Designation: D1676 – 17

Standard Test Methods for Film-Insulated Magnet Wire[1]

This standard is issued under the fixed designation D1676; 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 These test methods cover procedures for testing film-insulated magnet wire that is used in electrical apparatus. These test methods are intended primarily for the evaluation of the electrical insulating materials used. The intent is that these test methods be used, except where modified, by individual specifications for particular applications.

1.2 These test methods present different procedures for evaluating given properties of round, rectangular or square, copper or aluminum film-insulated magnet wire.

1.3 The values stated in inch-pound units are the standard. The SI units in parentheses are provided for information only.

1.4 The test methods appear in the following sections:

1.5 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* Specific hazard statements are given in 9.5, 19.1, 19.3, 19.8, 52.1, 58, 59.1, 74.1, 112.1, 135.4, and 182.3.

NOTE 1—This test method is related to IEC 60851. Since both methods contain multiple test procedures, many procedures are technically equivalent while others differ significantly.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

A228/A228M Specification for Steel Wire, Music Spring Quality

B3 Specification for Soft or Annealed Copper Wire

B43 Specification for Seamless Red Brass Pipe, Standard Sizes

B193 Test Method for Resistivity of Electrical Conductor Materials

B279 Test Method for Stiffness of Bare Soft Square and Rectangular Copper and Aluminum Wire for Magnet Wire Fabrication

B324 Specification for Aluminum Rectangular and Square Wire for Electrical Purposes

B609/B609M Specification for Aluminum 1350 Round Wire, Annealed and Intermediate Tempers, for Electrical Purposes

D149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies

D150 Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation

D374/D374M Test Methods for Thickness of Solid Electrical Insulation

D877 Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes

D1533 Test Method for Water in Insulating Liquids by

[1] These test methods are under the jurisdiction of ASTM Committee D09 on Electrical and Electronic Insulating Materials and are the direct responsibility of Subcommittee D09.12 on Electrical Tests.

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*A Summary of Changes section appears at the end of this standard

Coulometric Karl Fischer Titration
D1711 Terminology Relating to Electrical Insulation
D2475 Specification for Felt
D2519 Test Method for Bond Strength of Electrical Insulating Varnishes by the Helical Coil Test
D5423 Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation
E4 Practices for Force Verification of Testing Machines
E6 Terminology Relating to Methods of Mechanical Testing
E8 Test Methods for Tension Testing of Metallic Materials
E220 Test Method for Calibration of Thermocouples By Comparison Techniques
E1356 Test Method for Assignment of the Glass Transition Temperatures by Differential Scanning Calorimetry
E1545 Test Method for Assignment of the Glass Transition Temperature by Thermomechanical Analysis

2.2 *Other Documents:*[2]
CCCM-911 Federal Specification for Bleached Muslin
IEC 60851 Methods of Test for Winding Wire

3. Terminology

3.1 *Definitions:*

3.1.1 *conductor, n*—a wire or combination of wires not insulated from each other, suitable for carrying electric current.

3.1.2 *magnet wire, n*—a metal electrical conductor, covered with electrical insulation, for use in the assembly of electrical inductive apparatus such as coils for motors, transformers, generators, relays, magnets, and so forth.

3.1.3 For definition of other terms used in this test method refer to Terminology D1711.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *film coating, n*—cured enamel coating.

3.2.2 *film insulated wire, n*—a conductor insulated with a film coating.

BOND STRENGTH OF ROUND FILM-INSULATED SELF-BONDING MAGNET WIRE BY THE HELICAL COIL TEST

4. Scope

4.1 This test method covers the determination of the bond strength of a self-bonding outer coating on round film-insulated magnet wires (AWG 14 through 44). Both thermal and solvent bonding methods are defined.

4.2 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

5. Terminology

5.1 *Definitions of Terms Specific to This Standard:*

5.1.1 *bond strength, n*—a measure of the force required to separate surfaces which have been bonded together.

