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An American National Standard

Standard Test Method for Thermal Conductivity of Electrical Grade Magnesium Oxide¹

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ε¹ NOTE—Section 13 was added editorially in October 1997.

1. Scope

1.1 This method covers the determination of thermal conductivity of compacted, granular, electrical grade magnesium oxide (MgO) under conditions which simulate the use of this material as insulation in tubular heating units.

1.2 The values stated in inch-pound 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 Elements²

D 2755 Test Method of Sampling and Reduction to Test Weight of Electrical Grade Magnesium Oxide³

D 2771 Test Methods for Compaction Density of Electrical Grade Magnesium Oxide³

3. Summary of Test Method

3.1 The sample of MgO is compacted within the cylindrical space formed by a tubular sheath and a concentric, inner, hollow rod. The rod is heated electrically to produce a temperature gradient across the insulation. Thermal conductivity is calculated from measurements of internal and external temperatures, wattage applied to the unit, and the dimensions of the unit.

4. Significance

4.1 Thermal conductivity of the insulation affects the internal temperature of tubular heating units; therefore, it influences electrical leakage and life of the heaters.

5. Apparatus

5.1 *Filling Machine*, vibratory-type, with suitable loading devices.⁴

5.2 *Swaging Machine*,⁵ with 11.8-mm (0.465-in.) and 11.4-mm (0.450-in.) dies with 6-deg throat angle (12 deg included).

5.3 *Metal Lathe*, or other suitable equipment for cutting test unit to length.

5.4 *Spot Welding Machine*.

5.5 *A-c Voltmeter*, 10 V nominal, $\pm 1\%$ of full scale,

5.6 *A-c Ammeter*, 300 A nominal, $\pm 1\%$ of full scale.

5.7 *Thermocouple*, 26-gage, ANSI Type K, with appropriate potentiometer(s) and thermocouple switch.

5.8 *Variable a-c Power Source*, capable of handling 250 A at 8 V.

6. Materials

6.1 *Degreasing Agent*—Acetone or similar solvent.

6.2 *Hollow Rod*, 80 Ni - 20 Cr alloy, in accordance with Specification B 344, 4.06 ± 0.08 , -0.00 mm (0.160 ± 0.003 , -0.000 in.) in outside diameter, 0.89 ± 0.08 , -0.00 mm (0.035 ± 0.003 , -0.000 in.) in wall thickness, and 410 ± 0.8 mm ($16 \pm \frac{1}{32}$ in.) long, and straight within 0.42 mm/m (0.005 in./ft).

6.3 *Rubber Plugs*, 11.00 mm (0.430 in.) in outside diameter, 3.18 mm (0.125 in.) in inside diameter, and 12.70 mm (0.500 in.) long.

6.4 *Sheath Tubing*, Incoloy 800⁶ or equivalent, bright as welded, 12.70 ± 0.08 mm (0.500 ± 0.003 in.) in outside diameter, 0.89 ± 0.08 mm (0.035 ± 0.003 in.) in wall thickness, 360 ± 0.8 -mm ($14 \pm \frac{1}{32}$ in.) long, and straight within 0.43 mm/m (0.005 in./ft).

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.

Effective Feb. 27, 1970.

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

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

⁴ A suitable filling machine is a three station Oakley loader, available from Oakley Industries, Inc., 7315 N. Linder Ave., Skokie, IL.

⁵ Swaging machines found suitable for this purpose are size 4 swaging machines, available from either Torrington Co., 59 Field St., Torrington, CT, or Fenn Mfg. Co., 200 Fenn Road., Newington, CT.

⁶ Incoloy, 800® is a registered trademark of the International Nickel Co.



7. Sampling

7.1 Obtain a sample of MgO in accordance with Test Methods D 2755.

8. Test Sample

8.1 A sample size of approximately 150 g is required for each test unit.

9. Procedure

9.1 Clean the sheath and rod in the degreasing agent. After cleaning, handle the rod only at the ends.

9.2 Assemble the sheath and the rod with the loading devices to maintain the rod centrally within the sheath and effect bottom closure.

9.3 Using a vibratory filling machine, load the sample into the sheath, taking about 2 min to fill the unit.

9.4 Pour out the first load of sample and discard.

NOTE 1—The initial load serves as the final cleaning step by mildly abrading the metal components.

9.5 Refill the unit as before.

9.6 Remove the top filling device and remove the sample to a depth of approximately 4.8 mm ($\frac{3}{16}$ in.). Force the rubber plug over the end of the rod and firmly down inside the tube. Invert the tube and repeat the process at the bottom end.

