Designation: D 3215 – 93

An American National Standard

Standard Test Method for Measurement of the Specific Electrical Impedance of Electrical-Grade Magnesium Oxide for Use in Sheathed-Type Heating Elements[1]

This standard is issued under the fixed designation D 3215; 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 test method covers the determination of specific electrical impedance of electrical-grade magnesium oxide by externally heating a test cell to elevated temperatures using typical materials.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety problems, 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 *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. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *measured impedance, Z, n*—the ratio of the root mean square of the voltage applied between two electrodes that are in contact with the specimen to the root mean square of the current distributed throughout the volume of the specimen (neglecting phase effects).

3.1.2 *shape factor, F, n*—the ratio of the test cell length to the logarithm of the ratio of the test-cell diameters, relating the current flow per unit length to the logarithmic mean potential gradient across the insulation.

3.1.3 *specific electrical impedance, Z_s, n*—the ratio of the root mean square of an alternating potential gradient parallel to the current in the material to the root mean square of the current density, and equal to the product of the measured impedance *Z* and a geometrical shape factor *F*. (The impedance is essentially resistive and phase effects are ignored).

4. Summary of Test Method

4.1 The specimen of magnesium oxide is poured into a length of tubing around a centrally located rod, and the assembly is compacted to form a test cell simulating a sheathed heating element. The test cell is placed in a heated furnace. Voltage is applied across the magnesium oxide in the test cell in series with a known resistance. The leakage current is measured in milliamperes. The leakage current and the geometric factor are used to calculate the specific impedance.

5. Significance and Use

5.1 The specific electrical impedance can be used to indicate whether or not the magnesium oxide provides sufficient impedance to perform satisfactorily in high-temperature heating elements.

6. Apparatus

6.1 *Tube Furnace,*[4] horizontal, having a uniformly hot zone at least 178 mm (7 in.) long. A maximum temperature spread of ±5.5°C (±10°F) between three thermocouples is acceptable.

6.2 *Tube Loading Devices* (see Fig. 1 for suggested design).

6.3 *Swaging Machine.* [5]

6.4 *Swaging Dies*, 12.06 mm (0.475 in.), 11.43 mm (0.450 in.), and 11.18 mm (0.440 in.).

6.5 *Metal Trimming Device*.

6.6 *Vibrator.*[6]

6.7 *Spot Welding Machine*.

6.8 *Thermocouples*, three, Type R, No. 24 B & S gage,

[1] This test 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 Lindberg Single Zone Tube Furnace, Type 59545, 12 in., 500 to 1500°C, available from Lindberg Co., 304 Hart St., Watertown, WI 53094, with Temperature Control using Type R Thermocouple and suitable Ceramic Tube and Plugs, or equivalent, has been found suitable for this purpose.

[5] Size 4 swaging machines available from either the Torrington Co., 59 Field St., Torrington, CN 06790, or the Fenn Mfg. Co., 200 Fenn Rd., Newington, CN 06111, or their equivalent, are satisfactory for this test method.

[6] The L & A vibrator, Model F-769, Type B, Size 3, available from the Pressed Steel Co., 705 N. Pennsylvania Ave., Wilkes-Barre, PA 18703, or its equivalent, is satisfactory.

0.510-mm (0.020 in.) diameter with appropriate potentiometer.[7]

6.9 *Test Circuit*, (see Fig. 2), capable of measuring temperature from 500 to 1500°C and leakage current from 0 to 19.99 mA, comprised of the following:

6.9.1 *Essentially Sinusoidal Power Source*, with a minimum power rating of 100 VA at a frequency of 50 to 60 Hz.

6.9.2 *Isolation Transformer*,[8] T_1, with a minimum power rating of 100 VA and an output voltage of 500 V ac.

6.9.3 *Multirange Electronic Voltmeter, M*, capable of measuring up to 500 V ac with an ac input impedance of not less than 0.8 MΩ and an accuracy of ±1 % or better,

6.9.4 *Fixed Resistor*, R_1, with a nominal resistance of 500 Ω and a minimum rating of 5 W.

