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भारतीय मानक मसौदा

एबोनाइट – विशिष्टता
(IS 6693 का पहला पुनरीक्षण)

Draft Indian Standard

EBONITE — SPECIFICATION

(*First Revision of* IS 6693)

ICS 83.080.10

Rubber and Rubber Products Sectional Committee, PCD 13	Last date for receipt of comment is **21 May 2024**

FOREWORD

(*Formal clauses will be added later*)

This standard was originally published in 1972. Requirements for two types of ebonite, namely, unloaded and loaded, was covered by this standard. Unloaded ebonite is black in colour while loaded ebonites are usually supplied in red or brown colour to distinguish it from other types. Impact test was not included and its introduction was to be considered at a later stage. Considerable assistance was drawn from the following publications in the preparation of this standard:

BS 234 : 1971 Loaded and unloaded ebonites for electrical purposes. British Standards Institution.
BS 3164: 1959 Loaded and unloaded ebonites for general purposes. British Standards Institution.

This revision has been undertaken to update the cross-referred standards in the standard and editorial changes. Amendment no.1 has also been incorporated where the cross breaking strength was modified.

This standard contains clauses **4.1.1** to **4.1.3, 4.2.1**, **4.2.3**, **4.3.1**, **4.5** and **4.6** which call for agreement between the purchaser and the supplier.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1 SCOPE

This standard prescribes the requirements and the methods of sampling and tests for ebonite in the form of sheets, rods, tubes and mouldings.

2 TERMINOLOGY

2.1 For the purpose of this standard, the following definitions shall apply.

2.2 Cross Breaking Strength

The load required to fracture by bending a bar shaped test piece of given rectangular cross section.

2.3 Electric Strength

The breakdown strength in kilovolts per unit thickness of material required to produce a discharge through the body of the material.

2.4 Permittivity

The ratio of the capacity of a condenser having the material as dielectric to the capacity of a similar condenser having air, or more precisely vacuum, as dielectric, the measurements being made by alternating current.

2.5 Plastic Yield

The total deformation of bar shaped test piece stressed under given conditions at a given temperature for a given time.

2.6 Loss Tangent

The ratio of the power loss (watts) in the material when used as the dielectric of a condenser to the total power transmitted through the condenser.

3 TYPES

3.1 This standard covers two types, namely, Type 1 and Type 2 of the material depending upon the physical properties.

4 REQUIREMENTS

4.1 Material and Workmanship

4.1.1 Ebonite shall be manufactured from rubber and sulphur with or without the addition of suitable compounding ingredients of such value and quality that the finished product complies with the requirements specified in this standard. Any special characteristic other than those prescribed in this specification which may be desired for specific application shall be specified by the purchaser as they may influence the choice of the ingredients used.

4.1.2 All sheets shall be flat and free from irregularities and shall normally be supplied with the finish (such as matt, smooth or foil finish) as specified by the purchaser.

4.1.3 Rods and tubes shall be straight and free from cracks and flaws. They shall normally be supplied with a rough ground finish, a fine ground or polished finish when specified by the purchaser.

4.1.4 The material shall be free from embedded metallic particles.

4.1.5 *Machining*

The material shall be capable of being drilled, tapped, cut and machined without difficulty, and shall conform to the reference sample approved by the purchaser.

4.2 Dimensions and Tolerances

4.2.1 *Sheets*

The preferred dimensions for sheets are those given below. When material is required in other sizes, the nominal dimensions shall be the subject of agreement between the purchaser and the supplier.

Length and Width	*Thickness*
900 × 600 mm	Any thickness from 1.5 mm to 50 mm inclusive
900 × 450 mm	
600 × 600 mm	

4.2.2 *Rods*

The preferred dimensions for rods are:

Rod Diameter	*Preferred Length*
From 3 mm to 60 mm specified diameter	1 m
Above 60 mm and up to 100 mm specified diameter	0.6 m

4.2.3 *Tubes*

Unless otherwise specified, tubes of under 40 mm diameter shall be supplied in lengths of one metre. The length of tubes of over 40 mm diameter shall be by agreement between the purchaser and the supplier.

4.2.3.1 The diameters and wall thicknesses of tubes shall be as agreed to between the purchaser and the supplier.

4.3 Tolerances on Dimensions

4.3.1 *Sheets, Rods and Tubes*

The thickness of sheets, the diameter of rods and the internal and external diameters of tubes shall not differ from the specified values by more than the appropriate tolerance given in Tables 1, 2 and 3. The difference between the maximum and minimum wall thickness of any tube, measured near each end, shall not exceed the appropriate value given in Table 4.

4.3.1.1 When material is required in sizes not provided for in Tables 1 to 4 or with finishes other than rough-ground or fine-ground in the case of rod or tube, and foil finish in the case of sheet, the tolerances shall be as agreed to between the purchaser and supplier.

4.4 Plastic Yield

When three test pieces are tested in accordance with Annex A, the average plastic yield shall not exceed more than 3 mm at 55 °C for Type 1 and 3 mm at 70 °C for Type 2,

Table 1 Dimension Tolerance for Sheets
(*Clause* 4.3.1)

Specified Thickness (All dimensions in millimetres)		**Tolerance on Thickness** (All dimensions in millimetres)
Above	Up to and Including	
(1)	(2)	(3)
—	1.5	±0.08
1.5	2.5	± 0.10
2.5	3.0	± 0.13
3.0	10.0	±0.25
10.0	20.0	±0.40
20.0	30.0	± 0.50
30.0	50.0	± 0.65

Table 2 Dimensional Tolerances for Rods
(*Clause* 4.3.1)

Specified Diameter (All dimensions in millimetres)		**Tolerance on Diameter** (All dimensions in millimetres)			
Above	Up to and including	Rough-Ground Finish		Fine-Ground Finish	
		Plus	Minus	Plus	Minus
(1)	(2)	(3)	(4)	(5)	(6)
3.0	20.0	0.2	0.00	0.05	0.05
20.0	30.0	0.3	0.00	0.05	0.05
30.0	50.0	0.5	0.00	—	—
50.0	—	By agreement between the purchaser and the supplier			

