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INTERNATIONAL STANDARD

Specification for plastic films for electrical purposes –
Part 2: Methods of test

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Part 2: Methods of test

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SPECIFICATION FOR PLASTIC FILMS FOR ELECTRICAL PURPOSES –

Part 2: Methods of test

FOREWORD

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International Standard IEC 60674-2 has been prepared by IEC technical committee 15: Solid electrical insulating materials.

This second edition cancels and replaces the first edition published in 1988 and Amendment 1 (2001). This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) this document was completely revised editorially and technically and included in the IEC 60674 series of standards;
b) the test methods are updated to reflect today's state of the art;
c) a method to obtain DC electric strength is now specified according to IEC 60243-2.

The text of this standard is based on the following documents:

CDV	Report on voting
15/742/CDV	15/760/RVC

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60674 series, published under the general title *Specification for plastic films for electrical purposes*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

The contents of the corrigendum of December 2017 have been included in this copy.

INTRODUCTION

This document is one of a series which deals with plastic films for electrical purposes. The series consists of three parts:

Part 1: Definitions and general requirements (IEC 60674-1)

Part 2: Methods of test (IEC 60674-2)

Part 3: Specifications for individual materials (IEC 60674-3 (all parts))

SPECIFICATION FOR PLASTIC FILMS FOR ELECTRICAL PURPOSES –

Part 2: Methods of test

1 Scope

This part of IEC 60674 is applicable to plastic films used for electrical purposes. This part of IEC 60674 gives methods of test.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60212:2010, *Standard conditions for use prior to and during the testing of solid electrical insulating materials*

IEC 60216 (all parts), *Electrical insulating materials – Thermal endurance properties*

IEC 60243-1:2013, *Electric strength of insulating materials – Test methods – Part 1: Tests at power frequencies*

IEC 60243-2, *Electric strength of insulating materials – Test methods – Part 2: Additional requirements for tests using direct voltage*

IEC 60250:1969, *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*

IEC 60343, *Recommended test methods for determining the relative resistance of insulating materials to breakdown by surface discharges*

IEC 60394-2:1972, *Varnished fabrics for electrical purposes – Part 2: Methods of test*

IEC 60426, *Electrical insulating materials – Determination of electrolytic corrosion caused by insulating materials – Test methods*

IEC 60454-2:2007, *Pressure-sensitive adhesive tapes for electrical purposes – Part 2: Methods of test*

IEC 60589, *Methods of test for the determination of ionic impurities in electrical insulating materials by extraction with liquids*

IEC TR 60648, *Method of test for coefficients of friction of plastic film and sheeting for use as electrical insulation*

IEC 60674-3 (all parts), *Specification for plastic films for electrical purposes – Part 3: Specifications for individual materials*

IEC 62631-3-1, *Dielectric and resistive properties of solid insulating materials – Part 3-1: Determination of resistive properties (DC methods) – Volume resistance and volume resistivity – General method*

IEC 62631-3-2, *Dielectric and resistive properties of solid insulating materials – Part 3-2: Determination of resistive properties (DC methods) – Surface resistance and surface resistivity*

ISO 527-3:1995, *Plastics – Determination of tensile properties – Part 3: Test conditions for films and sheets*

ISO 534, *Paper and board – Determination of thickness, density and specific volume*

ISO 1183, *Plastics – Methods for determining the density of non-cellular plastics – Part 1: Immersion method, liquid pyknometer method and titration method*

ISO 4591:1992, *Plastics – Film and sheeting – Determination of average thickness of a sample, and average thickness and yield of a roll, by gravimetric techniques (gravimetric thickness)*

ISO 4592, *Plastics – Film and sheeting – Determination of length and width*

ISO 4593, *Plastics – Film and sheeting – Determination of thickness by mechanical scanning*

ISO 6383-1, *Plastics – Film and sheeting – Determination of tear resistance – Part 1: Trouser tear method*

