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Standard Test Method for Accelerated Life Test of Electrical Grade Magnesium Oxide as Used in Sheathed-Type Electric Heating Elements[1]

This standard is issued under the fixed designation D 2900; 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.

ϵ[1] NOTE—Section 13 was added editorially in October 1997.

1. Scope

1.1 This test method covers the accelerated life testing of electrical grade magnesium oxide (MgO) under conditions involving thermal cycling to an elevated temperature. The test determines both the rate at which electrical insulation impedance (Note 1) or test current through the insulation changes with time and the time span resulting in complete failure of a test cell incorporating the sample under test.

NOTE 1—At test temperatures, capacitive and inductive reactance are negligible, and therefore impedance values are considered essentially resistive.

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 specific safety precaution, see 9.4.1.

1.3 The values stated in acceptable metric units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

B 344 Specification for Drawn or Rolled Nickel-Chromium and Nickel-Chromium-Iron Alloys for Electrical Heating Elements[2]

D 2755 Test Method of Sampling and Reduction to Test Weight of Electrical Grade Magnesium Oxide[3]

3. Summary of Test Method

3.1 The specimen of magnesium oxide is loaded into a test cell, which is formed into an operative heater of specific construction. The test cell is thermally cycled by internal heating under conditions designed to accelerate deterioration and promote failure in a period of several months. Electrical resistance of the insulation is measured periodically. The total length of time the test cell operates before failure occurs is recorded as its life.

4. Significance and Use

4.1 The insulating quality of the magnesium oxide at high temperature and during the life span of a heating unit is a most significant aspect of the material to the user. Accordingly, a means is specified for determining the insulating quality in a relatively short time, with magnesium oxide being the only intended variable.

5. Apparatus

5.1 *Loading Machine*, vibratory-type, with suitable loading devices.[4]

5.2 *Rolling Machine*, capable of roll reducing to 6.35 mm (0.250 in.) diameter through five passes of 7.62 mm (0.300 in.), 7.24 mm, (0.285 in.), 6.86 mm, (0.270 in.), 6.60 mm (0.260 in.), and 6.35 mm (0.250 in.), with no subsequent sizing rolls.[5]

5.3 *Fusion or Spot Welding Machine*.

5.4 *Variable A-C Power Source*, (approximately 124 V) with voltage-regulation to ±1V and meter for measuring.

5.5 *Variable A-C Test Voltage*, supply of approximately 600 V max.

5.6 *Voltmeter*, A-C, 1000 Ω/V, 600 V full-scale deflection.[6]

5.7 *Thermocouple*, ANSI Type K, No. 26 B&S gage, 0.408 mm (0.0159 in.) in diameter with appropriate potentiometer.

5.8 *Milliammeter*, A-C rectifier type 0-10 ma full scale deflection.

5.9 *Voltage Divider*, Rheostat, 50W, 500 Ω.

6. Materials

NOTE 2—To reduce the number of variables from one test to another, it

[1] This method is under the jurisdiction of ASTM Committee D-9 on Electrical and Electronic Insulating Materials and is the direct responsibility of Subcommittee D09.14 on Electric Heating Unit Insulation.

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[2] *Annual Book of ASTM Standards*, Vol 03.04.

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

[4] A suitable loading machine is a three-station Oakley loader, manufactured by Oakley Industries, Inc., 7315 N. Linder Ave., Skokie, IL.

[5] A suitable rolling machine is an Oakley rolling machine, manufactured by Oakley Industries, Inc., 7315 Linder Ave., Skokie, IL. Although roll reducing is preferred, swaging is optional. Suggested sizes of reduction are 7.62 mm (0.300 in.) 7.24 mm (0.285 in.), 6.86 mm (0.270 in.), 6.60 mm (0.260 in.), and 6.35 mm (0.250 in.) If swaging is used, the sheath tube length must be increased about 3 % and the helix resistance increased about 4 %. A suitable swaging is a Size 4 Torrington machine manufactured by the Torrington Co., 59 Field St., Torrington, CT.

[6] A suitable voltmeter is a type DP2X manufactured by the General Electric Co.

is recommended that a stockpile of materials be maintained for making life test cells.