5.1.1.1 *Discussion*—For magnet wire which has been self bonded or varnish treated, the bond strength is reported as the force required to break a test specimen in flexure.

6. Summary of Test Method

6.1 Flexural strength tests are made on bonded helical coils to determine the force required to break the coil under specified conditions.

7. Significance and Use

7.1 Bond strength values obtained by flexural tests provide information with regard to the bond strength of a particular self-bonding outer coating in combination with a particular round film-insulated magnet wire when measured under conditions described in this test method.

8. Apparatus

8.1 *Testing Machine*—Tensile testing machines used for bond strength test shall conform to the requirements of Practices E4.

8.2 *Test Fixture*—The test fixture shall conform to the test fixture for bond strength tests required by Test Method D2519.

8.3 *Mandrel Holder*—The mandrel holder shall be a metal block of sufficient size and thickness with a hole capable of supporting the winding mandrel in a vertical position during the bonding cycle of the helical coil.

8.4 *Winding Tensions*—The winding tensions are listed in Table 1.

8.5 *Bonding Weights*—Bonding weights (listed in Table 1) are made with a hole through the center to allow the weight to slip freely over the winding mandrel and load a helical coil during bonding of coil.

8.6 *Forced-Air Oven*—See Specification D5423.

9. Test Specimen Preparation

9.1 Select the appropriate mandrel from Table 1, spray it with a suitable release agent (fluorocarbon or silicone spray is adequate), and allow it to dry. Carefully wind onto the prepared mandrel a length of wire, long enough to wind a helical coil at least 3 in. (76 mm) long. The winding tension shall be as prescribed in Table 1. Ensure that the coil is wound without space between turns.

9.2 Prepare six or more coils from each wire sample.

9.3 *Thermal Bonding*—Mount the mandrel supporting the coil vertically in the mandrel holder and loaded with the bonding weight specified in Table 1. Place the mandrel holder and coil into a forced-air oven at a specified temperature for a specified time, after which the assembly is removed from the oven and cooled to room temperature. Remove the coil from the mandrel and inspect the coil for breaks or physical damage prior to testing.

9.4 *Solvent Bonding*—After winding, immerse the coil and mandrel into the specified solvent for 5 s. Immediately

[2] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

TABLE 1 Helical Coil Bond Parameters

Wire Size, AWG	Mandrel Diameter[A]		Recommended Winding Tension		Bond Weights[A]	
	in.	mm	g	N	g	N
44	0.011	0.28	2.5	0.025	0.80	0.008
43	0.011	0.28	2.5	0.025	0.80	0.008
42	0.016	0.41	5.0	0.50	1.60	0.016
41	0.016	0.41	5.0	0.50	1.60	0.016
40	0.022	0.56	10.0	0.098	3.15	0.031
39	0.022	0.56	10.0	0.098	3.15	0.031
38	0.022	0.56	10.0	0.098	3.15	0.031
37	0.032	0.81	20.0	0.196	6.30	0.062
36	0.032	0.81	20.0	0.196	6.30	0.062
35	0.032	0.81	20.0	0.196	6.30	0.062
34	0.044	1.12	40.0	0.392	12.5	0.123
33	0.044	1.12	40.0	0.392	12.5	0.123
32	0.044	1.12	40.0	0.392	12.5	0.123
31	0.063	1.60	80.0	0.785	25.0	0.245
30	0.063	1.60	80.0	0.785	25.0	0.245
29	0.063	1.60	80.0	0.785	25.0	0.245
28	0.088	2.24	160.0	1.569	50.0	0.490
27	0.088	2.24	160.0	1.569	50.0	0.490
26	0.088	2.24	160.0	1.569	50.0	0.490
25	0.124	3.15	315.0	3.089	100.0	0.981
24	0.124	3.15	315.0	3.089	100.0	0.981
23	0.124	3.15	315.0	3.089	100.0	0.981
22	0.177	4.50	630.0	6.178	200.0	1.961
21	0.177	4.50	630.0	6.178	200.0	1.961
20	0.177	4.50	630.0	6.178	200.0	1.961
19	0.248	6.30	1250.0	12.258	400.0	3.923
18	0.248	6.30	1250.0	12.258	400.0	3.923
17	0.248	6.30	1250.0	12.258	400.0	3.923
16	0.354	8.99	2500.0	24.517	800.0	7.845
15	0.354	8.99	2500.0	24.517	800.0	7.845
14	0.354	8.99	2500.0	24.517	800.0	7.845