Table 3 Dimension Tolerances for Tubes
(*Clause* 4.3.1)

Specified External Diameter (All dimensions in millimetres)		**Internal Diameter** (All dimensions in millimetres)		**External Diameter**			
				Rough-Ground Finish		Fine-Ground Finish	
				(All dimensions in millimetres)			
Above	Up to and including	Plus	Minus	Plus	Minus	Plus	Minus
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
—	6.5	0.08	0.08	0.2	0.00	0.05	0.05
6.5	13	0.13	0.13	0.2	0.00	0.05	0.05
13	20	0.20	0.20	0.2	0.00	0.05	0.05
19	30	0.00	0.50	0.3	0.00	0.05	0.05
30	50	0.00	0.80	0.5	0.00	—	—

Table 4 Maximum Variation in Wall Thickness of Any One Tube
(*Clause* 4.3.1)

Specified Wall Thickness		**Maximum Variation In Wall Thickness**	
Above	Up to and Including	Extruded Tube	Tube Hand-Built from Calendered Sheet
(All dimensions in millimetres)		(All dimensions in millimetres)	
(1)	(2)	(3)	(4)
–	3.0	0.20	0.80
3.0	6.5	0.25	0.80
6.5	10.0	0.30	1.6
10.0	–	0.40	1.6

4.5 Cross Breaking Strength

When three test pieces are tested in accordance with Annex B, the average cross breaking strength shall satisfy the following requirements:

	Type 1	*Type* 2
Minimum proof load, kgf	6.0	3.0

4.6 Permittivity and Loss Tangent

The values of these two characteristics shall not exceed the following appropriate figures when determined at audio frequency or at radio frequency as given in Annex C and Annex D. Five samples are to be tested, out of which four test pieces shall withstand the required specification. Unless otherwise specified, the permittivity and loss tangent shall normally be determined at audio frequency:

	Type 1	*Type* 2
Permittivity at audio frequency, *Max*	3.3	3.8
Loss tangent at audio frequency, *Max*	0.008	0.008
Permittivity at radio frequency, *Max*	3.3	3.8
Loss tangent at radio frequency, *Max*	0.010	0.012

4.7 Electric Strength Optional Requirement

When five test pieces are tested in accordance with the test method given in Annex E, minimum of four test pieces shall withstand the following appropriate test voltage without breakdown for one minute:

	Type 1	*Type* 2
Electric strength, proof voltage, kV	40	30

5 PACKING AND MARKING

5.1 Packing

The material shall be packed as agreed to between the purchaser and the supplier.

5.2 Marking

5.2.1 Each piece of the material shall be marked in a suitable position with:

a) Manufacturer's name or trade-mark;
b) Month and year of manufacture, if required by the purchaser;
c) Essential dimensions like length, width, thickness and diameter; and
d) Type

5.2.2 *BIS Certification Marking*

The product(s) conforming to the requirements of this standard may be certified as per the conformity assessment schemes under the provisions of the *Bureau of Indian Standards Act*, 2016 and the rules and regulations framed thereunder, and the products may be marked with the Standard Mark.

6. SAMPLING

6.1 For the purpose of ascertaining conformity of the material to this standard, the method of sampling and criteria for conformity shall be as given in Annex F.

7. TEST METHODS

7.1 The material shall be tested as prescribed in Annex A to E. For permittivity and loss tangent it shall be clearly indicated as to whether the test is to be carried out at audio frequency or at radio frequency.

ANNEX A
(*Clauses* 4.4)
PLASTIC YIELD

A-1 OUTLINE OF THE METHOD

The total deformation of a bar shaped test piece is measured after subjecting it to a specified load under specified conditions.

A-2 APPARATUS

The apparatus shall consist of a clamp for mounting the test piece as a cantilever together with a stirrup for applying the load (see Fig. 1). The stirrup shall be of such shape that it will rest in the notch of the test piece and distribute the load uniformly across its width. The mass of the stirrup and of any other attachment (for example, scale pan pointer) shall not exceed 9 g. A weight shall be provided for attaching to the stirrup so that the total applied load including the mass of the stirrup is (180 ± 1) g.

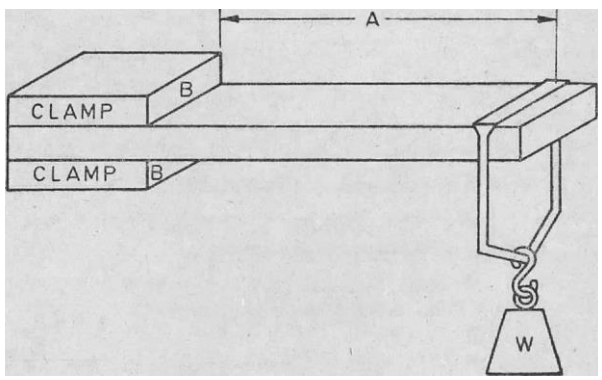
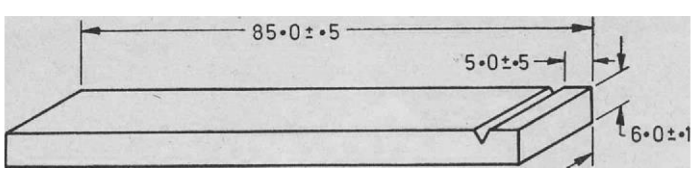


FIG. 1 PLASTIC YIELD TEST PIECE

A-3 PROCEDURE

A-3.1 Test Piece

The test piece shall be a bar (85.0 ± 0.5) mm long, (15.0 ± 0.1) mm wide and (6.0 ± 0.1) mm deep with a V-notch across one side (5.0 ± 0.5) mm from the end (*see* Fig. 2).



All dimensions in millimeters

FIG.2 TEST PIECE

A-3.1.1 *Number of test pieces*

Three test pieces shall be tested and the average of 3 results shall be taken as the plastic yield, of the material.