6.1 The material specifications shall be followed as closely as possible. However, due to variations in the magnesium oxide being tested, adjustments may be necessary in the tube length, terminal length, and helix resistance to obtain the dimensions and the wattage of the final test specimen as outlined in Section 8.

6.2 *Helix:*

6.2.1 *Material*—Resistance wire in accordance with Specification B 344, (80 Ni-20 Cr).

6.2.2 *Wire Size*—No. 29 B&S Gage, 0.287 mm (0.0113 in.) in diameter.

6.2.3 *Helix Outside Diameter*—2.41 mm (0.095 in.) as close wound.

6.2.4 *Total Resistance*—32.8 Ω (approx.).

6.2.5 *Resistance as Assembled and Welded*—32.3 Ω.

6.3 *Sheath Tube*—Incoloy 800[7] or equivalent, bright as welded, annealed temper, 7.92 ± 0.05 mm (0.312± 0.002 in.) in outside diameter, 0.635 mm (0.025 in.) wall thickness, 296.8 mm (11.687 in.) long.

6.4 *Terminals*—SAE 1006 or 1010 steel, 2.34 mm (0.092 in.) in diameter, 73.03 mm (2.875 in.) long; fusion end 1.91 mm (0.075 in.) in diameter, 6.35 mm (0.250 in.) long.

6.5 *Closing Washers*—Fiber or polyethylene, 7.62 mm (0.300 in.) in outside diameter, 1.96 mm (0.077 in.) in inside diameter, 1.57 mm (0.062 in.) thick.

6.6 *Degreasing Agent*—Acetone or similar solvent.

6.7 *Electrical Connector*—9.53 mm (0.375 in.) wide, 19.05 mm (0.750 in.) long, 1.98 mm (0.078 in.) thick, No. 8-32 tapped hole, or other suitable connector.

7. Sampling

7.1 Obtain sample of magnesium oxide in accordance with Test Method D 2755.

8. Processing of Test Cell

8.1 Determine the net tube volume in cubic centimetres either by calculation or by displacement measurement. The net tube volume is equal to the inside volume of the tube minus the volume of the helix and the volume of the terminal inside the tube.

8.2 Clean the sheath tube in degreasing agent. Do not sandblast. Bake at 260°C (500°F) for 1 h.

8.3 Fusion weld, or spot weld the helix to the two terminals. Pre-stretch the helix slightly. Clean in the degreasing agent. Handle only at terminal ends after cleaning. Bake at 260°C (500°F) for 1 h. Assemble the loading washer to the bottom terminal.

8.4 Before loading magnesium oxide, determine the total weight of the test cell parts to within 0.1 g.

8.5 Using a vibratory loading machine, position the helix-terminal assembly centrally within the tube, with the terminals extending 19.05 mm (0.750 in.) from each end of the tube. Load the magnesium oxide into the sheath. Close the top end with a loading washer. Weigh the loaded test cell to within 0.1 g.

8.6 Determine the density of the magnesium oxide as loaded. (The loaded density will vary with the magnesium oxide being tested. However, a density of 2.30 g/cm^3 would normally be considered a minimum.)

8.7 Roll reduce in rolling machine to 6.35 mm (0.250 in.) using the steps outlined in 5.2. Do not anneal.

8.8 Remove the end washers by suitable mechanical means.

8.9 Spot weld the electrical connectors to the terminals.

8.10 Radiographs or X-ray photographs of the test cell are optional, but desirable, as a means of detecting an off-center helix or irregular helix pitch before life testing. Two X-rays should be taken with the test cell rotated 90° around the longitudinal axis for the second X-ray.

8.11 *Finished Dimensions and Specifications:*

8.11.1 *Diameter*—6.35 ± 0.05 mm (0.250 ± 0.002 in.).

8.11.2 *Heated Length*—260 ± 3 mm (10.25 ± 0.125 in.).

8.11.3 *Sheath Length, Nominal*—394 mm (15.5 in.).

8.11.4 *Wattage, Nominal* at 124 V—655 W.

8.11.5 *Watt Density*—12.6 ± 0.4 W/cm^2 (81.4 ± 2.5 W/in.^{2}).

