

Cellulosic papers for electrical purposes —

Part 2: Methods of test

Cooperating organizations

The General Electrotechnical Engineering Standards Committee, under whose direction this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

- Associated Offices Technical Committee
- British Approvals Service for Electric Cables Ltd
- British Electrical and Allied Manufacturers' Association (BEAMA)
- British Radio Equipment Manufacturers' Association
- British Steel Corporation
- Department of Energy — Electricity
- Electric Cable Makers' Confederation
- Electrical Contractors' Association
- Electrical Contractors' Association of Scotland
- Electrical, Electronic, Telecommunications Plumbing Union
- Electrical Research Association*
- Electricity Supply Industry in England and Wales*
- Electronic Components Industry Federation*
- Engineering Equipment Users' Association
- Health and Safety Executive
- Home Office
- Institution of Electrical Engineers
- Ministry of Defence*
- National Coal Board
- Oil Companies Materials Association
- Post Office*
- Telecommunication Engineering and Manufacturing Association (TEMA)*

The 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 British Standard:

- Adhesive Tape Manufacturers' Association
- British Paper and Board Industry Federation (PIF)
- British Plastics Federation
- Department of Industry — British Calibration Service
- Department of Industry — National Physical Laboratory
- Electrical and Electronic and Insulation Association (BEAMA)
- Rotating Electrical Machines Association (BEAMA)
- Transmission and Distribution Association (BEAMA)

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National foreword

This Part of this British Standard is identical with IEC Publication 554-2 “*Specification for cellulosic papers for electrical purposes*” Part 2:1977 “*Methods of test*”, including Amendments 1, 2 and 3. It has been prepared under the direction of the General Electrotechnical Engineering Standards Committee.

Other Parts of BS 5626 are as given under “Cross-references” in this national foreword plus the following:

BS 5626-1:1979, *Definitions and general requirements*.

(Identical with IEC 554-1:1977)

BS 5626 supersedes BS 698:1956 “*Papers for electrical purposes*”, BS 4295:1968 “*Capacitor tissue paper*” and BS 5068:1974 “*Specification for crêpe paper for electrical purposes*”, all of which are withdrawn.

Terminology and conventions. The text of the international standard has been approved as suitable for publication, without deviation, as a British Standard. Some terminology and certain conventions are not identical with those used in British Standards; attention is especially drawn to the following.

In the “Introduction and scope”, the words “This standard is one of a series which deals with” should be interpreted as “BS 5626 deals with”; similarly, “The series will have three parts:” and “This Part 2 of the standard” should be interpreted as “BS 5626 will have three Parts:” and “This Part 2 of BS 5626” respectively.

Wherever page numbers are quoted in connection with references to figures, they are IEC page numbers.

The comma has been used in Figure 1 and Figure 5 as a decimal marker. In British Standards it is current practice to use a full point on the baseline as the decimal marker.

In the title of clause 3, the terms “mass per square metre, basis weight(*) or grammage” appear. In the UK paper industry, there is a movement towards adoption of the ISO term “grammage”.

Units. In 2.1 and 2.2, reference has been made to the “micron” in measurement of paper thickness. The term currently employed in British Standards (and in Part 1 of this standard) is the “micrometre”. Dimensionally, the “micrometre” and “micron” are identical.

In clauses 12, 13, 14, 16 and 20, liquid volumes have been quoted in “cm³” (cubic centimetres). The unit symbol currently employed in British Standards is “ml” (millilitre; 1 ml = 1 cm³).

Clarification of intention. The second sentence of the first paragraph of 7.1 does not agree with the figure referred to (Figure 1) in the first sentence as the plate (A) is clearly vertical. The second sentence should therefore be interpreted as “The edge tear stirrup consists of a thin steel plate (A) supported on edge by the ends of a stirrup-shaped frame so that the longer edges of the plate are horizontal”. Similarly, in the second sentence of the second paragraph of 7.1, “The horizontal plate” should be interpreted as “The plate (A)”.

For consistency with similar clauses and subclauses (for example 7.2), the test pieces of 9.2 should be interpreted as requiring to be conditioned in accordance with 1.3.