A-3.2 *Conditioning of Test Pieces*

Test shall not be carried out within 24 h after vulcanization. Test pieces shall he protected from light as completely as possible during the interval between vulcanization and testing.

A-3.3 *Temperature of Test,* the test shall be made at 55 °C or 70 °C.

A-3.4 Place the test apparatus in an oven and bring to within 1 °C of the specified temperature. Mount the test piece horizontally as a cantilever in the clamp (*see* Fig. 1), one end being rigidly clamped so that A = (60 ± 0.5) mm. Rest the stirrup in the notch. Attach the mounting of the test piece as quickly as possible so that the oven is not unduly cooled during the operation. After the test piece has been in the oven for 15 min., measure the height of the stirrup relative to a datum point. Then attach the weight to the stir up without disturbing the temperature conditions in the oven. Maintain the apparatus and loaded test pieces for 6 h ± 10 min at the specified temperature. At the end of this time, with the load still in position remeasure the height of the stirrup.

A-3.5 Result

Take the change in height of the stirrup as plastic yield of the test piece at the test temperature.

ANNEX B

(*Clause* 4.5)

CROSS BREAKING STRENGTH

B-1 APPARATUS

B-1.1 Testing machine to apply a tensile force to the test piece via the grips and conforming to the following requirements:

a) The applied force shall be known to within 1.5 percent of its true value, and

b) The rate of traverse of the power driven grip shall be uniform and such that the applied force reaches its maximum value in (30 ± 15) s.

B-1.2 Grips to hold the test piece in the test machine by exerting a uniform pressure across the gripping surface.

B-2 TEST PIECES

B-2.1 Shape and Dimensions

Test piece shall be prepared having the shape and dimensions shown in Fig. 1. The test pieces may be punched or cut from sheet material. The material may be softened by heating to facilitate punching. The faces and sides of the test piece shall be machined to a smooth finish.

A milling cutter of 50 mm radium cutting edge is suitable for shaping the narrow portion of the test piece.

For any individual test, the width at any point on the narrow part of the dumb-bell shall not deviate by more than 0.1 mm from the mean width, and the thickness at any point shall not deviate by more than 0.05 mm from the mean thickness.

B-2.2 Number of Test Pieces

Three test pieces shall be tested results on test pieces which break outside the narrow section or which are obviously defective shall be discarded and retests made.

B-3 TIME-LAPSE BETWEEN VULCANIZATION AND TESTING

B-3.1 For all test purposes the minimum time-lapse between vulcanization and testing shall be 16 h.

B-3.2 For product testing time lapse between vulcanization and testing shall not exceed 3 months.

B-4 CONDITIONING

Test pieces should be conditioned for 3 h.

B-5 TEMPERATURE OF TEST

All tests should be carried out at a temperature (27 ± 2) °C.

B-6 PROCEDURE

The width of the test pieces shall be measured to within 0.2 mm.

B-7 TESTING

Place the test piece with its wide face on the outer supports. Force to be applied by means of loading foot to act midway between the outer supports and perpendicularly to the test piece, until failure occurs. The rate of movement of the loading foot shall be (30 ± 15) s to reach maximum load. Record the maximum force.

B-8 EXPRESSION OF THE RESULT

B-8.1 The cross breaking strength, *S*, expressed in mega newton per square metre, is given by the formula:

$$S = \frac{3FI}{2ba}$$

where

S = cross breaking strength;
F = maximum force in N;
1 = distance in mm between the fixed supports;
b = width in mm of the test piece; and
a = thickness in mm of the test piece.

The medium value of the cross-breaking strength of the three test pieces shall be quoted as the cross-breaking strength.

B-9 TEST REPORT

The test report shall include the following particulars:

a) The cross-breaking strength in meganewtons per square meter,
b) The individual values of cross-breaking strength of the three test piece,
c) The temperature of the test, and
d) The time interval between vulcanization and testing

ANNEX C
(*Clause* 4.6)
PERMITTIVITY AND LOSS TANGENT (AUDIO FREQUENCY)

C-1 The loss tangent (tans) and permittivity of a sheet after conditioning shall be determined by a suitable form of apparatus, namely, Schering Bridge with Wagner Earthing Attachment.

C-1.1 Apparatus

C-1.1.1 *Electrodes*

The test piece shall be provided with electrodes and a guard ring (as shown in Fig. 3). The electrodes shall take on any of the following forms, preferably the one described in (a) which shall be used in any case for the referee method, in case of dispute:

a) *Graphite*

This shall be applied, before conditioning, in the form of a colloidal suspension in water. It is convenient to dilute the graphite suspension with distilled water to the consistency of drawing ink, and then to draw the circular outlines of the electrodes and guard ring on the surface of the test piece with this ink, afterwards painting the appropriate areas with graphite suspension. Alternatively, the graphite may be applied by spraying with the help of suitable stencils.

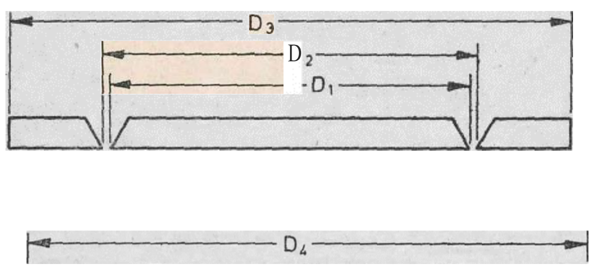
b) *Metal Foil*

Discs of metal foil about 0.025 mm thick shall be applied after conditioning to the flat faces, using a very thin coating of petroleum jelly or silicone grease as adhesive. The foil shall be pressed and rolled on to the surface and smoothed down until all irregularities are removed. It shall then be cut to the exact size of the electrode. Alternatively, the electrodes may be cut to the shape before application.

c) *Metal Films*

These shall be of adequate thickness, deposited in vacuo either by sputtering or by volatilization and shall be applied before conditioning. For each of these forms the electrodes and the guard ring shall be supplemented after conditioning by brass backing plates with cover surrounded by a guard ring. The dimensions of the electrodes, guard ring and plates shall be as shown in Fig. 3.

