

Determination of

Power-factor and permittivity of insulating materials —

(Hartshorn & ward method)

Co-operating organizations

The Electrical Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:—

- Admiralty*
- Air Ministry
- Association of Consulting Engineers (Incorporated)
- Association of Supervising Electrical Engineers
- British Electrical and Allied Industries Research Association*
- British Electrical and Allied Manufacturers' Association
- British Electrical Development Association
- British Electricity Authority and Area Boards
- British Railways, The British Transport Commission
- Cable Makers' Association
- Crown Agents for the Colonies
- Electric Lamp Manufacturers' Association
- Electric Light Fittings Association
- Electrical Contractors' Association (Incorporated)
- Electrical Contractors' Association of Scotland
- Engineering Equipment Users' Association
- General Post Office*
- Institution of Electrical Engineers
- Ministry of Fuel and Power
- Ministry of Labour and National Service (Factory Dept.)
- Ministry of Supply*
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- National Physical Laboratory*
- North of Scotland Hydro-Electric Board
- Oil Companies Materials Committee
- Public Transport Association (Incorporated)
- Radio Industry Council*
- War Office

The Government departments and scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this standard.

- Accumulator Makers Association
- British Plastics Federation
- Glass Textile Association Ltd.
- National Paint Federation
- Radio and Electronic Component Manufacturers' Federation
- Research Association of British Rubber Manufacturers

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Foreword

The method described in this British Standard for the determination of the power-factor and permittivity of insulating materials at radio frequencies was originally described in the *Journal of the Institution of Electrical Engineers*, Vol. 79, page 597 (1936), and it has since been adopted as a standard test in certain British Standards for insulating materials. It is appreciated that this is not the only method of measuring the power-factor and permittivity at radio frequencies, and the possibility of extending the scope of the present British Standard to cover other methods used in industry is under consideration.

Obsolescent (by Amendment No. 3)

The standard has been reviewed and it has been decided that it should now be regarded as obsolescent. Its use for testing purposes is therefore not recommended. The standard will be withdrawn in due course.

NOTE 1 IEC 250:1969 "Recommended methods for the determination of the permittivity and dielectric dissipation factor of electrical insulating materials at power, audio and radio frequencies including metre wavelengths" is under revision.

NOTE 2 Attention is drawn to ERA Publication 73-5 (issued 1973) "Determination of loss tangent and permittivity of insulating materials from 104 Hz to 108 Hz (Revised Hartshorn & Ward method)".

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 17 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.

1 Scope

This British Standard describes the Hartshorn and Ward method for the determination of the power-factor and the permittivity of insulating materials at radio frequencies. The method is suitable for the measurement of power-factor and permittivity within a frequency range of 10 kc/sec. to 100 Mc/sec. at normal room temperatures, and full details are given of the procedures to be followed as well as of the underlying theory (Appendix A) and of the testing equipment (Appendix B).

2 General principles

The method makes use of capacitance variation in a tuned circuit, a thermionic voltmeter being employed as a detector of resonance.

The power-factor of the test specimen is calculated from the width of the resonance curve as determined from the observed change in capacitance necessary to reduce the maximum (resonant) voltage to a known fraction of its value.

Permittivity is determined by measuring by substitution the capacitance of a specimen of known dimensions. The same adjustable capacitor is used in turn as test capacitor and standard air capacitor.

NOTE For definitions of the symbols used in this British Standard, see Appendix B.

3 Accuracy and range

It is possible to measure power-factors of the order of 0.03 to within 0.0003, and power-factors of the order of 0.0002 to within 0.00005 of the true values (see Note 3, page 5). The range of power-factor is normally 0.0001 to 0.1 but may be extended above 0.1, as described in Clause 9. Permittivities from 1 to 5 may be measured to ± 2 per cent of the true value. Methods for recalibration of the apparatus and the necessary precautions to be observed in use are given in Appendix D.