9.7 Swage the tube through a 11.80-mm (0.465-in.) die by first inserting one end and pushing through smoothly to within 25 mm (1 in.) of the other end, removing, then repeating the process from the other end.

9.8 Swage the tube through a 11.40-mm (0.450-in.) die in a similar manner. Measure and record the sheath diameter at the center of the unit.

9.9 Cut the unit to 334 mm ($13\frac{1}{8}$ in.), removing about equal portions from each end.

9.10 Trim back the sheath and sample 38 mm ($1\frac{1}{2}$ in.) from each end to expose the rod.

9.11 Recess the sample to a depth of 1.6 mm ($\frac{1}{16}$ in.) on each end with a pointed metal probe.

9.12 Oxidize the sheath by heating the cell in a furnace at an air atmosphere of $980 \pm 20^\circ\text{C}$ for 12 to 16 h.

9.13 Spot weld 26-gage ANSI Type K thermocouple wires to the sheath about 25 mm (1 in.) apart in the center of the cell. (Before welding, peen wires flat, and remove the oxide on the sheath at points of attachment.)

9.14 Spot weld 20-gage 80 Ni - 20 Cr (Specification B 344) wires to each end of the rod about 3.2 mm ($\frac{1}{8}$ in.) from the sheath for use as leads for measuring the applied voltage input.

9.15 Make a thermocouple from 26-gage ANSI Type K wires. Insulate with alumina thermocouple tubing. Insert the couple into the hollow rod of the test cell, with one leg extending out each end and the bead in the center of the cell. Use a new thermocouple for each cell.

NOTE 2—For improved accuracy, both thermocouples should be made from the same spools of wire.

9.16 Set up the test cell in a horizontal position in an open but draft-free area, with the sheath thermocouple on top of the cell. Wrap the thermocouple wires one full turn around the sheath and weight if necessary to maintain the surface contact. Attach the thermocouples through the thermocouple switch to the potentiometer, or to two different potentiometers.

9.17 Attach the voltmeter to the instrument leads. Attach the power terminals from the power source to the rod and the ammeter.

NOTE 3—It is desirable to use water-cooled copper clamps for attaching the power leads to the test cell.

9.18 Energize the test cell and operate in accordance with Table 1 for high-temperature MgO. (For low-temperature MgO other test temperatures may be used, but the time schedule will remain the same.)

9.19 After the completion of the test, cut a cell near the center and measure the outside diameter of the rod.

9.20 Determine the compaction density at the center of

10. Calculation

10.1 Calculate the thermal conductivity of the insulation as follows:

$$k = [0.0876 V A \log (d_2/d_1)]/L(T_1 - T_2)$$

where:

- k = thermal conductivity, $\text{cal/s}\cdot\text{cm}\cdot^\circ\text{C}$,
- V = voltage, V,
- A = current, A,
- d_2 = final inside diameter of the sheath, mm,
- d_1 = final outside diameter of the rod, mm,
- L = length of rod between the instrument leads, cm,
- T_1 = temperature of the rod, $^\circ\text{C}$, and
- T_2 = temperature of the sheath, $^\circ\text{C}$.

10.2 The final inside diameter of the sheath (d_2) can be calculated from the outside diameter after swaging by assuming that the wall thickness has increased by 0.064 mm (0.0025 in.) during swaging.

TABLE 1 High-Temperature MgO

Elapsed Time, min	Test Schedule
	Operation
0	Energize, approximately 5 V, 165 A
10	Adjust power to stabilize sheath temperature at $920 \pm 10^\circ\text{C}$. ^A
20	Adjust power to stabilize sheath at $925 \pm 3^\circ\text{C}$. ^A
30	Maintain at $925 \pm 3^\circ\text{C}$. ^A Observe and record sheath and rod temperatures, voltage, and current.
60	Maintain $925 \pm 3^\circ\text{C}$. ^A Observe and record all readings.
90	Maintain $925 \pm 3^\circ\text{C}$. ^A Observe and record all readings. Reduce power to lower temperature to $815 \pm 5^\circ\text{C}$. ^A within 5 min.
120	Stabilize sheath at $815 \pm 3^\circ\text{C}$. ^A Observe and record all readings.
150	Maintain at $815 \pm 3^\circ\text{C}$. ^A Observe and record all readings. Turn off power.

^A Indicate the temperature.