Cross-references

International standard ^a	Corresponding British Standard
	BS 5691 <i>Guide for the determination of thermal endurance properties of electrical insulating materials</i>
IEC 216-1:1974	Part 1:1979 <i>General procedures for the determination of thermal endurance properties, temperature indices and thermal endurance profiles</i> (Identical)
IEC 216-2:1974	Part 2:1979 <i>List of materials and available tests</i> (Identical)
IEC 247:1978	BS 5737:1979 <i>Method for the measurement of relative permittivity, dielectric dissipation factor and d.c. resistivity of insulating liquids</i> (Identical)
Part 3 of IEC 554 (This Part is being published as separate specification Sheets, each dealing with a specific material or group of materials. Some sheets have been published, some are in preparation and others are under consideration.)	BS 5626 <i>Cellulosic papers for electrical purposes</i> Part 3 <i>Specifications for individual materials (Sections published so far are dual numbered with the corresponding Sheets.)</i>
ISO 287:1978	BS 3433:1980 <i>Method for determination of moisture content of paper and board by the oven-drying method</i> (Identical)
ISO 186:1977	BS 3430:1980 <i>Method for sampling for testing paper and board</i> (Identical)
ISO 534:1980	BS 3983 <i>Thickness and apparent density of paper and board</i> Part 2:1982 <i>Method for determining the single sheet thickness of paper and board and apparent density of board</i> (Identical)
ISO 535:1976	BS 2644:1980 <i>Method for determination of water absorption of paper and board (Cobb method)</i> (Identical)
ISO 536:1976	BS 3432:1980 <i>Method for determination of grammage of paper and board</i> (Identical)

^a Misprinted as "basic weight" in the contents list and title of clause 3 in the standard; the error has been reported to the International Electrotechnical Commission.

International standard ^a	Corresponding British Standard
ISO 1924-1:1983 ^a	BS 4415 <i>Determination of the tensile properties of paper and board</i> Part 1:1985 <i>Constant rate of loading method</i> (Identical)
ISO 1974:1974	BS 4468:1969 <i>Method for the determination of the internal tearing resistance of paper</i> (Technically equivalent)
ISO 2144:1983	BS 3631:1984 <i>Method for determination of ash of paper and board</i> (Identical)
ISO 2758:1974	BS 3137:1972 <i>Methods for determining the bursting strength of paper and board</i> (Technically equivalent)

^a The text refers to ISO 1924:1976. This standard has been withdrawn and superseded by ISO 1924-1:1983, which is technically equivalent to the 1976 edition, but which has added requirements concerning elongation. ISO 1924-2 is a constant rate of extension method.

The Technical Committee has reviewed the provisions of IEC 216-3, IEC 216-4 and IEC 450, to which reference is made in the text, and has decided that they are acceptable for use in conjunction with this standard.

A related British Standard to IEC 243:1967 is BS 2918 “*Determination of electric strength of solid insulating materials at power frequencies*” (obsolescent). Related British Standards to IEC 250:1969 are BS 2067 “*Determination of power-factor and permittivity of insulating materials (Hartshorn & Ward method)*” (obsolescent), and BS 4542 “*Determination of loss tangent and permittivity of electrical insulating materials in sheet form (Lynch method)*”. A related British Standard to IEC 296:1982 is BS 148 “*Specification for unused mineral insulating oils for transformers and switchgear*”. A related British Standard to ISO 438:1980 is BS 3983 “*Thickness and apparent density of paper and board*” Part 1:1982 “*Method for determining the bulking thickness and apparent density of paper*”.

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 to iv, pages 1 to 24, 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 and Scope

This standard is one of a series which deals with insulating cellulosic papers.

The series will have three parts:

- *Part 1: Definitions and general requirements;*
- *Part 2: Methods of test;*
- *Part 3: Specifications for individual materials.*

This Part 2 of the standard contains the test methods to be used in testing cellulosic papers for electrical purposes to meet the requirements prescribed in the specification sheets of Part 3.

1 General notes on tests

1.1 In this standard, reference is made in several places to ISO publications accompanied by a short description of the method used. It is to be understood that this short description is meant for identification purposes only and that all details should be taken from the ISO publication itself.

1.2 In this standard, the definitions of “specimen” and “test piece” as defined in ISO Recommendation R 186 are used.

Specimen: A rectangle of paper or board cut to given dimensions from sheets drawn from selected units.

Test piece: The quantity of paper or board on which the determination is carried out in accordance with the method of test. It may be taken from a specimen; in some instances it may be the specimen itself.

1.3 Unless otherwise specified, the specimen, after being cut, shall be conditioned for not less than 16 h in an atmosphere of 23 ± 2 °C and 50 ± 5 % r.h. Test pieces are cut from the specimen and tested in this atmosphere.

In case of dispute the conditioning atmosphere shall be 23 ± 1 °C and 50 ± 2 % r.h. and shall be approached from the dry side (after drying at 70 °C to a moisture content less than 4 %).

1.4 Unless otherwise specified, the number of specimens shall be three.

2 Thickness

Thickness shall be measured either in accordance with ISO Recommendation R 534 or, for thin papers, in accordance with ISO Recommendation R 438, in each case with the exceptions given below.

