



Designation: D2149 – 13

# Standard Test Method for Permittivity (Dielectric Constant) And Dissipation Factor Of Solid Dielectrics At Frequencies To 10 MHz And Temperatures To 500°C<sup>1</sup>

This standard is issued under the fixed designation D2149; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method covers the determination of the relative permittivity (dielectric constant) and dissipation factor of solid dielectrics from 50 Hz to 10 MHz over a range of temperatures from  $-80$  to  $500^{\circ}\text{C}$ .<sup>2,3</sup> Two procedures are included as follows:

1.1.1 *Procedure A*—Using Micrometer Electrode.

1.1.2 *Procedure B*—Using Precision Capacitor.

NOTE 1—In common usage the word “relative” is frequently dropped.

1.2 *This standard does not purport to address 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.*

## 2. Referenced Documents

2.1 *ASTM Standards*:<sup>4</sup>

**D150** Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation

**D1711** Terminology Relating to Electrical Insulation

**E197** Specification for Enclosures and Servicing Units for Tests Above and Below Room Temperature (Withdrawn 1981)<sup>5</sup>

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D09 on Electrical and Electronic Insulating Materials and is the direct responsibility of Subcommittee D09.12 on Electrical Tests.

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<sup>2</sup> R. Bartnikas, Chapter 2, “Alternating-Current Loss and Permittivity Measurements,” *Engineering Dielectrics, Vol IIB, Electrical Properties of Solid Insulating Materials, Measurement Techniques*, R. Bartnikas, Editor, ASTM STP 926, ASTM, Philadelphia, 1987.

<sup>3</sup> R. Bartnikas, Chapter 1, “Dielectric Loss in Solids,” *Engineering Dielectrics, Vol IIA, Electrical Properties of Solid Insulating Materials: Molecular Structure and Electrical Behavior*, R. Bartnikas and R. M. Eichorn, Editors, ASTM STP 783, ASTM Philadelphia, 1983.

<sup>4</sup> For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard’s Document Summary page on the ASTM website.

<sup>5</sup> The last approved version of this historical standard is referenced on www.astm.org.

## 3. Terminology

3.1 *Definitions*:

3.1.1 Permittivity and dissipation factor are fully defined in Terminology **D1711**. Briefly, the permittivity of an insulating material is the ratio of the capacitance between two conductors when embedded in the material to the capacitance between the same configuration of conductors in a vacuum (or air). The dissipation factor is the ratio of the resistive to capacitive currents in the dielectric. The product of the permittivity and dissipation factor is the loss index.

## 4. Significance and Use

4.1 Permittivity and dissipation factor are sensitive to changes in chemical composition, impurities, and homogeneity. Measurement of these properties is, therefore, useful for quality control and for determining the effect of environments such as moisture, heat, or radiation.

## 5. Apparatus

5.1 *Measuring Circuits*—Suitable measuring circuits are described in Test Methods **D150**. For measurements from 50 Hz to 100 kHz a substitution method using a low-voltage capacitance bridge is recommended. For measurements at 1 MHz and above, a resonant-circuit susceptance variation method is recommended. The  $Q$  of the circuit has to be at least 200 except for very low loss materials, for which a  $Q$  of 500 or higher is desirable.

5.2 *Test Enclosure*—Unless testing only at room temperature, it is necessary to adapt a Hartshorn-Ward type specimen holder to a temperature-controlled test enclosure. Where applicable, use the requirements for a grade A enclosure as in Specification **E197**. A suggested arrangement is shown in **Fig. 1**. This arrangement provides terminal connections away from the temperature zone.

5.3 *Specimen Holder*—The suggested arrangement shown in **Fig. 1** incorporates the following requirements:

5.3.1 The selection of the metals is of utmost importance. The metal has to be of good thermal and electrical conductivity and yet be oxidation resistant and have sufficient strength to maintain its mechanical dimensions after repeated heating.

