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Standard Specification for Fiber Reinforced Aluminum Matrix Composite (AMC) Core Wire for Aluminum Conductors, Composite Reinforced (ACCR)[1]

This standard is issued under the fixed designation B976; 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 fiber reinforced, aluminum matrix composite core wire used for mechanical reinforcement in the manufacture of aluminum conductor, composite reinforced (ACCR). This wire consists of continuous filament fibers of aluminum oxide in a matrix of aluminum.

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.

1.2.1 *Exception*—Some non-standard SI units provided for information only do not appear in brackets.

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 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

B830 Specification for Uniform Test Methods and Frequency

D3552 Test Method for Tensile Properties of Fiber Reinforced Metal Matrix Composites

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *fiber reinforced aluminum matrix composite wire, n*—a wire consisting of two constituents: the first a number of continuous fibers of aluminum oxide along the axis of the wire, which is embedded in the second constituent of aluminum metal, as shown in Fig. 1.

3.1.2 *lot, n*—unless otherwise specified in the contract or order, a lot shall consist of all coils of wire of the same diameter submitted for inspection at the same time.

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

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

3.1.5 *specimen, n*—a length of wire removed for test purposes.

3.1.6 *tow, n*—a bundle, containing multiple fibers.

3.1.7 *AMC, n*—Aluminum Matrix Composite, a material consisting of two constituents: the first a series of continuous fibers of aluminum oxide which is embedded in the second constituent of aluminum metal.

3.1.8 *ACCR, n*—Aluminum Conductor Composite Reinforced, a concentric-lay-stranded conductor made up of outer aluminum strands of hard, heat resistant aluminum wires and a core of round, aluminum matrix composite wire(s), for use as overhead electrical conductors.

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 8.1),

4.1.3 Place of inspection (see 11.1),

4.1.4 Package size and type (see 12.1),

4.1.5 Special package marking.

5. Materials and Manufacture

5.1 The fiber reinforcement shall be continuous tows of aluminum oxide.

[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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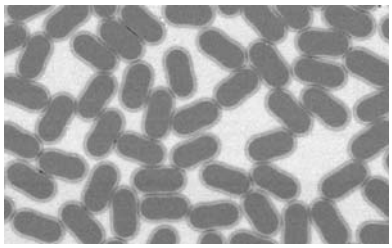
[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.



NOTE 1—Dark Phases are fiber viewed end-on and the light phase is aluminum matrix. The equivalent diameter of the fibers is approximately 470 µin. (12 µm).

FIG. 1 Polished Cross-section of an Aluminum Matrix Composite Wire

5.2 The core wires shall be of such quality and purity that the finished product shall have the approximate properties and characteristics prescribed in this specification, including breaking load, elongation, modulus properties, and electrical resistivity requirements set forth in Table 1.

6. Tensile Test

6.1 Before stranding, the composite core wire of any diameter shall conform to the tensile breaking load requirements set forth in Table 2 (see Explanatory Note 1).

6.2 *Test Method*—Tensile testing of metal matrix composite materials is covered by D3552, including the need for stringent test frame alignment. However, this standard does not specify testing of round metal matrix composite wire samples. Thus, for AMC core wire samples, the tensile test shall use a minimum gauge length of 24 in. (610 mm) (see Explanatory Note 2). Each end of the wire shall be adhesively bonded to a depth of 4 in. (100 mm) into a 6 in. (150 mm) long steel gripping tube. A Hi-flex epoxy is suggested such as Scotch-Weld DP-810 Hi-flex epoxy adhesive. The test machine gripping jaws shall grip the end section of the tube that contains no wire. Direct gripping of the core wire in the test machine jaws without end tubes is not permitted, unless the tester can demonstrate the effect of direct gripping on the wire does not cause failure of the wire within the gripping length. The cross-head speed shall provide a strain rate of 0.002in./in./min (0.002 mm/mm/min).

6.3 *Test Specimens*—The test specimens shall be free of sharp bends, dents or kinks other than the curvature resulting from the packaging operations.

TABLE 1 Typical Physical Properties

NOTE 1—See Explanatory Note 1 for Tensile Strength property.

Property	Value
Tensile Strength	200 ksi (1380 MPa)
Elongation (strain to failure)	0.65 %
Tensile Modulus	30.6 Msi (210 GPa)
Electrical Resistivity at 68°F (20°C)	43.2 Ω·cmil/ft (0.0718 Ω·mm^2/m)
Thermal Expansion Coefficient 68-464°F (20-240°C)	3.5 x 10^{-6}/°F (6.3 x 10^{-6}/°C)
Density at 20°C	0.122 lb/in.^{3} (3370 kg/m^3).

7. Density and Resistivity

7.1 For the purposes of calculating mass per unit length, cross-sections, and so forth, the density of the composite wire at 20°C shall be taken as 0.122 lb/in.^{3} (3370 kg/m^3).

7.2 Electrical resistivity, determined on samples selected and tested in accordance with Test Method B193, shall not exceed 43.2 Ω·cmil/ft (0.0718 Ω·mm^2/m) at 68°F (20°C).