6.9.5 *Ammeter*,[9] M_1, capable of measuring 19.99 mA with a sensitivity of 0.01 mA,

6.9.6 *Capacitor*, C_1, 0.01 MFD, 1000 VDC, and

6.9.7 *Variable Transformer*,[10] T_2, capable of 0 to 120 V ac.

6.10 *Tubing*,[11] 177.8 ± 8 mm (7.0 ± 0.03 in.) long by 12.70 ± 0.08 mm (0.500 ± 0.003 in.) in outside diameter by 0.89 ± 0.08 mm (0.035 ± 0.003 in.) in wall thickness.

6.11 *80 Nickel-20 Chromium Alloy Rod*, 203.2 ± 0.8 mm (8.0 ± 0.06 in.) long by 4.11 mm (0.162 in.) in diameter (AWG 6), in accordance with Specification B 344.

6.12 *Rubber Plugs*, 12.70 mm (0.500 in.) long by 11.0 mm (0.430 in.) in outside diameter by 3.2 mm (0.125 in.) bore.

6.13 *80 Nickel-20 Chrome Wire*, 0.51 mm (0.20 in.) diameter (AWG 24), in accordance with Specification B 344.

7. Sampling

7.1 Obtain the sample of magnesium oxide (approximately 50 g) in accordance with Test Method D 2755.

8. Procedure

8.1 Clean the tube and rod using standard laboratory cleaning procedures. Measure the tube initial outside diameter, OD_1; inside diameter, ID_1; and initial length, L_1.

8.2 Assemble the rod and tube in the loading device and fill the tube with the specimen of magnesium oxide. Vibrate 2 min to assist densification.

8.3 Pour out the first load of magnesium oxide and repeat 8.2 using new magnesium oxide. Vibrate 7 to 10 min.

8.4 Remove the top filling device and the magnesium oxide to a depth of approximately 8 mm (0.3 in.). Force a rubber plug over the end of the rod and press it down into the tube, firmly against the magnesium oxide. Invert the tube and repeat the process at the bottom end.

8.5 Swage the tube through the 12.06 mm (0.475 in.) die by inserting the bottom end as filled, and pushing smoothly to the middle of the tube. Remove and swage from the other end to overlap the first swaged portion.

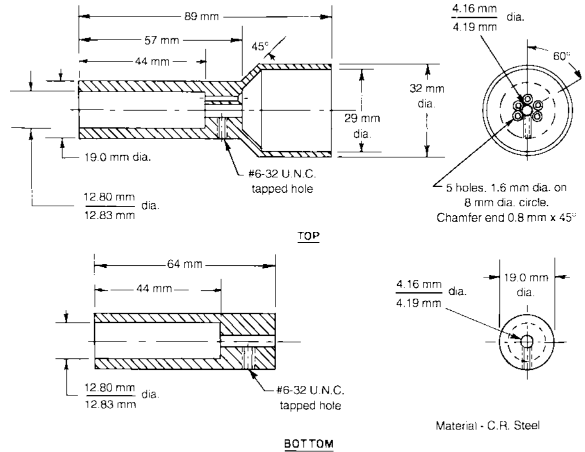

FIG. 1 Test Cell Loading Devices

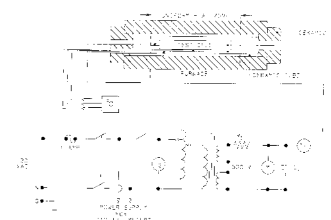

FIG. 2 Test Circuit

8.6 Repeat 8.5 with the 11.43 mm (0.450 in.) and the 11.18 mm (0.440 in.) dies to produce the test cell.

8.7 Wipe the test cell clean. Measure and record the final outside diameter of the tube, OD_2, and the tube length, L_2.

8.8 Machine the test cell to the dimensions in accordance with Fig. 3.

8.9 Measure and record the length, *L*, of the magnesium oxide insulation in the prepared test cell to the nearest 0.8 mm (0.03 in.). Measure the final diameter of the rod, D_2.

