Designation: D 5470 – 01

An American National Standard

Standard Test Method for Thermal Transmission Properties of Thin Thermally Conductive Solid Electrical Insulation Materials[1]

This standard is issued under the fixed designation D 5470; 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 standard covers a test method for measuring thermal impedance of thin electrical insulation materials.

1.2 This test method is useful with either homogeneous or composite thermally conductive sheet material ranging from 0.02 to 10 mm in thickness.

1.3 This test method measures steady-state heat flux through a flat specimen. Calculations are made as if the specimens were homogeneous. In fact, these materials are usually not homogeneous, but the assumption does not detract from the usefulness of the test methods.

1.4 The term "thermal conductivity" applies only to homogeneous materials. Thermally conductive electrical insulating materials are usually heterogeneous since they typically include fillers, binders, reinforcements such as glass fiber mesh, or a layer of polymeric film. To avoid confusion, this test method uses "apparent thermal conductivity" for measurements of both homogeneous and non-homogeneous materials.

1.5 A limitation of using this test method to calculate apparent thermal conductivity is the problem of accurately determining the specimen thickness. To reflect the commercial practice of measuring thickness as manufactured rather than measuring thickness in an assembly, thickness is determined from measurements made at room temperature in accordance with Method C of Test Methods D 374.

1.6 Thermal impedance test data are influenced by contact pressures, specimen surface characteristics, and the existence of alternate paths for heat transmission which are not through the specimen. This test method determines thermal conduction properties under a specific set of conditions (including a 50°C average test temperature) which may not agree exactly with the conditions in an application. As a result, the degree of correlation between this test method and any particular application needs to be determined.

1.7 The values stated in SI units are to be regarded as standard.

1.8 *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.*

NOTE 1—Earlier versions of this document included a Method B (the Roiseland Method). This method is now deleted because of a lack of general support.

2. Referenced Documents

2.1 *ASTM Standards:*

D 374 Test Methods for Thickness of Solid Electrical Insulation [2]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[3]

E 1225 Test Method for Thermal Conductivity of Solids by Means of the Guarded-Comparative-Longitudinal Heat Flow Technique[3]

2.2 *Military Specification:*

MIL-I-49456 Insulation Sheet, Electrical, Silicone Rubber, Thermally Conductive, Fiberglass Reinforced[4]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *average temperature (of a surface)*, *n*— the area-weighted mean temperature.

3.1.2 *composite*, *n*—a material made up of distinct parts which contribute, either proportionally or synergistically, to the properties of the combination.

3.1.3 *homogeneous material*, *n*—a material in which relevant properties are not a function of the position within the material.

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[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 D09.19 on Dielectric Sheet and Roll Products.

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

[3] *Annual Book of ASTM Standards*, Vol 14.02.

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

3.1.4 *thermal conductivity* (λ), *n*—the time rate of heat flow, under steady conditions, through unit area, per unit temperature gradient in the direction perpendicular to the area.

3.1.5 *thermal impedance* (θ), *n*—the total opposition that an assembly (material, material interfaces) presents to the flow of heat.

3.1.6 *thermal interfacial impedance (contact resistance)*, *n*—the temperature difference required to produce a unit of heat flux at the contact planes between the specimen surfaces and the hot and cold surfaces in contact with the specimen under test. The symbol for contact resistance is R_I.

3.1.7 *thermal resistivity*, *n*—the reciprocal of thermal conductivity. Under steady-state conditions, the temperature gradient, in the direction perpendicular to the isothermal surface per unit of heat flux.

3.2 *Symbols:Symbols Used in This Standard:*

3.2.1 λ = thermal conductivity, watt per metre-K.