ISO 6383-2, *Plastics – Film and sheeting – Determination of tear resistance – Part 2: Elmendorf method*

ISO 11357-3:2011, *Plastics – Differential scanning calorimetry (DSC) – Part 3: Determination of temperature and enthalpy of melting and crystallization*

3 General notes on tests

3.1 Discard at least the first three layers of film from the roll to be tested before removing test specimens.

3.2 Sample rolls shall be exposed for at least 24 h to the standard atmosphere 23 °C ± 2 K and 50 % ± 5 % RH before test specimens are removed for test. Unless otherwise specified, all individual test specimens shall be conditioned for 1 h and tested in the same standard atmosphere.

4 Thickness

4.1 General

Thickness shall be measured by any one or more of the methods given below as required by IEC 60674-3 (all parts).

4.2 Determination of thickness by mechanical scanning

4.2.1 General

Two methods, the first using a single sheet and the second using a stack of sheets, are given individually as follows.

4.2.2 Measurement by a single sheet

4.2.2.1 Principle

The method is based on ISO 4593 using a precision micrometre to measure the thickness of a single sheet test specimen.

4.2.2.2 Test specimens and measuring points

Cut three strips about 100 mm wide across the width of the sample. The test strips shall not contain creases or other defects.

Determine the thickness of the test strips in accordance with the requirements of ISO 4593 using a micrometre having plane or radiused measuring surfaces.

Measurements shall be made at nine points at approximately equally spaced intervals along the length of the test strips. In the case of samples less than 300 mm wide make the measurements every 50 mm along the length of the test strips. In the case of untrimmed rolls, readings shall not be taken within 50 mm of the edges.

4.2.2.3 Result

The thickness is the central value of all the measurements, the highest and lowest values on each strip being reported.

4.2.3 Measurement by a multi-layer of sheets

Bulking (micrometric) thickness shall be measured according to ISO 534, except that the method for obtaining sample pieces is different. Before taking samples, some outer layers of the roll should be removed to obtain undamaged film surface. The four test pieces are initially made up of 12 film layers, the layers being cut together using a suitable template (preferably 250 mm × 200 mm, the 200 mm dimension being in the machine direction) from a stack of film pieces. Discard the first and last layer of each pack or test piece just prior to placing the pack between the pressure faces of the micrometre.

4.3 Determination of thickness by gravimetric method

4.3.1 Measurement by a sample

Principle: calculation of the thickness of a sample from measurements of mass, area and density in accordance with Clause 3 of ISO 4591:1992.

4.3.2 Measurement by a roll

Principle: calculation of the average thickness from measurements of the length, average width and net mass of the roll and the density of the film in accordance with Clause 4 of ISO 4591:1992.

4.4 Crosswise thickness profile and lengthwise variation in thickness

The non-contacting measurement methods, for example using radiation or laser light, are commonly used. The apparatus may be installed in the production line by the manufacturer if the profile and the variation in a roll are required. The minimum resolution for the measurement, its accuracy and testing surface area (width and length) are the subjects specified in IEC 60674-3 (all parts).

5 Density

Density shall be determined in accordance with ISO 1183. The particular method is specified in IEC 60674-3 (all parts).

6 Width

The width is to be determined in accordance with ISO 4592, except that a 5 m sample length is used. Determine the width five times along the length at equal intervals after the film has relaxed for 1 h.

Record each width measured and report the central value as the width of the roll.

7 Windability (bias/camber and sag)

7.1 Principle

An assessment is made of the distortion of the film as supplied in the roll.

Two forms of distortion may be apparent in the film which can impair its subsequent winding characteristics. These distortions are:

1) the film may exhibit bias or camber and therefore its edges may not be straight (see Figure 1);
2) the film may sag below its general level in areas where it has been stretched (see Figures 2 and 3).

7.2 General

Two methods are given. Method A is appropriate for narrow (i.e. less than 150 mm) films where distortion is apparent mainly as bias/camber and also for the measurement of sag for very thick films where the tension required for extension by Method B is excessive.