8.10 Spot weld the 80 nickel-20 chromium (AWG 24) bare leads to the exposed rod and opposite end of the sheath.

8.11 Center the test cell in the furnace and age for 16 h at 975°C in an oxidizing atmosphere.

8.12 After aging the test cell, connect the test leads and adjust the furnace temperature to 975°C as measured by the average of the three thermocouples and allow the furnace to stabilize at 975 ± 1°C (1787 ± 2°F).

8.13 When the furnace has stabilized, maintain this temperature for 1 h, then energize the test circuit to 500 V ac. Record the leakage current in milliamperes.

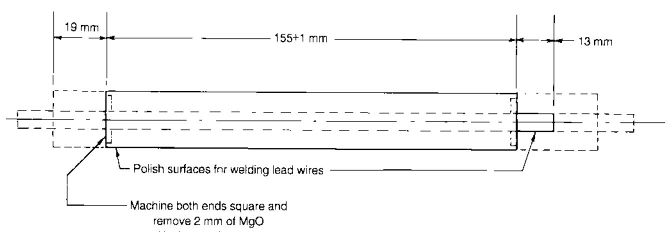

FIG. 3 Preparation of Test Cell

[7] The Omega Engineering potentiometer, available from major electrical/electronic parts suppliers, Model DP701R, or its equivalent, is satisfactory.

[8] A Superior Electric Type 21, available from major electrical/electronic parts suppliers, or equivalent, is satisfactory.

[9] An Electro Industries ammeter, available from major electrical/electronic parts suppliers, VA20G, modified to 19.99-mA full scale, or its equivalent, is satisfactory.

[10] A Magnetek-Triad variable transformer, available from major electrical/electrical parts suppliers, Type N470A, or its equivalent, is satisfactory.

[11] Incoloy 800 tubing, available from the International Nickel Co., One New York Plaza, Dept. T, New York, NY 10004, or its equivalent, is satisfactory.

8.14 Reduce the furnace temperature to 875 ± 1°C (1607 ± 2°F) and allow it to stabilize. Hold for 1 h, then energize the test circuit to 500 V ac. Record the leakage current in milliamperes.

8.15 Calculate the final inside diameter of the tube, ID_2, as follows:

$$ID_2 = \sqrt{(OD_2{}^2R + ID_1{}^2 - OD_1{}^2)/R} \quad (1)$$

where:
OD_1 = initial outside diameter of tube, mm,
OD_2 = final outside diameter of tube, mm,
ID_1 = initial inside diameter of tube, mm,
R = L_2/L_1,
L_1 = initial length of tube, mm, and
L_2 = final length of tube, mm.

9. Calculations

9.1 Calculate the cell impedance, Z, in megohms, as follows:

$$Z = \frac{V}{\text{mA}} \times 10^{-3} \quad (2)$$

9.2 Calculate the geometric shape factor, F, in centimetres, for test cell as follows:

$$F = 2.73 \times L/[\log_{10}(ID_2/D_2)] \quad (3)$$

where:
L = length of insulation, mm,
ID_2 = final inside diameter of tube, mm, and
D_2 = final diameter of rod, mm.

9.3 Calculate the specific impedance, Z_s, in megohm-centimetres for the two test temperatures as follows:

$$Z_s = Z \times F \quad (4)$$

10. Report

10.1 Report the following information:

10.1.1 Complete identification of sample,

10.1.2 Specific electrical impedance at temperatures of 875°C and 975°C obtained from calculation in 9.3, and

10.1.3 Test frequency in hertz.

11. Precision and Bias

11.1 The precision of this test method has not been determined. In a well-equipped laboratory with trained personnel, it is expected that duplicate determinations of specific impedance of a sample of magnesium oxide will agree with ±20 % of the mean value.

11.2 This test method has no bias because the value for specific impedance of magnesium oxide is defined in terms of this test method.

12. Keywords

12.1 electrical resistance; impedance; magnesium oxide; sheathed heating elements; specific electrical impedance