NOTE — Before conditioning and applying electrodes each test piece shall be wiped carefully with absorbent paper or with soft cotton.



All dimensions in millimetres.

Diameters	D_1	D_2	D_3	D_4
Large Electrodes	150	154	200	200
Small Electrodes	50	54	100	100

FIG. 3 ELECTRODES FOR PERMITTIVITY AND LOSS TANGENT AT AUDIO FREQUENCY

C-1.1.2 *Schering Bridge*

This shall be Schering Bridge with Wagner Earthing attachment or any bridge which can be shown to give the same results. A suitable form of this apparatus is shown in Fig. 4.

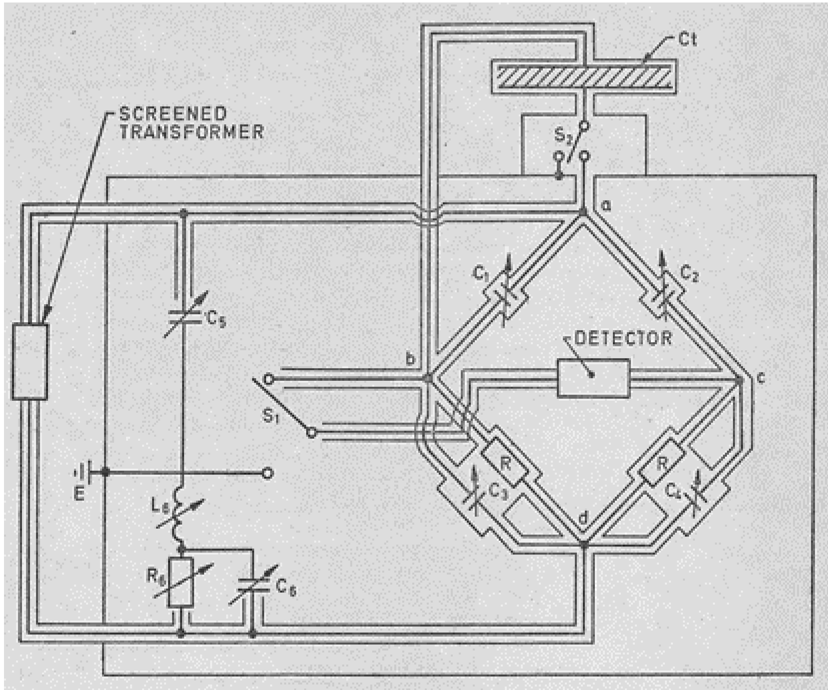


FIG. 4 SCHERING BRIDGE FOR PERMITTIVITY AND LOSS TANGENT TEST

C-1.1.2.1 The condenser C_1 is a variable air condenser of good quality having a range of about 600 pF and C_2 is a variable air condenser of reasonably good quality of about the same range as C_1. The ratio arms are non-inductively wound and are of equal value, ranging from 1000 ohms to 10000 ohms each. The value used is 1000 ohms wherever possible, although a higher value may be necessary to obtain the required sensitivity. C_3 and C_4, are variable air condensers of ordinary quality and of a range of 1000 pF. When materials of high power factor are being measured, it may be necessary to connect additional capacitors, for example, fixed mica capacitors of suitable value, in parallel with C_4. If three terminal condensers are used the screening is as shown; otherwise the screens of two terminal condensers are connected to the points *b* and *c* of the bridge.

C-1.1.3 The test piece with its electrodes forms the condenser C_t which is screened as shown in Fig. 4. The Wagner earthing arrangement consists of variable air condenser C_5 and C_6 of ordinary quality of range 500 pF and 1000 pF respectively (C_6 being increased when necessary by the addition of fixed capacitors of suitable value) and a variable resistor R_6. It may be necessary to include the air cored inductor L_6 in one arm of the Wagner circuit in order to obtain balance.

C-1.1.4 The detector is a telephone, preferably of low resistance or a value detector, which is coupled to the bridge through a matching transformer which is screened electrically and magnetically. One pole of the secondary winding of the transformer is connected to the earth point *E*. A switch S_1 selects the detector positions; in the normal position it connects the detector between points *b* and *c* of the bridge circuit, and in the other position it connects one side of the detector to earth and the other side to one junction point of bridge.

C-1.1.5 The source of supply is connected to the points *a* and *d* of the bridge through a screened transformer with an earthed electrostatic screen between the primary and secondary windings, the voltage applied to the bridge being 100 volts to 150 volts. The source of supply shall be reasonably good sine wave form of a frequency within the range of 800 Hz to 1600 Hz, but preferably of 1000 Hz. It shall be several metres away from the bridge unless it is carefully screened from the detector.

C-1.1.6 *Micrometer*

A suitable type of micrometer to measure the thickness of ebonite pieces of dial gauge type or an external micrometer capable of reaching the centre of the test piece and having flat measuring faces between 3 mm and 6 mm in diameter.

C-2 PROCEDURE

C-2.1 Test Piece

The test piece shall be a disc not exceeding 3.6 mm in thickness and not less than 100 mm or 200 mm in diameter depending on the size of electrodes to be used. With the discs approximating to this thickness, the mean thickness of the test pieces used for comparative tests shall not vary by more than 1 mm. The variation in thickness within a given test piece shall not exceed 0.2 mm.

C-2.2 Conditioning of Test Pieces

The test pieces shall be conditioned for 18 h to 72 h before test at a relative humidity of (65 ± 5) percent and a temperature of (27 ± 2) °C.

C-2.3 Testing Temperature

The test shall be carried out at (27 ± 2) °C.

C-2.4 Thickness Measurement

The thickness of the ebonite shall be measured with a micrometer.