Method B is appropriate for wider (i.e. greater than 150 mm) films where distortion is apparent, mainly as sag.

7.3 Method A

7.3.1 Principle

To assess bias/camber, a length of film is unwound and laid on a flat surface and the deviation of each of its edges from a straight line is measured (see Figure 1).

To assess sag, a length of film is unwound and laid orthogonally over two parallel bars under defined conditions and the deviation from a uniform catenary is measured (see Figure 2). It may sometimes be convenient to make this measurement using the rollers of a winding machine, but in cases of dispute the dimensions and distances shall be as given below.

7.3.2 Measurement of bias/camber

7.3.2.1 Apparatus

A flat, horizontal table of any suitable material having a satin finish (not polished) of sufficient width to accommodate the maximum width of film to be tested and of length 1 500 mm ± 15 mm with ends parallel to within 0,1° (or 1,8 mm per 1 metre of table width). Alternatively, the table may be longer than the above length but shall then have two reference lines clearly marked on its surface 1 500 mm ± 15 mm apart and parallel to the same accuracy.

- A soft brush suitable for smoothing the film specimen on the table surface.
- A long (in excess of 1 525 mm) steel straight-edge.
- A 150 mm steel rule with 1 mm graduations.

7.3.2.2 Test specimens

The first three layers of film from the roll are discarded. For each specimen a fresh length of approximately 2 m is taken, being drawn from the roll with the lightest tension necessary to unwind it slowly (at about 300 mm/s).

7.3.2.3 Procedure

The specimen length of film is placed lengthwise over the table as shown in Figure 1. Starting from one end, the soft brush is used to lightly press the film into intimate contact with the table surface, expelling any trapped air as far as possible.

The steel straight-edge is then placed along one edge of the film so that any deviation of the film edge from a straight line can be readily observed. The straight-edge is adjusted to coincide with the film edge at the two table ends (or at the reference marks if these are used) and the distance between these points shall be 1 500 mm ± 15 mm. The distance between the straight edge and the film edge is measured to the nearest 1 mm at approximately mid-span by means of the steel rule.

The deviation of the second film edge is then measured using the same procedure.

The sum of the distances in millimetres of the two edges of the film from the steel straight-edge at the mid-span is the bias/camber value for that test specimen.

The above procedure is repeated for two further test specimens.

7.3.2.4 Results

The bias/camber is the central value of the three determinations, the other two values being reported.

7.3.3 Measurement of sag

7.3.3.1 Apparatus

A rigid framework supporting two parallel, freely rotatable metal rollers, each roller 100 mm ± 10 mm in diameter and of sufficient length to accommodate the maximum width of film are to be tested. The axes of the rollers shall be in the same horizontal plane and set mutually parallel to within 0,1° (i.e. within 1,8 mm per 1 m length of roller) with a separation of 1 500 mm ± 15 mm. The roller surfaces shall be accurately cylindrical to within 0,1 mm with any suitable satin finish (not polished) (see Figure 2). The framework shall be fitted with a device for mounting the roll of film being tested immediately below one of the rollers. The mounting shall be such that the axis of the film roll is parallel to the superior roller to within 1° and the film may be drawn off the roll against an adjustable unwind tension. At the opposite end of the framework a weighted or sprung clamp is fixed to the film web hanging freely from the second roller. The weight or spring loading and its position on the film may be adjusted so as to give a substantially uniform tension across the web as specified in IEC 60674-3 (all parts).

A device for measuring along a line midway between the rollers the distance of the film below the plane of those rollers is set up (see Figure 3). The device may comprise simply a long (in excess of 1,525 mm) steel straight-edge and a 150 mm steel rule with 1 mm graduations, or more complex devices may be employed whereby the film position is noted automatically or semi- automatically.

7.3.3.2 Test specimens

The first three layers of film from the roll are discarded. For each specimen a fresh length of approximately 2 m is drawn from the roll with the lightest tension necessary to unwind it slowly (at about 300 mm/s).