8.11.6 *Resistance, Nominal, Cold (As-rolled)*—21.6 Ω.

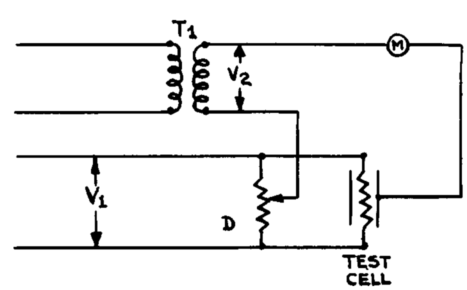
8.11.7 *Magnesium Oxide Density, Nominal*—3.05 g/cm^3 (0.110 lb/in^3)

9. Insulation Impedance (Note 1) and Current Measurement Methods

9.1 Any one of the three methods described in 9.2, 9.3, or 9.4 may be used. The magnitude of the insulation impedance values will vary according to the method used. It is necessary, then, to report the method of measurement used. Sections 9.2, and 9.3 are insulation impedance methods, and 9.4 is a current measurement method.

9.2 *Voltmeter Method with Quadrature Test Voltage*—(See Fig. 1) With the two test probes held together, adjust the test voltage, V_2, to 600 V. Isolate the test specimen from ground. Place one test probe on the sheath of the test specimen and one test probe on the center tap of the voltage divider. Record the voltage indicated by the voltmeter, *M*.

$$R = [(600/E) - 1]r$$



T_1 = isolation transformer
V_1 = variable a-c test voltage for energizing test cell
V_2 = variable a-c test voltage of approximately 600 V. 90 deg out of phase (in quadrature) with energizing test voltage
D = voltage divider
M = a-c voltmeter, rectifier type, 1000 Ω/V, 600 V full-scale deflection.

FIG. 1 Voltmeter Method with Quadrature Test Voltage

[7] Registered trademark, International Nickel Co.

where:
R = insulation resistance, M Ω
E = voltage at M, V, and
r = resistance of voltmeter, M, M Ω.

NOTE 3—This method has three advantages: (*a*) the quadrature test voltage minimizes the additive effect of superimposing the test voltage on the energizing voltage, (*b*) test current is limited to a maximum of 1 mA, (*c*) the voltage divider minimizes any unbalance in the test cell.

9.3 *Voltmeter Method — In-Phase Test Voltage*—(See Fig. 2) With the two test probes held together, adjust the test voltage V_2 to 600 V. Isolate the test cell from ground. Place one test probe on the sheath and the other test probe at *A*. Record the voltage indicated on meter *M*. Leaving the one test probe on the sheath, relocate the other test probe from *A* to *B*. Again record the voltage.

$$R = [1200/(M_A + M_B)]r$$

where:
R = insulation resistance, M Ω,
M_A = voltage V_2 at meter M with test probe at A,
M_B = voltage V_2 at meter M with test probe at B, and
r = resistance of meter M, M Ω

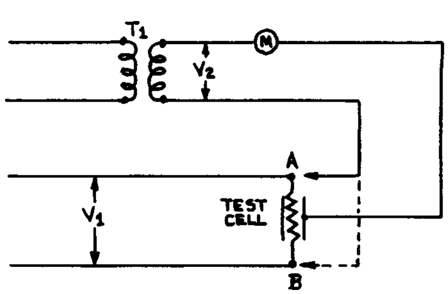
9.4 *Milliammeter—Variable Resistor Method with In-Phase Test Voltage*—(See Fig. 3) Isolate test cell from ground. Adjust the variable resistor until no current flows through the milliammeter. Close the switch and adjust the test voltage to 600 V. Record the current as indicated by the milliammeter.

$$R = \left(\frac{600}{I} - \frac{Rm}{1000} - \frac{Rd}{4000}\right)\frac{1}{1000}$$

where:
R = insulation resistance, M Ω,
I = current on meter M, ma,
Rm = internal resistance of meter, M, Ω, and
Rd = total resistance of voltage divider, Ω.