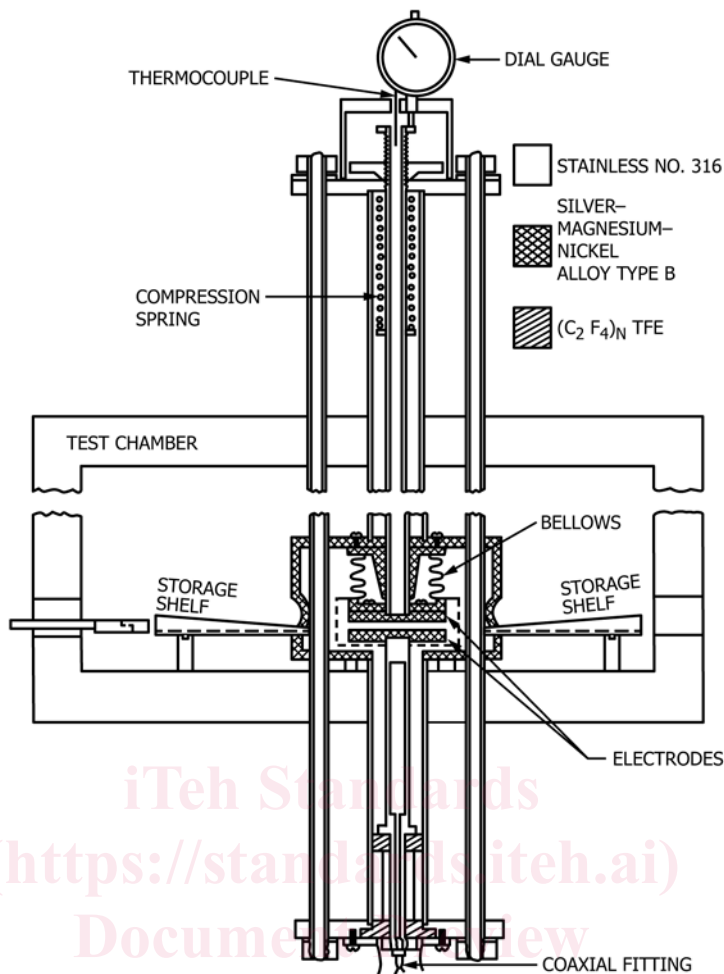


FIG. 1 Suggested Specimen Holder

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AISI Stainless No. 316 fulfills these requirements except for the thermal conductivity. The time required for a specimen to reach equilibrium in a holder made from this material is quite long. Precious metal alloys such as type B silver-magnesium-nickel have better overall properties but require special heat treating.

5.3.2 The preferable insulator materials are aluminum oxide, beryllium oxide, or polytetrafluoroethylene.

5.3.3 Use electrodes 50 mm in diameter and at least 5 mm thick, with sharp corners. Maintain electrode parallelism to within 0.01 mm.

5.3.4 Select a length and cross-section for the lower tube so that the temperature of each insulator does not exceed 100°C when the oven is at 500°C. Select a length and cross-section for the upper tube so that the drive nut can be touched with the operator's fingers (keep the drive nut less than 60°C) when the oven is at 500°C.

5.3.5 Use a micrometer or dial gage with a precision of 0.005 mm to determine electrode separation and to monitor specimen expansion.

## 6. Electrodes

6.1 Prior to measurement, apply conducting film or foil electrodes to both flat surfaces of the specimen. (The specimen

thickness is to be determined before applying electrodes.) Silver paint, tin or tin-lead foil, or evaporated metal electrodes have ranges of usefulness. Evaporated metal electrodes are the most suitable. When the specimen is porous sprayed-on metal electrodes are useful. Additional information on the suitability of various electrode systems is contained in Test Methods D150.

## 7. Sampling

7.1 See ASTM standards for specific materials.

## 8. Test Specimen

8.1 Use a disk test specimen with a diameter of  $40.00 \pm 0.01$  mm and a thickness of 2 to 3 mm. Finish the surfaces to 1.8  $\mu$ m or better and maintain parallel surfaces to within 0.01 mm. The samples have to be free of bubbles and other defects.

## 9. Standard Test Frequencies

9.1 Unless otherwise specified, make measurements at one or more of the following frequencies:

|         |            |
|---------|------------|
| 60 Hz   | 100 000 Hz |
| 100 Hz  | 1 MHz      |
| 400 Hz  | 10 MHz     |
| 1000 Hz |            |