7.3.3.3 Procedure

The specimen length of film is placed over the apparatus rollers. the free end of the film is clamped in the tensioning device, the tension adjusted to the value given for the film in IEC 60674-3 (all parts) and the lateral position of the film as it passes over the second roller adjusted so that the film web lies approximately horizontal at mid-span.

Using the steel straight-edge and graduated steel ruler or other suitable device, the film is checked across the film width at mid-span and any edge sag or sag lanes noted. The maximum depth of any sag lane below the general film surface surrounding it is measured to the nearest 1 mm (see Figure 3) and reported as the sag value for that test.

The above procedure is repeated for two further test specimens.

7.3.3.4 Result

The sag value is the central value of the three determinations, the other two values being reported.

7.4 Method B

7.4.1 Principle

The total amount of sag and bias/camber is assessed by one measurement. A length of film is unwound and laid orthogonally over two parallel bars under defined conditions. The film is strained until free of visible sag and bias/camber and the extension necessary to achieve this is measured. It may sometimes be convenient to make this measurement using the rollers of a winding machine but in cases of dispute the dimensions and distances shall be as given in 7.4.2.

7.4.2 Apparatus

A rigid framework supporting two parallel, freely-rotatable metal rollers, each roller 100 mm ± 10 mm in diameter and of sufficient length to accommodate the maximum width of film are to be tested. The axes of the rollers shall be in the same horizontal plane and set mutually parallel to within 0,1° (i.e. within 1,8 mm per 1 m length of roller) with a separation of 1 500 mm ± 15 mm. The roller surfaces shall be accurately cylindrical to within 0,1 mm with any suitable satin finish (not polished). The framework shall be fitted with a device for mounting the roll of film being tested immediately below one of the rollers. The mounting shall be such that:

a) the axis of the film roll is parallel to the superior roller to within 2°;
b) the lateral position of the film may be adjusted as desired, and
c) the film may be drawn off the roll against an adjustable unwind tension.

At the opposite end of the framework a weighted or sprung clamp is fixed to the film web hanging freely from the second roller. The weight or spring loading of the clamp and its position on the film may be varied to give an adjustable tension substantially uniform across the web.

- A steel straight-edge (in excess of 1 525 mm).
- A flexible steel rule 2 m or more in length with 1 mm graduations.
- Suitable self-adhesive labels.

7.4.3 Test specimens

The first three layers of film from the roll are discarded and a fresh length of approximately 2 m is drawn from the roll with the lightest tension necessary to unwind it slowly (at about 300 mm/s).

7.4.4 Procedure

The specimen length of film is placed over the apparatus rollers. With light hand tension applied to the web, the free end of the film is moved so that the film web between the rollers is as flat as possible and the free end is then clamped in the tensioning device. The tension is adjusted to (1,0 ± 0,2) MN/m^2 (based on the nominal thickness and width of the film).

Two reference marks (between 1,0 m and 1,1 m apart) are applied to the film on a line exhibiting minimal sag and which is approximately parallel to the edges of the film. These marks may conveniently be specific edges of two self-adhesive labels applied to the film surface.

The distance between the marks is measured to within ±0,5 mm using the flexible steel tape.

The tension applied to the film is increased until:

a) the film is visually smooth;
b) each film edge is straight to within 0,5 mm at mid-span when compared with the straight-edge, and
c) the sag at any point does not exceed 7,5 mm when compared with the straight-edge.

The distance between the reference marks at this tension is measured using the steel tape and the extension of the film is expressed as a percentage of the original mark separation.

The above procedure is repeated for two further test specimens.

7.4.5 Result

The total sag and bias/camber is the central value of the three determinations, the other two values being reported.