7.3 Equivalent conductivity; the wire shall meet or exceed 24.0 % IACS at 68°F (20°C).

7.4 The temperature coefficient of resistance at 20°C is taken as 0.00404.

8. Dimensions and Permissible Variations

8.1 The specified diameter shall be expressed in inches to four decimal places or in millimeters to two decimal places.

8.2 Measure the diameter of each specimen with a micrometer caliper to the nearest 0.0005 in. or 0.01 mm. Take two measurements at one location, the second 90° from the first. Average the two measurements to obtain the specimen diameter. The specimen diameter shall not vary from the specified diameter by more than ±0.0035 in. (±0.09 mm) for all wire diameters.

8.3 Continuous process control using an optical diameter measurement device, or other methods, may be substituted in accordance with section 8.2 if the tester can demonstrate the accuracy of the measurement system relative to the method in section 8.2.

8.4 Should questions arise regarding diameter compliance, the actual diameter shall be determined in accordance with section 8.2.

9. Joints

9.1 No joints shall be made in the finished wire.

10. Number of Tests and Retests

10.1 A minimum of one test specimen of sufficient length shall be taken from a lot to perform the required testing (see Explanatory Note 2). A lot shall consist of at least one continuous length of input material (for example, a fiber setup).

10.2 Each specimen shall be tested for compliance with Sections 6, 7, and 8.

TABLE 2 Tensile Load Requirements

Wire Diameter, (in.)	Wire Diameter, (mm)	Ultimate Tensile Breaking Load, min., (lbs)	Ultimate Tensile Breaking Load, min., (kN)
0.0741	1.88	858	3.82
0.0774	1.97	935	4.16
0.0803	2.04	1005	4.47
0.0831	2.11	1080	4.80
0.0863	2.19	1159	5.16
0.0889	2.26	1229	5.47
0.0919	2.33	1311	5.83
0.0943	2.40	1382	6.15
0.0971	2.47	1464	6.51
0.1017	2.58	1604	7.13
0.1031	2.62	1616	7.19
0.1046	2.66	1699	7.56
0.1065	2.71	1757	7.82
0.1090	2.77	1839	8.18
0.1111	2.82	1909	8.49
0.1135	2.88	1991	8.86
0.1155	2.93	2060	9.16
0.1181	3.00	2154	9.58

10.3 Should one or more of the test specimens fail any of the tests specified, the nonconforming production unit or units may be removed and the balance of the lot subjected to retests (see Explanatory Note 3). For retest purposes, two additional production units in the lot shall be sampled and tested for the property in which the original sample failed to comply.

10.4 Should any of the retest specimens fail to meet the properties specified, the lot represented by the test specimen shall be rejected.

10.5 Instead of rejecting the entire lot as provided in 10.4, the producer may test specimens from every production unit in the lot for the property in which failure occurred, and reject only the nonconforming production units.

11. Inspection

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

11.2 All inspections and tests shall be made at the place of manufacture, unless otherwise agreed upon between the manufacturer and the purchaser.

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

12. Product Marking

12.1 Package dimensions, kind of package (coils, reels or reel-less coils), and quantity of wire in each package shall be agreed upon between the manufacturer and purchaser. Unless otherwise specified, each package shall contain one continuous length of wire.

12.2 The wire shall be protected against damage in handling and shipping. A protective sheet (for example, 1/8 in. (3 mm) thick rubber sheeting) shall be wrapped around the wire on the package and secured by tape. No metal or plastic bands shall be used to secure the wire.

12.3 There is a minimum bending radius required for the AMC wire to prevent damage. The drum diameter shall not be less than 24 in. (610 mm) for the reels used to transport the wire.

13. Keywords

13.1 aluminum matrix composite wire; composite core wire; fiber reinforced aluminum wire; metal matrix composite wire; aluminum composite wire; composite wire

EXPLANATORY NOTES

NOTE 1—Tensile breaking load and not tensile strength is specified because in composite materials of these sizes, the main strength member is the fiber and not the metal matrix. Fiber is provided in discrete packages or tows. Thus a wire that is nominally 0.0831 in. (2.11 mm) diameter may have a deviation in diameter due to tolerance fluctuation (for example, ±0.0035 in. (±0.09 mm)) but will contain the same amount of fiber. The breaking load of this wire will be the same, independent of the actual wire diameter, since it contains the same amount of fiber, and changes in diameter due to changes in metal content do not affect the strength. Computation of the tensile strength due to the change in wire diameter will thus give a range of tensile strengths. Thus tensile strength is not a fixed parameter, only breaking load. This is one difference between composite materials and metals and alloys. As extra packages or tows of fibers are added, then the breaking load increases stepwise to reflect this.

NOTE 2—In tensile testing the minimum gauge length is 24 in. (610 mm). This reduces the need for stringent test frame alignment required for shorter specimens and the resulting end effects from end tabs. This also reduces the amount of time and extra materials used for testing.

NOTE 3—Should a failure occur, the manufacturer may retest if the cause of the failure is suspected to be an error in the testing procedure, set-up, or factors other then non-conformance with the property being tested. For example, if a tensile test fails due to a break that occurs within the gripping region, the failure may be due to a gripping deficiency, and that would be a valid cause for retesting the production unit.