Designation: D 3145 – 01

An American National Standard

Standard Test Method for Thermal Endurance of Electrical Insulating Varnishes by the Helical Coil Method[1]

This standard is issued under the fixed designation D 3145; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the determination of the thermal endurance of electrical insulating varnishes alone or in combinations with wire insulation. Changes in the helical coil bond strength are used as the test criteria. The coils can be made from bare aluminum or copper wire, or from film- or fiber-insulated magnet wire.

1.2 *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.* For a specific precautionary statement, see Section 7.

1.3 The values stated in SI units are the standard. The values given in parentheses are for information only.

NOTE 1—There is no similar or equivalent IEC standard.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1711 Terminology Relating to Electrical Insulation[2]

D 1932 Test Method for Thermal Endurance of Flexible Electrical Insulating Varnishes[2]

D 2307 Test Method for Relative Thermal Endurance of Film-Insulated Round Magnet Wire[2]

D 2519 Test Method for Bond Strength of Electrical Insulating Varnishes by the Helical Coil Test[3]

D 3251 Test Method for Thermal-Aging Characteristics of Electrical Insulating Varnishes Applied Over Film-Insulated Magnet Wire[3]

D 3850 Test Method for Rapid Thermal Degradation of Solid Electrical Insulating Materials by Thermogravimetric Method[3]

D 5423 Specification for Forced Convection Laboratory Ovens for Evaluation of Electrical Insulation[3]

D 6054 Practice for Conditioning Electrical Insulating Materials for Testing[3]

2.2 *International Electrotechnical Commission Publications:*[4]

IEC 60216 Guide for the Determination of Thermal Endurance Properties of Electrical Insulation Materials (Part 1)

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

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

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, etc.

3.1.2.1 *Discussion*—The electrical insulation is usually composed of a film covering formed from a magnet wire enamel applied over a bare conductor. In some specific applications, fibrous coverings, either taped or linear filament served, are also used as electrical insulation.

3.1.3 *varnish, electrical insulating, n*— a liquid resin system that is applied to and cured on electrical components providing electrical, mechanical and environmental protection.

3.1.3.1 *Discussion*—There are two types of electrical insulating varnishes—solvent-containing and solventless. Solvent-containing types are solutions, dispersions or emulsions of a polymer or a mixture of polymers in a volatile, nonreactable liquid. Solventless types are liquid resin systems free of volatile, nonreactable solvents.

3.1.4 Refer to Terminology D 1711 for definitions of other terms.

4. Summary of Test Method

4.1 Flexural strength of the helical coils is measured periodically after exposure to several aging temperatures. The time to reach an arbitrarily selected value of bond strength at each aging temperature is determined. The logarithms of these times

[1] This test method is under the jurisdiction of ASTM Committee D09 on Electrical and Electronic Insulating Materials and is the direct responsibility of Subcommittee D09.01 on Electrical Insulating Varnishes, Powders, and Encapsulating Compounds.

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[2] *Annual Book of ASTM Standards*, Vol 10.01.

[3] *Annual Book of ASTM Standards*, Vol 10.02.

[4] Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.

in hours are plotted as a function of the reciprocal temperature (1/K) to give an Arrhenius plot.

5. Significance and Use

5.1 This test method is used to determine the effect of exposure to elevated temperatures on the bond strength of combinations of magnet wire insulations and electrical insulating varnishes. The results are used as a guide for the comparison and selection of varnishes and combinations of varnishes and wire insulation for specific applications. Test Methods D 1932, D 3251, and D 3850 describe additional tests for determining the thermal endurance of insulating varnishes. A comprehensive evaluation of thermal aging should include a comparison of the thermal endurance determined in these different ways.

5.2 This test method is useful for research and product qualifications purposes.

6. Apparatus

6.1 *Testing Machine*, see Test Method D 2519.
6.2 *Test Fixture*, see Test Method D 2519.
6.3 *Ovens*, see Specification D 5423, Type II.

7. Hazards

7.1 It is unsafe to use varnish at temperatures above flash point without adequate ventilation, especially if the possibility exists that flames or sparks are present. Store varnish in sealed containers.

8. Test Specimen

8.1 Prepare 60 or more specimens for each aging temperature, following the procedure specified in Test Method D 2519.

9. Selection of Test Temperatures

9.1 Expose the material to at least three temperatures. Choose the lowest temperature such that it is not more than 25°C higher than the estimated temperature index. Exposure temperatures should differ from each other by at least 10°C, preferably 20°C.