4 Temperature of test specimen and test frequency

The power-factor and permittivity of a dielectric may change considerably with frequency and temperature and consequently the measured values obtained from test may be taken to indicate a performance over only a narrow band of frequencies and temperatures near those adopted for the test. A statement of the frequency and temperature at which measurements were made shall therefore accompany test results.

5 Form of test specimen: moulding material and sheet material

The test specimen may be in the form of a disk or a tube, as described below:

a) *Disk specimens.* The specimen shall normally be a disk 53 ± 1 mm. (2.087 ± 0.039 in.) in diameter. Specimens of smaller diameter are permissible, however, and indeed are necessary for material of high permittivity. The most suitable thickness of specimen for a given material is that which will give a capacitance within the range 20–100 μF . It will generally be found in the range 0.50–2.50 mm. (0.020–0.098 in.).

The specimen shall be sensibly flat and its thickness should not vary by more than 0.025 mm. (0.001 in.). The thickness of the specimen may be reduced by suitable machining.

In testing moulding material the specimen shall be moulded to shape under the conditions specified in the relevant British Standard if such exists, and, if necessary, subsequently machined.

In testing sheet material the specimen shall be machined from the sheet under test. When it is necessary to reduce the thickness of a specimen to a suitable value, this shall be carried out by machining one of its faces.

b) *Tube specimens.* The specimen shall be a round tube at least 40 mm. greater in length than the longer outer electrode. (See Clause 6.) A 150 mm. (6 in.) length will often be found suitable. The outer surface of the tube shall be smoothly finished and shall be substantially coaxial with the inner surface.

6 Specimen electrodes

a) *For moulding material and sheet material.* When the specimen is 50 mm. or more in diameter it shall be tested with disk electrodes of metal foil (hereafter called “foils”) 0.025–0.050 mm. (0.001–0.002 in.) thick and 50 mm. (1.97 in.) in diameter. The foils shall be applied concentrically to the specimen with the thinnest possible film of petroleum jelly and shall be pressed on to the surfaces and smoothed down until all irregularities are removed. The surface of the foils shall then be cleaned with benzene. Alternatively, metal films of adequate thickness deposited in vacuo, either by sputtering or by volatilization, may be used.

If the material is known to be of high permittivity (in which case the specimen and electrodes will usually be less than 50 mm. in diameter) the electrodes shall be one of the following forms:—

- i) Fired-on silver films of adequate thickness, of the type commonly applied to ceramic materials.
- ii) Metal films of adequate thickness deposited in vacuo either by sputtering or by volatilization.

b) *For tube.* For the Procedures 1 and 2 described in Clause 11 the foil electrodes shall be cylinders of foil 0.025–0.050 mm. (0.001–0.002 in.) thick. The foils shall be applied to the specimen with the thinnest possible film of petroleum jelly and shall be pressed on to the outer surface and smoothed down until all irregularities are removed. The surface of the foils shall be cleaned with benzene.

For Procedure 1, described in Clause 11, the outer electrode shall be a cylinder of foil with at least 20 mm. of the specimen protruding from each end of the cylinder. The inner electrode shall be mercury and shall be adjusted to two levels in turn. The lower level shall be at least 10 mm. (0.4 in.) higher than the bottom edge of the outer foil electrode and the upper level shall be at least 10 mm. (0.4 in.) lower than the top edge of the outer foil electrode. The change in capacitance of the specimen, resulting from raising the level of the inner mercury electrode, shall be in the range 20–100 μF .

For Procedure 2, described in Clause 11, two pairs of electrodes shall be used in turn. Each pair of electrodes shall consist of an inner mercury electrode and an outer foil electrode of equal length. The difference between the lengths of the pairs of electrodes shall be such that the capacitance change of the specimen lies in the range 20–100 μF . The specimen shall protrude at least 20 mm. (0.79 in.) from each end of the longer foil electrode.

7 Test procedure for moulded materials and sheet materials using specimens of 50–54 mm. in diameter

The theory of the method is given in Appendix A and a description of the apparatus is given in Appendix B. In Figure 1, however, are depicted the basic features of the circuit. C_1 represents the capacitance formed by the insertion of a test specimen in a capacitor assembly (depicted in Figure 2) to which is connected a coil LR and a thermionic voltmeter V. A second capacitor C_2 is connected in parallel with these components.