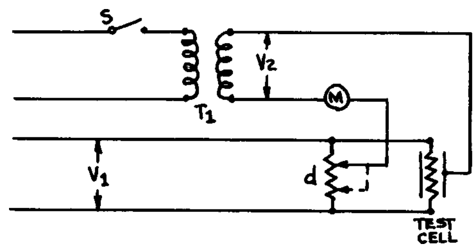
NOTE 4—This method eliminates variables due to unbalanced test cells and does not require quadrature circuitry.

9.4.1 **Caution:** Since the magnitude of the test current is determined by the insulation resistance of the test cell, safety precautions should be taken to protect the milliammeter and operating personnel from high test circuit currents.



T_1 = isolation transformer
V_1 = variable a-c test voltage for energizing test cell.
V_2 = variable a-c test voltage of approximately 600 V. V_2 may be in phase with V_1.
M = a-c voltmeter, rectifier type, 1000 Ω/V, 600 V full-scale deflection.

FIG. 2 Voltmeter Method—In-Phase Test Voltage



T_1 = isolation transformer
V_1 = variable a-c test voltage for energizing test cell.
V_2 = variable a-c test voltage of approximately 600 V. V_2 need not be in quadrature with V_1.
M = a-c milliammeter, rectifier type, 0-10ma, full scale deflection
d = variable resistor
s = switch

FIG. 3 Milliammeter—Variable Resistor Method with In-Phase Test Voltage

10. Procedure

10.1 Peen No. 26 B&S gage, 0.408-mm (0.0159-in.) diameter, ANSI Type K thermocouple wires flat and spot weld about 25 mm (1 in.) apart in the center of the test cell. Wrap the thermocouple one full turn around the test cell to minimize heat conduction from the point of measurements.

10.2 Position the test cell horizontally in a draft-free, but open area. Support the cell at the cold ends of the sheath on insulating supports that do not restrict longitudinal movement due to thermal expansion and contraction. Locate the test cells at least 50 mm (2 in.) apart and a minimum of 100 mm (4 in.) above a matte finished heat resistant surface.

10.3 Attach energizing leads to the electrical connectors on the test cell.

10.4 Oxidize sheath surface by the following procedure: energize the test cell for approximately 10 h, maintaining a sheath temperature of 927°C (1700°F) +0 − 28°C (+ 0 − 50°F). Due to the initial low emissivity of the unoxidized metals, take care that the sheath temperature does not exceed 927°C (1700°F) for this period.

10.5 Before starting the test, apply a proof voltage (hipot) of 1200 V for 1 min to each cell at operating temperature. Discard hipot failures.

10.6 Readjust the energizing voltage to obtain a sheath temperature of 927°C (1700°F). If more than one cell is being tested at one time, the 927°C (1700°F) temperature shall be the mean sheath temperature of all the cells on the test. Readjust the temperature after the first 24 h as required. Maintain the energizing voltage level, thus established to ±1 V for the remainder of the test.

10.7 Ground the sheath except for taking insulation resistance or test measurements.

10.8 Remove the thermocouples.

10.9 Measure and record the insulation resistance or test current initially at 50 h on heat and weekly thereafter. Make measurements during the last half of the ON cycle. Use one of the three methods described in 9.2, 9.3, or 9.4.

10.10 Use a test cycle of 60 min ON and 20 min OFF.

10.11 Continue the test until failure occurs by an open circuit or a ground fault, or for a previously specified time period.

11. Report

11.1 Report the following for each test cell:

11.1.1 Identification of the magnesium oxide specimen,

11.1.2 Initial insulation resistance or test current and test method used,

11.1.3 Final insulation resistance or leakage current and the cumulative ON time at which the measurement was made,

11.1.4 Graph of insulation resistance or leakage current versus ON time,

11.1.5 Life in ON hours to failure or the length of the predetermined test,

11.1.6 Description of type of failure (open circuit, ground, etc.), and

11.1.7 Description of any abnormalities during the test and an explanation if possible.

12. Precision and Bias

12.1 This test method has been in use for many years, but no statement for precision has been made and no activity is planned to develop such a statement.

13. Keywords

13.1 accelerated life; electrical grade; electrical heating elements; magnesium oxide; sheathed type