9.2 Select exposure temperatures in accordance with those shown in Table 1 as indicated by the anticipated temperature index of the material under test. It is recommended that exploratory tests be first made at the highest temperature to obtain data establishing the 100 h minimum life requirement, and that this be used as a guide for the selection of the lower test temperatures.

9.3 Choose the exposure temperature so that any essentially linear portions of the Arrhenius plot (log of time to failure versus the reciprocal of the absolute temperature) is well established; that is, confirm the suspicion of significant non-linearity by test at one or more additional temperatures. Generally the additional temperatures are lower than the ones previously tested.

10. Procedure

10.1 Suspend at least 20 sets of coils containing at least 3 coils in each set vertically in each oven.

10.2 Periodically remove one set of coils and condition 2 h at standard laboratory conditions in accordance with Practice D 6054. Measure flexural strength at room temperature in accordance with Test Method D 2519.

10.3 The length of the aging period and the number of coils tested per cycle will depend on the deterioration rate at each exposure temperature. The aging period will be longer at the start, shorter as the deterioration rate increases.

10.4 Continue the test until the breaking strength reaches less than 22 N (5 lbf). Other values may be specified. The end point is that point where the curve intersects the 22-N (5-lbf) line, or other specified value.

11. Calculation

11.1 Plot the breaking strength value after each aging period versus time in hours on a three-decade semilog paper with time as the ordinate.

11.2 From the curve, pick the 22-N (5-lbf) point, or specified value, and record the number of hours to reach this point. This is to be done for each temperature and will be known as the end point at that temperature.

11.3 In order to calculate the temperature index, data must be available from a minimum of three aging temperatures. The highest aging temperature must have a thermal life of at least 100 h. The life at the lowest aging temperature must have a thermal life of at least 5000 h.

11.4 Plot the end points at each temperature on graph paper having a logarithmic time scale as the ordinate and the reciprocal of the absolute temperature as the abscissa. Draw the best fit straight line through all points. For definition of how to

TABLE 1 Suggested Exposure Temperatures and Cycle Durations[A]

Cycle Duration, day	Temperatures Corresponding to the Estimated Temperature Index Range,° C[B,C]													
	Class 105			Class 130		Class 155			Class 180		Class 200		Class 220	
	100 to 109	110 to 119	120 to 129	130 to 139	140 to 149	150 to 159	160 to 169	170 to 179	180 to 189	190 to 199	200 to 209	210 to 219	220 to 229	230 to 239
1	170	180	190	200	210	220	230	240	250	260	270	280	290	300
2	160	170	180	190	200	210	220	230	240	250	260	270	280	290
4	150	160	170	180	190	200	210	220	230	240	250	260	270	280
7	140	150	160	170	180	190	200	210	220	230	240	250	260	270
14	130	140	150	160	170	180	190	200	210	220	230	240	250	260
28	120	130	140	150	160	170	180	190	200	210	220	230	240	250
49	110	120	130	140	150	160	170	180	190	200	210	220	230	240

[A] Taken from IEC Publication 216-1.
[B] Exposure temperatures above and below those given are to be selected by experimentation.
[C] Range to which the temperature is assumed to correspond to an extrapolated 20 000 h time to failure.

draw the best fit line, see the Annex of Test Method D 2307 for calculation of the regression line.

11.5 The temperature where the life line crosses the specified hour line is the temperature index for the combination used for the test. Unless otherwise specified, use an hour line of 20 000 h.

12. Report

12.1 Report the following information:
12.1.1 Identification of the varnish,
12.1.2 Identification of the magnet wire insulation,
12.1.3 Cure schedule used,
12.1.4 Aging temperatures, and
12.1.5 Temperature index.

13. Precision and Bias

13.1 *Precision*—Data from a between-laboratory study[5] involving three laboratories testing a single unsaturated polyester resin yielded:

Average temperature index	204
Range of values	8
Standard deviation	4

13.2 *Bias*—This test method has no bias because the value for the thermal endurance of insulating varnish using the helical coil method is defined in terms of this test method.

14. Keywords

14.1 electrical insulating; helical coil; magnet wire; thermal endurance; varnish

[5] Supporting data are available from ASTM International Headquarters. Request RR: D-9-1033.