

Methods of test for

Determination of permittivity and dissipation factor of electrical insulating material in sheet or tubular form

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- British Plastics Federation
- British Rubber Manufacturers' Association Ltd.
- EEA (Association of Electronics, Telecommunications and Business Equipment Industries)
- ERA Technology Ltd.
- Electrical and Electronic Insulation Association (BEAMA Ltd.)
- Federation of Resin Formulators and Applicators (Ferfa)
- Health and Safety Executive
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Foreword

This British Standard was prepared under the direction of the Plastics and Rubber Standards Policy Committee.

Useful background information may be obtained from IEC 250 and from BS 2067 both of which cover a wider frequency range than this standard.

The resonance substitution methods described in BS 2067 have become obsolescent owing to the non-availability of suitable commercial equipment. The methods in this standard will, in due course, supersede those in BS 2067, except for materials of very low dielectric loss or for measurements at high frequencies.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 12, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Introduction

The methods described may be used for sheet materials in the thickness range 0.3 mm to 5.0 mm. The air substitution method is suitable for sheet materials of thickness 1.0 mm to 5.0 mm.

The two immersion methods are capable of better precision for sheet materials of thickness 0.3 mm to 1.0 mm and have the advantage that accurate knowledge of the specimen thickness is not required.

One of the immersion methods is suitable for measurements on tubular specimens but individually constructed electrodes may be needed for specific sizes of tube.

1 Scope

This British Standard describes three methods for the measurement of permittivity and of dissipation factor of electrical insulating materials in the form of sheets or rigid circular tubes at frequencies between 50 Hz and 1 MHz, under normal ambient temperatures and conditions. The methods described are applicable to sheet materials in the thickness range 0.3 mm to 5.0 mm and for tubes at least 75 mm long.

The methods are:

- an air substitution method, commonly called the “Lynch” method (method A)
- a two fluid immersion method (method B)
- a single fluid immersion method (method C).

Methods A and B are suitable for materials of permittivity up to 10.0. For materials of dissipation factor below 250×10^{-6} the precision achieved by these methods may not be acceptable.

Method A requires accurate knowledge of the specimen thickness and should be used in all cases when this information is available. If the thickness is not accurately known, methods B or C may be used subject to the limitation that method C is suitable for materials for which a liquid matching its permittivity to within 0.1 is available. Method C is suitable for measurement of polyolefin sheets whose permittivity sufficiently closely matches that of silicone oil of kinematic viscosity of 1 cSt to 2 cSt¹⁾.

Methods B and C are not suitable for materials with an open cell structure.

Method B is suitable for measurements on straight cylindrical tubes of circular cross section.

2 References

2.1 Normative references

This British Standard incorporates, by reference, provisions from specific editions of other publications. These normative references are cited at the appropriate points in the text and the publications are listed on the inside back cover. Subsequent amendments to, or revisions of, any of these publications apply to this standard only when incorporated in it by updating or revision.

2.2 Informative references

This British Standard refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on the inside back cover, but reference should be made to the latest editions.

3 Definitions

For the purposes of this standard the definitions given in BS 4727-1:Group 10:1991 apply.

4 General

In the methods described, the electrode assembly is an integral part of the specimen holder into which the specimen and appropriate insulating fluid(s) are introduced, the capacitance and dissipation factor of the assembly being measured.

Such systems introduce smaller errors in measurement than intimately applied electrodes, and facilitate the provision of guard electrodes which eliminate electric field distortions and stray capacitances.

Suitable electrode systems for each of the methods are described in 8.2, 9.2 and 10.2. Suitable measuring instruments are described in clause 7.

5 Test conditions

Unless otherwise specified in the materials specification, specimens shall be conditioned for (20 ± 4) h under the following conditions:

- temperature $(23 \pm 2) ^\circ\text{C}$;
- relative humidity $(50 \pm 5) \% \text{ r.h.}$

Unless otherwise specified in the materials specification, measurements shall be carried out under the same conditions.

The specimen, electrode system and immersion fluid(s) and their environment shall be in thermal equilibrium when the measurement is made, the temperature difference being less than $1 ^\circ\text{C}$.

¹⁾ 1 cSt = $1 \times 10^{-6} \text{ m}^2 \text{ s}^{-1}$

NOTE The permittivity and dissipation factor of a dielectric may change considerably with frequency, temperature and relative humidity. Accordingly the measured values should only be taken to indicate the dielectric properties of the specimen under conditions similar to those used for the test.