3.2.2 T_A = temperature of hot surface in contact with a specimen, K.

3.2.3 T_B = temperature of hot surface of a specimen, K.

3.2.4 T_C = temperature of cold surface of a specimen, K.

3.2.5 T_D = temperature of cold surface in contact with a specimen, K.

3.2.6 A = area of a specimen, m^2.

3.2.7 X = thickness of specimen, m.

3.2.8 Q = time rate of heat flow, W or J/s.

3.2.9 q = heat flux, or time rate of heat flow per unit area, W/m^2.

3.2.10 θ = thermal impedance, temperature difference per unit of heat flux, $(K \cdot m^2)/W$.

4. Summary of Test Method

4.1 In this test method (a modification of Test Method E 1225), a specimen is sandwiched between two metal masses, compressed, and supplied with a measured amount of heat energy. At equilibrium, temperatures are measured and a thermal impedance is calculated. The thermal impedance and thickness are used to compute apparent thermal conductivity.

5. Significance and Use

5.1 This test method measures the thermal transmission properties of low-modulus (deformable) dielectric materials. These materials are used to aid heat transfer in electrical and electronic applications.

NOTE 2—This test method is useful with high-modulus materials if layers of low-modulus materials are combined with test specimens to exclude air from test interfaces.

5.2 This test method is especially useful for generating thermal data on specimens that are too thin to be fitted with thermocouples for temperature sensing. This test method may avoid problems of measurement due to nonuniform pressures, surface conditions, or techniques used to assemble electronic equipment.

5.3 In effect, this test method assumes that specimen layers coalesce and that there is no effective interfacial resistance between layers. The slope of the plot of thermal impedance against cumulative thickness permits the determination of thermal conductivity without regard to thermal interfacial impedance.

5.4 This test method is approved for use by the Department of Defense, and is included in Military Specification MIL-I-49456.

TEST METHOD

6. Apparatus

6.1 General features are shown in Fig. 1 and Fig. 2. The apparatus shown in Fig. 1 uses a reference calorimeter to determine the rate of heat flow through the specimen. Optionally omit the reference calorimeter (Fig. 2). The rate of heat flow in the specimen is determined from the electrical power applied to the heater. Smoothly finish all contacting surfaces to within 0.4 µm to approximate a true plane for the metre bars in contact with the specimen surface.

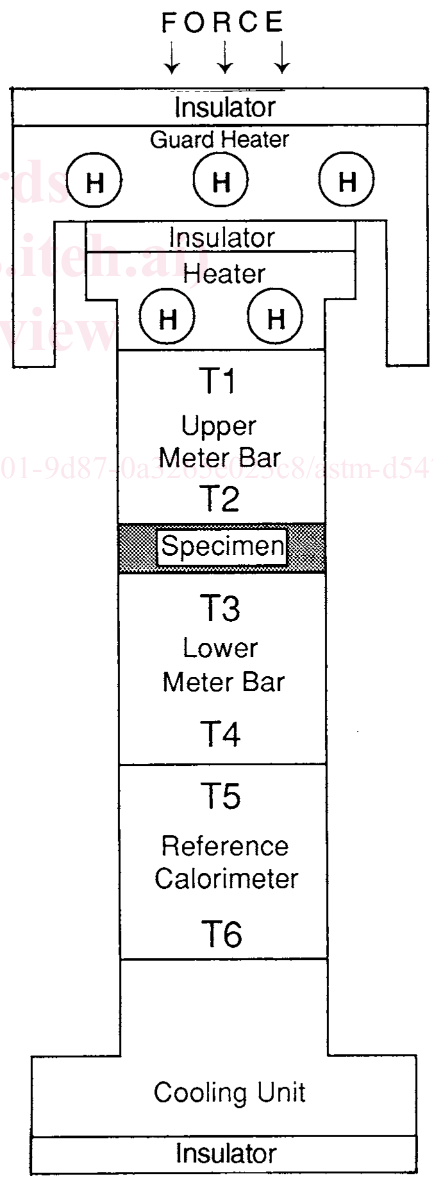

FIG. 1 Guarded Heater with Reference Calorimeter