Figure 2 shows a capacitor assembly for testing circular specimens; the capacitance C_1 of Figure 1 is the specimen capacitor M_1 , which consists of a fixed plate and an adjustable plate, A and B respectively, between which the test specimen is inserted. The other capacitor (C_2 of Figure 1) is the micrometer incremental capacitor M_2 which, as shown in Figure 2, is formed by the micrometer stem and the fixed electrode A of the specimen capacitor M_1 . Both M_1 and M_2 are adjusted by micrometer heads incorporating graduated scales.

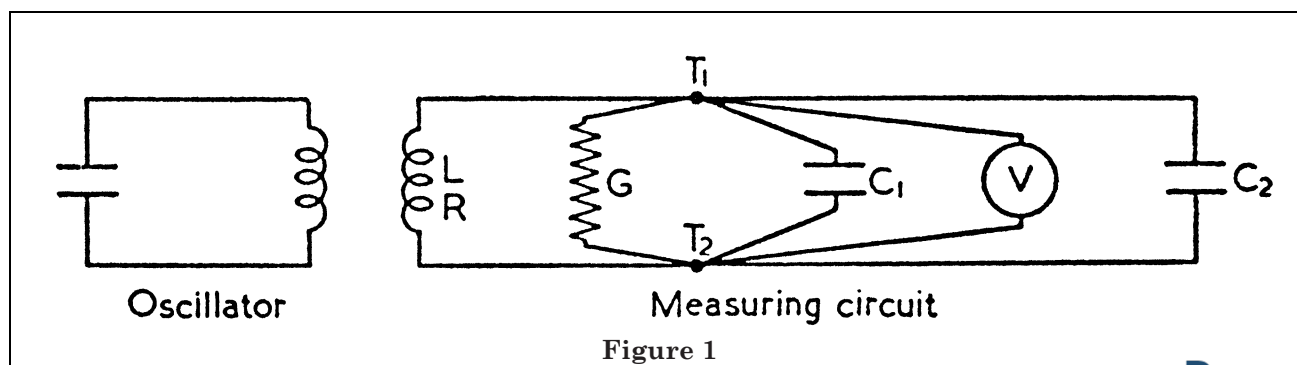


Figure 1

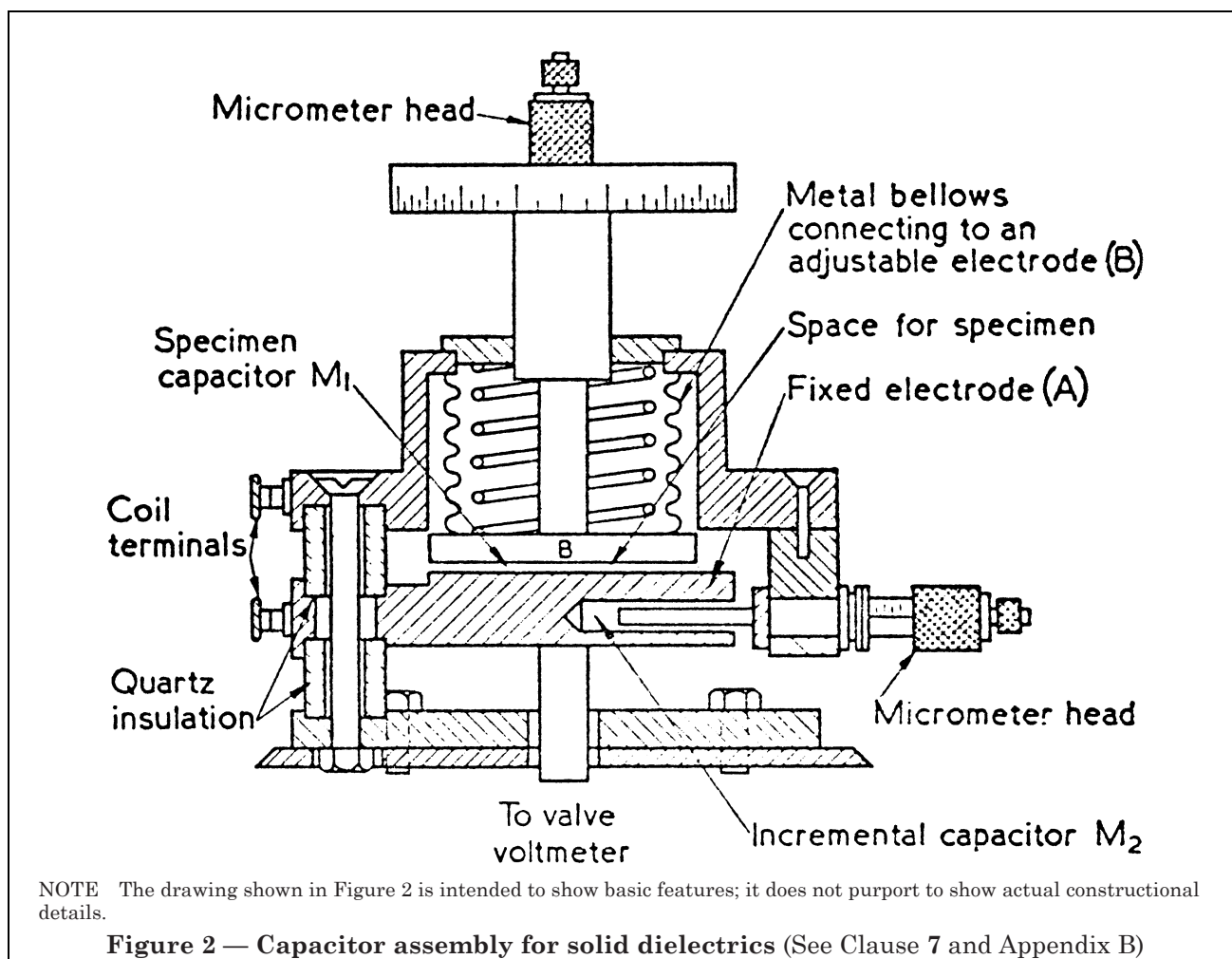


Figure 2 — Capacitor assembly for solid dielectrics (See Clause 7 and Appendix B)

Specimens of 50–54 mm. in diameter shall be tested in the following manner:—

- a) The appropriate oscillator and measuring circuit coils shall be connected to the apparatus (see Appendix B).
- b) The specimen, together with electrodes, if used, shall be placed centrally between the plates of the specimen capacitor M_1 , and the adjustable plate screwed gently down so that the specimen is gripped sufficiently to ensure good contact, but without unnecessary compression. The specimen capacitor scale reading shall be noted and used to obtain the corresponding capacitance, C_i .
- c) The micrometer incremental capacitor M_2 shall be set by adjusting its micrometer head to the approximate centre of its range, and the oscillator shall then be tuned to the measuring circuit resonant frequency as indicated by peak galvanometer deflection. The frequency shall be checked by reference to the oscillator calibration graph or table supplied with the oscillator. If the frequency is not within the required range, the measuring circuit coil shall be changed.
- d) If the correct resonance frequency cannot be obtained as described under c), then, provided that the requirements of Appendix B, b) i), are satisfied, the oscillator shall be set to the required frequency and an auxiliary capacitor shall be connected in parallel with the specimen capacitor and resonance obtained by varying this auxiliary capacitor. Care should be taken to ensure that the true resonance is found. In most cases this presents no difficulty, but with close coupling between the measuring circuit and the oscillator, the measuring circuit may respond to a harmonic of the oscillator frequency. To guard against this, the effect of multiplying the oscillator frequency say by 2, 3, $\frac{1}{2}$ and $\frac{1}{3}$, should be tried until the frequency giving the largest deflection is found.