2.1 ISO Recommendation R 534: Determination of the thickness of single sheets of paper

Principle

The method is based on the use of a precision dial micrometer to measure the thickness of a single sheet when a static load is applied. The static load to be applied shall correspond to a pressure of 100 ± 10 kPa.

Exceptions

The test shall be carried out on three conditioned test pieces, one determination being made on each of the three test pieces.

Reporting of the standard deviation is optional.

The central value is taken as the result, the two others are reported. The results are given in terms of the thickness of a single sheet in microns.

Where thickness is determined across the width to establish the variation over the width, the details of this procedure will be found in Part 3.

2.2 ISO Recommendation R 438: Method for the determination of the bulking thickness and bulk of paper

Principle

The method is based on the use of a precision dial micrometer to measure the thickness of a stack composed of a minimum of five sheets. The static load to be applied shall correspond to a pressure of 100 ± 10 kPa.

Exceptions

The test shall be carried out on three conditioned specimens, each composed of five sheets.

For narrow width material where the width is less than the stipulated 250 mm, the five measurements on each stack shall be made at approximately equal intervals on a specimen 400 mm in length.

The central value is taken as the result, the two others being reported. The results are given in terms of the thickness of a single sheet in microns.

Where thickness is determined across the width to establish the variation over the width, the details of this procedure will be found in Part 3.

3 Substance (mass per square metre, basic weight or grammage)

Paper grammage shall be measured according to the method described in ISO Standard 536: Paper and board — Determination of grammage, with the following exceptions:

- Clauses **5** and **6** of ISO Standard 536 are ignored.
- The test shall be carried out on three conditioned test pieces, one determination is made on each of the three test pieces.
- The mass is to be determined to an accuracy of 0.5 % on conditioned test pieces of not less than 500 cm².
- The central value is taken as the result, the two others being reported.

Principle

The area of each test piece and its mass are measured and the mass per square metre is calculated, all measurements being made on conditioned test pieces.

Where grammage is determined across the width to establish the variation over the width, the details of this procedure will be found in Part 3.

4 Apparent density

The thickness and grammage are determined on each of three test pieces in accordance with Clauses **2** and **3**. For each test piece the apparent density is calculated and the central value of these three densities taken as the result, the two others are reported. The apparent density is expressed in grams per cubic centimetre.

5 Tensile strength and elongation

Tensile strength and elongation shall be measured according to the method described in ISO Standard 1924: Paper and board — Determination of the tensile strength, with the following exceptions:

- Nine measurements are made on test pieces cut from both the machine direction and the cross direction.
- The central value of the test pieces, in each direction, is taken as the result and the highest and the lowest values in each direction are reported.
- Alternatively, the results can be expressed as breaking length in metres to the nearest 100 m.

Principle

Measurement of the tensile force required to cause failure of test pieces 15 mm by approximately 250 mm, cut from both directions of the paper, when applied under standard test conditions.

6 Internal tearing resistance

Internal tearing resistance shall be measured according to the method described in ISO Standard 1974: Paper — Determination of tearing resistance. The single tear tester shall be used with the following exceptions:

- Nine measurements are made on test pieces cut from both the machine direction and the cross direction.
- The central value of the test pieces, in each direction, is taken as the result and the highest and the lowest values in each direction are reported.

Principle

Rectangular test pieces having a single cut leaving 43 mm length to be torn and measuring the energy required to tear this.

7 Edge tearing resistance

7.1 Test apparatus

An edge tear stirrup (see Figure 1, page 19) shall be used, attached to the tensile testing apparatus as described in Clause 5. The edge tear stirrup consists of a thin steel plate (A) which forms a horizontal plate supported on edge by the ends of a stirrup-shaped frame.

The thin metal tang of the stirrup frame is fastened in the lower clamp of the tension testing machine, so that the vertical centre line of the stirrup coincides with the line connecting the midpoints of the upper and lower clamps. The horizontal plate is removable from the stirrup frame and two plates of different thickness are supplied for use with papers of different thickness ranges. One plate has a thickness of 1.25 ± 0.05 mm and one plate a thickness of 2.50 ± 0.05 mm. The edge of the plate forms a shallow V-notch, the sides of which subtend an angle of $150 \pm 1^\circ$. The sides of the V-notch are semicircular in cross-section and shall be smooth and straight.

7.2 Test pieces

Nine test pieces shall be cut in the machine direction and nine in the cross direction of the paper, 15 mm to 25 mm in width and not less than 250 mm in length.

The test pieces shall be conditioned according to Sub-clause 1.3.

7.3 Procedure

Attach a plate of the proper thickness to the stirrup frame. The plate with the thickness of 1.25 ± 0.05 mm is to be used for papers of up to 0.75 mm in thickness and the plate with the thickness of 2.50 ± 0.05 mm for thicker papers.