[A] ±2 % on all mandrels and bond weights.

thereafter, secure the mandrel supporting the coil in the mandrel holder and load the coil with the bonding weight specified in Table 1. Dry the coils for 1 h at room temperature. Carefully remove the coils from the mandrels and further dry in a forced air oven for 15 ± 2 min at 100 ± 3°C (unless otherwise specified). Cool the coil to room temperature, inspect for breaks or physical damage, and test.

9.5 *Resistance Bonding*—Mount the mandrel supporting the coil vertically in a mandrel holder and loaded with the bonding weight specified in Table 1. Energize the coil with enough current and time to allow bonding. Remove the coil from the mandrel and inspect for breaks or physical damage, and test. Specific bonding conditions shall be agreed upon between the manufacturer and the user. (**Warning**—*Lethal voltages are a potential hazard during the performance of this test. It is essential that the test apparatus, and all associated equipment electrically connected to it, be properly designed and installed for safe operation. Solidly ground all electrically conductive parts which it is possible for a person to contact during the test. Provide means for use at the completion of any test to ground any parts which were at high voltage during the test or have the potential for acquiring an induced charge during the test or retaining a charge even after disconnection of the voltage source. Thoroughly instruct all operators as to the correct procedures for performing tests safely. When making high voltage tests, particularly in compressed gas or in oil, it is possible for the energy released at breakdown to be sufficient to result in fire, explosion, or rupture of the test chamber. Design test equipment, test chambers, and test specimens so as to minimize the possibility of such occurrences and to eliminate the possibility of personal injury. If the potential for fire exists, have fire suppression equipment available.)*

10. Procedure

10.1 Use a rate of loading such that the duration of the test shall be greater than the full-scale response time of the load recording instrument.

10.2 Prepare sufficient specimens to obtain six data points for each wire sample. One or more of the specimens are potentially going to be destroyed in adjusting the rate of loading.

10.3 Break specimens according to the test procedures described in Test Method D2519.

10.4 Tests at other than room temperature are able to be performed, if desired, using an insulated heat-resistant enclosure, designed to fit around the test fixture and in the stress strain analyzer. Place the specimens in the fixture in the oven for 15 min but not more than 30 min after the oven has recovered to the set temperature ±2°C. Break the specimens according to the test procedures described in Test Method D2519. The specified test temperature and minimum bond strength shall be agreement upon between the manufacturer and the user.

11. Report

11.1 Report the following:

11.1.1 Identification of size, build and type of insulation used,

11.1.2 Heat or solvent bonding (including temperature or type of solvent, or both),

11.1.3 Test temperature, and

11.1.4 A table listing the individual values in pounds, grams or newtons of bond strength and their averages.

TABLE 2 Critical Differences, Percent of Average Pounds to Break[A]

Number of Observations in each Average	Single-Operator Precision	Within-Laboratory Precision	Between-Laboratory Precision
6	10	11	12

[A] The critical differences were calculated using t = 1.960, which is based on infinite degrees of freedom

12. Precision and Bias[3]

12.1 In comparing two averages of six observations, the differences are not expected to exceed the critical difference in Table 2, in 95 out of 100 cases when all of the observations are taken by the same well-trained operator using the same piece of test equipment and specimens randomly drawn from the same sample of material.

[3] Supporting data are available from ASTM International Headquarters. Request RR:D09-1007.