer's name or trademark; the product identification as Aluminum-Zirconium heat resistant wire; the

size, length, and net mass of the material. Additional information shall be as agreed upon by the manufacturer and the purchaser at the time of placing the individual orders.

18. Keywords

18.1 aluminum electrical conductor; aluminum heat-resistant wire; aluminum wire; aluminum-zirconium wire; electrical conductor; heat-resistant wire; wire

EXPLANATORY NOTES

NOTE 1—A lot should comprise material taken from a product regularly meeting the requirements of this specification. Inspection of lots of less than 5000 lb [2500 kg] of wire cannot be justified economically. For small lots of less than 5000 lb [2500 kg] the purchaser may agree to the manufacturer's regular inspection of the product as a whole as evidence of acceptability of such small lots.

NOTE 2—Evidence of statistical control must be demonstrated. To do this, control charts, as described in Part 3 of *ASTMSTP 15D*[A3] may be used, or process capability indices, Cpk, as described in ASTM B830.

NOTE 3—The speed of testing can affect the results of the tensile strength and elongation test. In order to ensure uniformity in the test method and valid applicability of the test results to the conformance criteria, it is recommended that the rate of separation of the heads of the tensile test machine not exceed 0.5 in. for each inch or 0.5 mm for each millimeter of length between grips per minute.

NOTE 4—Resistivity units are based on the International Annealed Copper Standard (IACS) adopted by IEC in 1913, which is l/58 $\Omega.mm^2/m$ at 20°C (68°F) for 100 % conductivity. The value of 0.017241 $\Omega.mm^2/m$ at 20°C (68°F) is the international equivalent of volume resistivity of annealed copper equal to 100 % conductivity. The use of five significant figures in expressing resistivity does not imply the need for greater accuracy of measurement than that specified in Test Method B193. The use of five significant figures is required for reasonably accurate reversible conversion from one set of resistivity units to another.

NOTE 5—Small wires typically have high strengths in the range of 26 ksi but do tend to lose heat resistance faster than larger sizes. For wire sizes ranging from 0.005 to 0.128 in., taking 90 % of the minimum strength specification of 24.0 ksi (equals 21.6 ksi) makes it an absolute rather than relative heat resistance number.

[3] *Manual on Presentation of Data and Control Chart Analysis, ASTM STP I5D*, 1976.