Fasten the thin tang of the stirrup in the lower clamp (see note) of the tension-testing machine so that the vertical centre line of the stirrup coincides with the line connecting the mid-points of the upper and lower clamps of the testing machine, and so that the sides of the V-notch are symmetrically located with the line through the mid-points of the clamps.

NOTE The stirrup may be fastened in the upper clamp, if desired. This procedure will require rebalancing the tension-testing machine to compensate for the mass of the stirrup.

Place the lower clamp of the machine so that the lower edge of the upper clamp is about 90 mm above the V-notched plate.

Thread the test piece through the stirrup, under the plate, and bring the two ends together and fasten them in the upper clamp.

In this operation, most of the slack in the test piece is taken up, but care shall be exercised not to apply a tearing force to the test piece. Make the application of the first increments of load to the test piece very slowly if possible, to minimize abnormal strains due to inertia effects. Increase the load so that tearing starts in 5 s to 15 s and record this load in kilograms.

7.4 Results

Report the central values for each of the two directions of the paper in newtons, mentioning the thickness of the plate used, the rate of loading and the width and thickness of the test pieces.

8 Bursting strength

The bursting strength shall be determined according to the method described in ISO Standard 2758: Paper — Determination of bursting strength, with the following exceptions:

- The test pieces shall be conditioned in accordance with Sub-clause 1.3.
- The central value shall be taken as the result; the highest and lowest values shall be reported.

Principle

A test piece, placed in contact with a circular elastic diaphragm, is rigidly clamped at the periphery but free to bulge with the diaphragm. Hydraulic fluid is pumped at a constant rate, bulging the diaphragm until the test piece ruptures. The bursting strength of the test piece is the maximum value of the applied hydraulic pressure.

9 Folding endurance

9.1 Test apparatus

A folding tester (Schopper type).

9.2 Test pieces

Nine strips 15 mm wide, cut in the machine direction, and nine other strips cut in the cross direction.

9.3 Procedure

Clamp the specimen in both clamps. Apply a tension of 5 N with specimens up to 0.03 mm in thickness and a tension of 10 N with thicker specimens. Determine the number of double folds which the paper withstands, applying a plate of 0.5 mm in thickness with a radius of curvature of 0.25 mm, at a speed of 100 to 200 double folds per minute.

9.4 Results

Report the central value of each series to two significant figures. The highest and lowest values shall also be reported.

10 Moisture content

Moisture content of paper, as received, shall be measured according to the method described in ISO Recommendation R 287: Paper — Method for the determination of moisture content of paper (oven-drying method). The result should be expressed as percentage moisture of the original mass. Three test specimens shall be taken from the reel according to Sub-clause 6.2.3 of ISO Recommendation 287. The central value obtained is taken as the result; the highest and lowest values are reported.

Principle

Weigh the test piece at the time of sampling and again after drying in an oven at 102 °C to 105 °C to constant mass.

11 Ash

The amount of residue of paper left after incineration shall be determined according to the method described in ISO Standard 2144: Paper and board — Determination of ash.

Three determinations shall be made. The result should be expressed as a percentage of the oven dry mass. Report the central value obtained as the result; the highest and lowest values are reported.

12 Conductivity of aqueous extract

12.1 Test apparatus

- A conductivity cell with known cell constant K .
- A measuring instrument, capable of measuring conductance or admittance to a minimum reading of 1 μS with an accuracy of 5 %, in the frequency range 50 Hz to 3 000 Hz. Alternatively, the resistance may be measured with the same accuracy.
- Wide-mouth 250 cm³ conical flasks with reflux condensers in acid- and alkali-resistant glass.

12.2 Procedure

The determination is to be made on the material as received. One measurement shall be made on each of three extractions. First, a blank test shall be carried out on water which has been boiled for 60 ± 5 min in the flask to be used. If the conductivity of that water is not more than 200 $\mu\text{S}/\text{m}$, the flask may be used. If the conductivity is more than this value, then the flask shall be boiled with a fresh portion of water. If the conductivity of the second test exceeds 200 $\mu\text{S}/\text{m}$ then, another flask shall be used.

The test on the paper shall then be carried out as follows:

Cut a test specimen weighing approximately 20 g into pieces of about 10 mm $\times$ 10 mm. Weigh 5 g into a 250 cm³ glass flask with a reflux condenser and add 100 cm³ water having a conductivity of not more than 200 $\mu\text{S}/\text{m}$. The water shall be boiled gently for 60 ± 5 min, and then cooled in the flask to room temperature. It is necessary to take precautions against the absorption of carbon dioxide from the air.