C-2.5 Permittivity Determination

When testing by means of the Schering Bridge adopt the following procedure for the determination of permittivity:

a) With the lower electrode of the condenser C_t connected to the bridge point by means of a switch S_2, connect the detector between the points *b* and *c* of the bridge and C_1 set near its minimum value. Roughly balance the bridge circuit by adjustment of C_2 and C_4, C_3 having been set near its minimum value. Transfer the detector to the Wagner circuit by means of switch S_1 and balance obtained by adjustment of C_5, R_6, L, and C_6. The bridge circuit shall now be balanced by adjustment of C_1 and C_4. Repeat the balancing procedure, the bridge circuit and Wagner circuit being adjusted alternatively until the balances converge.

b) With the lower electrode of the condenser C_t connected to earth by means of switch S_2 and with detector connected between points *b* and *c* of the bridge, rebalance the bridge circuit by adjustment of C_1 and C_4 only. Adjust the Wagner bridge circuits alternately as before until the balances converge. C_2 and C_3 shall not be altered during this operation.

c) Alternatively, the adjustment (a) may be carried out with the lower electrode earthed and C_1 set at a suitable value, and (b) with the lower electrode connected to the bridge point a.

C-2.6 Calculation

C-2.6.1 Let $C_4\,a$ and $C_4\,b$ be the reading of C_4, and $C_1\,a$ and $C_1\,b$ be the readings of C_1 for balances with the lower electrode connected to *a* and to earth respectively, all readings being expressed in pico-farads.

The permittivity shall be calculated by the formula:

$$\varepsilon = \frac{1.44T\ (C_1\,b - C_1\,a)}{D^2}$$

where

$\mathcal{E}$ = permittivity,
T = thickness in mm of test piece,
D = mean diameter in cm = $\frac{D_1+D_2}{2}$,
D_1 = diameter of the upper electrode, and
D_2 = inner diameter of the guard ring

C-2.6.2 The tangent of the loss angle (tan δ) shall be calculated by the formula:

$$\text{Tan}\ \delta = \frac{2\pi\, fRC_1b\ (C_4a - C_4b \times 10^{-12}}{(C_1b - C_1a)}$$

where

f = frequency of the source of supply, in cycles per second; and
R = resistance of the ratio arms in ohms.

For values of tan δ up to 0.07 the difference between the value of tan and the power factor (sin δ) is less than 1 part of 400.

ANNEX D
(*Clause* 4.6)
PERMITTIVITY AND LOSS TANGENT (RADIO FREQUENCY TEST)

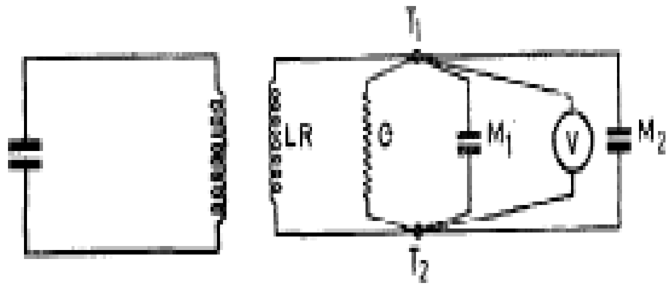
D-1 PRINCIPLE OF THE METHOD

The loss tangent (tan δ) and permittivity of a sheet in the condition as received shall be determined by the Hartshorn and Ward method at a temperature of (27 ± 5) °C and at a frequency of a one megacycle per second.

D-2 APPARATUS

D-2.1 Oscillator

It is shown diagrammatically in Fig. 5.



OSCILLATOR MEASURING CIRCUIT

FIG. 5 BASIC FEATURES OF THE MEASURING CIRCUIT

The oscillator provides the emf applied to the specimen and its associated test circuit. A range of frequencies is obtained by the use of suitable coils, each coil being tuned over a portion of the total range by means of an air-spaced variable condenser. A series fed Hartley oscillator is found to be generally satisfactory. If, at any time, doubt is felt about the performance of the oscillator, the latter may be checked by listening to a heterodyne note with another oscillator. If a change of frequency occurs as the test circuit passes through the resonant condition, the change should be considerably less than 1 part in 10000 should the change of frequency be greater than one part in 10000, loss tangent measurement should be carried out at a slightly different frequency. If the change of frequency while passing through resonance is still greater than 1 part in 10000, the oscillator circuit components should be checked.

D-2.2 *Measuring Circuit*

It is shown diagrammatically in Fig. 5, consists of the coil *LR*, two micrometer condensers M_1 and M_2 and the valve voltmeter V.

D-2.2.1 *Coil, LR*

As with the oscillator, suitable measuring circuit coils are required to cover the total frequency range. If the specimen capacitance is such that the resonant frequency is not exactly the frequency required, then an auxiliary condenser (either variable air condenser or a small fixed mica condenser) shall be connected in parallel with the specimen condenser to give the required frequency. Care shall be exercised in the use of the auxiliary air condenser because errors due to residual inductance and resistance will rapidly become more serious above 5 megacycles per second. At frequencies between 5 megacycles per second and 30 megacycles per second, suitable small auxiliary fixed mica condensers may be used.

D-2.2.2 *Micrometer Condensers*
The specimen condenser M_1 in which specimen is placed comprises of two circular plates which are usually 50 mm in diameter. The plates may be made of copper or other suitable metal. The distance between the plates shall be adjustable by means of a micrometer head, held in an inverted cup-shaped copper mounting (*see* Fig. 6). The upper (adjustable) plate is connected to the cup-shaped mounting

by means of a flexible metal tube in the form of bellows. The plate is maintained in contact with the end of the micrometer by means of a spiral spring joining the top of the cup mounting to the plate. When the apparatus is in operation, this portion of the assembly is at earth potential.

The lower (fixed) plate is in the form of a boss on a fixed stout copper plate, which is insulated from the upper assembly and from the copper base plate of the assembly by means of pillars made from fused quartz or other suitable insulating material.

A second condenser, the micrometer incremental condenser M_2 is formed by a second micrometer head and the lower fixed plate of the specimen condenser M_1. The barrel of this micrometer head is clamped into a copper extension piece fixed to the upper plate assembly, and its plunger moves in a cylindrical hole in the lower fixed plate.