6 Number and handling of specimens

In all three methods the test shall be carried out on three specimens unless otherwise specified. Each specimen comprises one test piece for methods A and B, and two test pieces for method C. At all times the specimens shall be handled with stainless steel flat-faced forceps to minimize the likelihood of damage or contamination, taking particular care not to compress or distort flexible or soft materials.

7 Measuring instruments

An instrument of adequate sensitivity²⁾ shall provide a minimum detectable change in capacitance of 0.3 fF (i.e. 0.3×10^{-15} F) and a minimum detectable change in dissipation factor of 0.00001 (i.e. 10×10^{-6}).

NOTE 1 A variety of modes of output is offered by commercial measuring equipment. Some of the more sophisticated offer a variety of outputs from the same instrument thus enabling the user to select the appropriate output. This standard assumes that the output is in the form of capacitance (*C*, in pF) and dissipation factor (*D*). See Annex A for conversion of other forms of output to this format.

NOTE 2 The electrode systems described in methods A and B are of three terminal “guarded” design. This practically eliminates the influence of stray electric fields at the electrode edges and removes the need for “edge capacitance” corrections. In method C there is a close match in permittivity between the material and the immersion fluid and thus there is little change in edge capacitance when the specimen is inserted or removed.

NOTE 3 Care should be taken to ensure that all measurement leads are screened and kept as short as possible, consistent with the manufacturers’ instructions.

Some types of instrument require a “short” and “open” circuit calibration. The “short circuit” should be established between the electrodes of the electrode system i.e. in the position which the specimen would occupy. Care should be taken to ensure that the short circuit used is of low resistance and inductance and that it does not damage the surfaces of the electrode. It is essential also to ensure the micrometer zero is not altered. A smooth metal disc, the diameter of which, is approximately 75 % that of the guarded electrode and 1 mm to 3 mm thick is suitable for use as a short circuit.

The “open” circuit is established by disconnection of the electrodes at the end of the cables furthest from the capacitance meter, i.e. so that allowance is again made for the effect of the measuring leads. Reference should be made to the manufacturer’s instructions to discover whether it is necessary to link the outer connections of the coaxial cables during this calibration and whether the error introduced by omission of the electrode system is small and may be ignored.

Accordingly it is to be preferred if a three terminal measuring instrument, with for example “high”, “low” and “guard” connections can be used.

NOTE 4 Many commercial instruments are now based on measurement of current, voltage and phase angle. These instruments are commonly of four (or five) terminal design. Reference should be made to the manufacturer’s instructions before connecting a three terminal electrode system to such an instrument, since the preferred mode of connection may differ between instruments.

8 Method A: Air substitution technique

8.1 Principle

The test piece is inserted into a guarded electrode system in which the electrode separation is variable. Small air gaps are left between the sample and electrodes to ensure that the test piece is not mechanically stressed. The capacitance and dissipation factor of the assembly are measured.

The test piece is removed and the electrode separation adjusted so that the capacitance is restored to its original value. The electrode movement and the new value of dissipation factor are measured.

The permittivity and dissipation factor of the test material are calculated, as shown in 8.5.2, from the test piece thickness, the change in electrode spacing and the change in observed values of dissipation factor.

8.2 Electrode system

The electrode system shall be of rigid mechanical design and of sufficient thermal capacity that rapid changes in ambient temperature do not significantly affect its dimensions. It shall comprise three parallel concentric electrodes, one of which is a guard. The electrode surfaces shall be flat and shall remain substantially parallel at all times.

Figure 1 illustrates a possible construction and means of connection to a three terminal measuring instrument.

NOTE 1 For connection to four or more terminal instruments, reference should be made to the manufacturer’s instructions.

The system comprises a circular measuring electrode surrounded by a concentric coplanar guard electrode, and a movable electrode whose separation from the measuring electrode is controlled by a micrometer head. Rotation of the drive mechanism should not be transmitted to the electrode.

NOTE 2 A more precise means of determining the changes in electrode spacing, e.g. a displacement transducer, which will not disturb the electric field between the electrodes may be introduced.

8.3 Test pieces

The test piece shall be flat and uniform in thickness and shall extend beyond the unguarded electrode by at least 5 mm.

²⁾ For information on the availability of suitable instruments and electrode systems write to Customer Services Information, Services Group, BSI, Linford Wood, Milton Keynes MK14 6LE.