The resonant circuit inductance, *LR* (Fig. 5), is connected to two terminal points on the upper and lower plate assemblies. Thus, inductance LR and specimen condenser M_1 are connected in parallel.

The incremental condenser M_2 should have a movement of 25 mm and the capacitance change over this movement should be approximately 10 µµF.

Capacitance changes of both condensers can conveniently be noted from calibration graphs or tables.

D-2.2.3 *Valve voltmeter*

The circuit employed by Hartshorn and Ward is of the balanced value type, so that no standing current passes through the galvanometer which is connected between the anodes of the two valves employed.

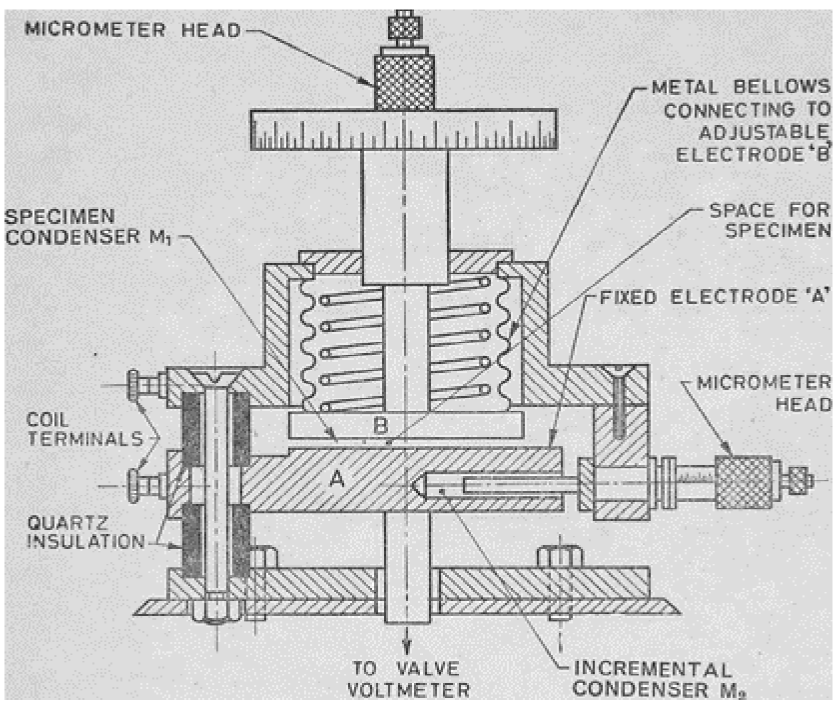


FIG. 6. CONDENSER ASSEMBLY

The input valve operates as a detector and may operate on a square law or any other known law. It is used without its base, the leads from its electrodes being connected to the required points by means of the shortest possible lengths of wire. The input is applied to the grid of this valve through a small condenser to ensure that the input conductance of the voltmeter is small. An essential feature of the voltmeter is that the input impedance shall be substantially independent of the input voltage over the working range. The second valve is specially selected to match the input valve, and the two are arranged in a Wheatstone bridge network with a galvanometer as the indicator. The controls are adjusted so that the galvanometer deflection is zero when the input voltage is zero and the anode currents of the two valves are therefore balanced. The zero of the voltmeter may be checked either by connecting together the two plates of the specimen capacitor or by switching off the high tension supply to the oscillator.

D-2.3 Power Unit

The supply to the valve filaments and anodes of the oscillator and the voltmeter may be from a voltage-stabilized unit operating from the mains or from batteries.

D-3 Procedure

D-3.1 The test shall not be carried out within 24 h after vulcanization. Test pieces shall be protected from light as completely as possible during the interval between vulcanization and testing.

D-3.2 Test Specimen

A flat disc (53 ± 1) mm in diameter shall be used. The most suitable thickness of the test piece is that which will give capacitance within the range of 20 µµF to 100 µµF. It will be generally found in the range of 1 mm to 250 mm. The two faces of the test pieces shall be flat. The variation in thickness in a given test piece shall not exceed 0.1 mm.

D-3.3 Conditioning of Test Piece

The test pieces shall be conditioned for 18 h to 72 h before test at a relative humidity of (65 ± 5) percent and a temperature of (27 ± 2) °C.

D-3.4 Electrode Application

After the test piece has been conditioned it shall be provided with electrodes of metal foil 0.025 mm to 0.050 mm thick and (53 ± 1) mm in diameter. The foils shall be applied concentrically to the specimen with the thinnest possible film of petroleum jelly or silicon grease, and shall be pressed on to the surfaces and smoothened down until all irregularities are removed. Alternately metal films of adequate thickness deposited in vaquo either by sputtering or by volatilization, shall be applied and the test piece subsequently conditioned.

NOTE — Before conditioning and applying the electrodes each test piece shall be wiped carefully with absorbent paper or with a soft cloth.

D-3.5 *Thickness Measurement*

The thickness of ebonite test pieces shall be measured with a micrometer dial gauge or external micrometer capable of reaching the centre of the test piece and having flat measuring faces between 3.00 mm and 6.00 mm in diameter.

D-3.6 Specimen shall be tested in the following manner:

a) The appropriate oscillator and measuring circuit coils shall be connected to the apparatus (*see* **D-2** and Fig. 5).

b) The specimen, together with electrodes, if used, shall be placed centrally between the plates of the specimen condenser 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 condenser scale reading shall be noted and used to obtain the corresponding capacitance, C_1.

c) The micrometer incremental condenser 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 resonant frequency cannot be obtained as described under (c) above, then provided that the requirements given in **A-4.2.2.1** are satisfied, the oscillator shall be set to the required frequency and an auxiliary condenser shall be connected in parallel with the specimen condenser and resonance obtained by varying this auxiliary condenser. 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.

e) The valve voltmeter controls shall be adjusted to ensure that the voltmeter reads zero when its input voltage is zero. The input voltage shall then be adjusted to give approximately full scale deflection on the galvanometer scale. (On some commercial models of this apparatus, this is achieved by moving the oscillator relative to the voltmeter and on other by varying the output from the oscillator).

f) The micrometer head of the incremental condenser M_2 shall be screwed out until the galvanometer deflection is reduced to a convenient fraction 1/q (for example, $\frac{1}{2}$) of the initial resonant reading and the micrometer reading shall be noted.

g) The micrometer head of M_2 shall then be screwed in until the galvanometer deflection attains its maximum value (which should have remained constant) and then screwed in further until the galvanometer deflection is again reduced in the ratio 1/q. The reading of the micrometer head shall again be noted, and the difference in capacitance (ΔC_1), corresponding to the difference between these two readings of the micrometer, shall be obtained from the calibration graph or table.

h) To check the square law relation of the valve voltmeter, the difference ΔC_1 shall be obtained for values of q = 2 and q = 5. The value of ΔC_1 and q = 5 should be twice that for q = 2 if the valve voltmeter satisfies the square law relation. With specimens of high power factor, it may not be possible to reduce the galvanometer deflection to these fractions of the maximum deflection by means of the micrometer incremental condenser. In this case, the deflection shall be reduced to a convenient fraction (say, $\frac{1}{2}$) of its maximum value, where, for example, q = 3/2, 5/4 or 10/9.

The ratios of the two values of ΔC_1 for any two values of q may be found from the following formula:

$$\frac{(\Delta\, C_1\,)\,1}{(\Delta\, C_1\,)\,2} \qquad\qquad \sqrt{\frac{q_{1-1}}{q_2-1}}$$

The ratio of the two values of ΔC_1 shall be within ± 2 percent of that corresponding to the square law relation.

j) The measuring circuit shall be returned to resonance by means of the incremental capacitor M_2 and the specimen shall be removed from between the plates of the specimen condenser M_1.

k) The movable electrode of the specimen condenser M_1 shall be adjusted until the measuring circuit is again in resonance that is the capacitance lost by removing the specimen is restored by decreasing the distance between the condenser plates. The input voltage shall be adjusted, if required, to give approximately full scale deflection. The specimen condenser scale reading shall be noted and used to obtain the corresponding capacitance, Cs, from the specimen condenser calibration grapher table. The edge capacitance, Ce, corresponding to the separation of the plates when the specimen is in the specimen condenser, shall be obtained as described in **D-4**. The capacitance C_s-Ce (= C's) is equal to that of the specimen.

m) The operation described in **D-3.6**(*e*) and **D-3.6**(*g*) shall be repeated using the same ratio 1/q as before, and the corresponding change, ΔCq, of capacitance of the incremental condenser M_2 shall be obtained.

n) The square law relation may be checked at this stage in accordance with **D-3.6**(h).

D-4 EDGE CORRECTION — For sheet material in the form of disc, the edge capacitance, that is, capacitance representing the portion of the electric field located round the edges of the plate electrodes, may be calculated from Kirchhoff's formula:

Edge capacitance, Ce (μμF)

$$= \frac{D}{72\pi}\left[\,\log_e \frac{8\pi\, D_1\,(t+d)}{d_2} + \frac{t}{d}\log_e \frac{t+d}{t} - 3\right]$$

where

D_1 = diameter in mm of the plate electrodes;
t = thickness in mm of the plate electrodes; and
d = thickness in mm of the specimen.

Experience with typical specimens has shown that, if the edge capacitance is derived from the formula on the assumption that the edge capacitance lies wholly in air, the error in the calculated value of specimen capacitance is not likely to exceed 2 percent for any ordinary specimen and in general the error will not exceed 1 percent. The following table gives the values of edge capacitance calculated in this way for different thickness of specimen, for a value of t of 5 mm:

Specimen of Thickness, d	*Edge Capacitance, C*
1.0	1.5
1.3	1.4
1.6	1.3
2.1	1.2
2.7	1.1

D-5 Calculation and Report

D-5.1 Calculate tangent loss and permittivity by either set of formulae given under (a) and (b) below:

a) Tangent loss (tan) Tan δ = $\frac{\Delta C_1 - \Delta C_0}{2\,(C_s - C_e)\sqrt{q-1}}$.

Permittivity, K= $\frac{144d}{D_1^2}(C_s — C_o)$

b) Tangent loss (tan) Tan δ = $\frac{\Delta C_1 - \Delta C_0}{2C'_s\sqrt{q-1}}$

Permittivity, K = $\frac{144d}{D_1^2}(C'_s — C_o)$

where

$C'_s = C_s — C_1 + \frac{D_1^2}{144\, d_1}$
$C'_s = C_1$ and ΔC_0 are obtained as described in **D-3.6** (b), **D-3.6**(k), and **D-3.6** (m);
C_e = edge correction as determined in **D-4**;
q = value of the fraction used in **D-3.6**(f) or **D-3.6**(h);
d = thickness in mm of the specimen;
d_1 = separation of plates in mm of specimen condenser when the specimen is between the plates; and
D_1 = diameter in mm of circular plates of specimen condenser.

NOTES

1 If there is a linear relationship between the micrometer reading and the capacitance change of the incremental condenser M_2, the capacitance change $\Delta C_1 — \Delta C_0$ can be determined by multiplying the corresponding readings of the incremental condenser by a constant corresponding to the capacitance change per unit change (millimetre) of the micrometer head reading.

2 These formulae are derived on the assumption that the edge capacitance lies wholly in air.

3 When measurements are required to the highest accuracy, then immediately after operations **D-3.6**(f) and **D-3.6**(g) have been carried out, operation **D-3.6**(f) shall be repeated; the reading obtained should be the same or very near the same as before. The capacitance ΔCi is obtained from the difference between the reading of M_2 obtained from **D-3.6**(g) and the mean of the two readings obtained from **D-3.6**(f). The same procedure is carried out when the specimen has been removed.

ANNEX E
(*Clause* 4.7)
PROOF TEST FOR ELECTRIC STRENGTH

E-1 Outline of the Method

Prescribed voltage is applied uniformly and rapidly to the electrodes, whose plane faces are in contact with the test piece, starting from zero and examined for any breakdown.

E-2 Apparatus

The test voltage shall be provided by a transformer and shall be alternating of nominal frequency 50 Hz. They shall be of approximately sine wave form and the ratio of the peak value of the root mean square value shall be within the limit $\sqrt{2} \pm 5$ percent. The output of the testing set shall be sufficient to maintain on the test piece the necessary voltage for the maximum time required. The test voltage shall be determined by means of a peak or other type of voltmeter connected across a portion of the output winding. Any instrument used except the peak voltmeter shall be calibrated against a peak voltmeter connected across the output winding of the transformer. If there is any risk of the current taken by the test piece altering the no load calibrating appreciably, calibration against a sphere gap shall be made with a test piece in circuit.

E-2.1 Electrodes

The lower electrode shall consist of a solid cylinder of brass 80 mm in diameter and approximately 25 mm thick and the upper electrode shall consist of a solid cylinder of brass 40 mm in diameter and not less than 40 mm thick, the plane faces of the electrode being in contact with the test piece and concentric with each other during the test. The sharp edges shall be removed from the electrode, the radius at the edge being approximately 1 mm (*see* Fig. 7).

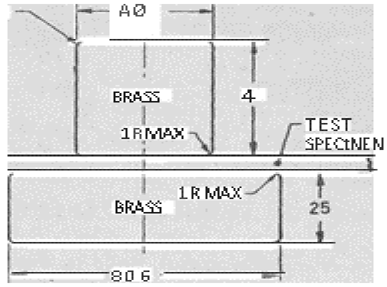
E-3 PROCEDURE

Five test pieces shall be tested.

E-3.1 Test Pieces

The test pieces shall be flat disc with smooth surfaces not less than 100 mm in diameter and (3.2 ± 0.2) mm in mean thickness. The variation in thickness shall not exceed 0.2 mm.

E-3.1.1 Test pieces shall be protected from light as completely as possible during the interval between vulcanization and testing and care should be taken to avoid handling and contamination of the surface.



All dimensions in millimetres

FIG. 7 ARRANGEMENT OF ELECTRODES FOR ELECTRIC STRENGH TEST

E-3.1.2 The test pieces shall be conditioned at a temperature of (27 ± 2) °C and relative humidity of (65 ± 5) percent, for not less than 18 hours immediately before test.

E-3.2 Temperature of Test

The test shall be made at a temperature of (27 ± 2) °C.

E-3.2.3 Place the test pieces concentrically, between the electrodes and carry out the test under transformer and switch gear oil. Commence the test as soon as possible after immersion of the test piece in oil. When the test is commenced, raise the voltage applied to the electrodes as rapidly as consistent with avoiding transient over voltages from zero until the prescribed voltage is reached. Maintain the prescribed voltage for one minute.

A-5.3.3.1 The electrodes shall be applied within 3 min after removal of the test pieces from the controlled atmosphere. The test shall be started within 3 min after the application of the electrodes.

A-5.3.4 *Results*

Individual test pieces shall be deemed to have passed the test if no breakdown occurs before the end of this period.

A-5.3.4.1 Not more than one of the samples shall fail the test out of the five samples tested.

ANNEX F

(*Clause* 6.1)

SAMPLING OF EBONITE

F-1 SCALE OF SAMPLING

F-1.1 Lot

In any consignment all the pieces of ebonite manufactured by the same firm under similar conditions of manufacture shall be separated in groups of 5000 pieces of ebonite or less and each shall constitute a lot.

F-1.2 Test for the determination of the conformity of the lot to the requirements of this specification shall be carried out for each lot separately. The number of pieces to be selected for carrying out the test for dimensional characteristics shall be in accordance with col 1 and 2 of Table 5.

Table 5 Scale of Sampling

Number of Pieces in the Lot (*N*)	**Number of Pieces to be Selected (*n*)**	**Permissible Number of Defective Pieces**
(1)	(2)	(3)
Up to 500	8	0
501 to 1000	13	1
1001 to 3000	32	1
3001 to 5000	50	2

F-1.3 The test pieces shall be selected at random (*see* IS 4905). In order to ensure the randomness of selection, a random number table as agreed to between the purchaser and the supplier shall be used. In case, such a table is not available, the following procedure shall be adopted:

> Starting from any piece in the lot, count them as 1, 2, 3,…..up to *r* and so on, in one order, where *r* is the integral part of *N/n*, *N* being the number of pieces in the lot and *n* the number of pieces in the sample. Every *r*th piece thus counted shall be withdrawn to give the sample for test.

F-2 TEST PIECES

F-2.1 For rods, tubes, and moulded sections, tests other than the tests for dimensional characteristics shall be carried out by standard methods on sheet material of the same composition and the same degree of vulcanization as the material supplied, which shall be processed simultaneously through all the stages with each batch of production.

F-3 NUMBER OF TEST

F-3.1 Tests for dimensional characteristics shall be carried out on each of the pieces selected in **F-1.**

F-3.2 Tests for the remaining characteristics shall be carried out preferably on test pieces taken from the sample in **F-3.1**, otherwise on the test pieces supplied by the supplier. At least one test shall be carried out for each of these requirements.

F-4 CRITERIA FOR CONFORMITY

F-4.1 Dimensional Requirements

The lot shall be considered to satisfy the requirement for dimensional characteristics if the number of defective pieces in the sample (*see* **F-3.1**) does not exceed the permissible number given in col 3 of Table 5. A piece shall be considered as defective if it fails to satisfy any of the requirements for dimensions.

F-4.2 Other Requirements

The lot shall be considered to satisfy the requirements for each of the characteristics other than the dimensional if the test piece (*see* **F-3.2**) satisfies the requirement for each of these characteristics.

F-4.2.1 If the test piece fails to comply with any specified test, two additional sets of test pieces shall be drawn and subjected to that test. The lot shall be considered to satisfy the requirement if both the test pieces pass the test.

F-4.3 The lot shall be considered to satisfy all the requirements of this specification if it passes in **F-4.1** and **F-4.2**, otherwise not.