8 Surface roughness

Both contact and non-contact detection methods are used for measurement of surface roughness. The measurement by surface mapping in 2 dimensions or one dimension is recommended for the evaluation of surface roughness. The minimum resolution for the roughness, its accuracy, area of testing surface and a distance between the mapping points are the subjects which need the agreement between supplier and purchaser.

9 Space factor

The space factor is the percentage increase in bulking (micrometric) thickness over gravimetric thickness, which is caused by surface roughness.

The space factor, SF (%), is calculated using the following formula:

$$SF = \frac{t_b - t_g}{t_g} \times 100$$

where

t_b is the bulking thickness in µm;

t_g is the gravimetric thickness in µm.

The bulking thickness and the gravimetric thickness should be measured using the same sample of film in accordance with Clause 4.

10 Coefficient of friction

The coefficient of friction is to be determined in accordance with IEC TR 60648.

Principle:

This method covers determination of starting and sliding friction of plastic film and sheeting when sliding over itself or other substances under specified conditions. The procedure permits the use of a stationary sled with a moving plane or a moving sled with a stationary plane. Both procedures yield the surface coefficient of friction for a given test specimen.

11 Wetting tension (polyolefine films)

11.1 Test principle and introductory remarks

The determination of the wetting tension is based on the phenomenon that drops of a series of an organic liquid mixture with gradually increasing surface tension, when they have reached a specific concentration, have the ability to wet the film surface. Since the wetting tension of a film in contact with a drop of the respective liquid mixture in the presence of air is a function of the surface energies of both the air-film and the film-liquid interfaces, any trace of surface-active impurities in the liquid reagents or on the film may affect the results. It is, therefore, important that the film surface to be tested should not be touched or rubbed, that all equipment be clean and that reagent purity be carefully controlled.

11.2 Apparatus

- Cotton-tipped wooden applicators approximately 150 mm long.
- Two burets, 50 ml.
- Bottles, 100 ml with caps and labels rinsed with distilled water.

11.3 Reagents

Prepare mixtures of reagent-grade formamide ($HCONH_2$) and reagent-grade ethylene-glycol-monoethyl-ether ($CH_3CH_2 – O – CH_2CH_2 – OH$) in the proportions shown in Table 1 for the integral values of wetting tension in the range over which measurements are to be made.

If desired, add to each of the mixtures mentioned in Table 1 a very small amount of dye of high tinctorial value.

The surface tension of the liquid mixtures shall be checked weekly. Any wetting tension method usually applied in the laboratory is suitable. Although the shown liquid mixtures are relatively stable, exposure to temperatures above 30 °C and humidity above 70 % RH should be avoided.

NOTE The dye of such colour is used as to make drops clearly visible on the surface of the polyolefin film. Furthermore, the selected dye has such chemical composition that it will not measurably affect the wetting tension of the liquid mixtures.

Both ethylene-glycol-monoethyl-ether and formamide are toxic and be handled with due precaution. Since formamide is particularly dangerous when in direct contact with the eyes, safety goggles be worn when making up the liquid mixtures. Follow to national safety regulations.

Table 1 – Concentrations of ethylene-glycol-monoethyl-ether, formamide mixtures used in measuring wetting tension of polyethylene and polypropylene films

Formamide volume per cent	Ethylene-glycol-monoethyl-ether per cent	Wetting tension (mN/m)
0	100,0	30
2,5	97,5	31
10,5	89,5	32
19,0	81,0	33
26,5	73,5	34
35,0	65,0	35
42,5	57,5	36
48,5	51,5	37
54,0	46,0	37
59,0	41,0	39
63,5	36,5	40
67,5	32,5	41
71,5	28,5	42
74,7	25,3	43
78,0	22,0	44
80,3	19,7	45
83,0	17,0	46
87,0	13,0	48
90,7	9,3	50
93,7	6,3	52
96,3	3,7	54
99,0	1,0	56

11.4 Test specimens

The first three layers of film from the roll are discarded. One sample across the entire width of a roll should be tested in such a way that one determination at each location ¼ , ½ , ¾ of the way across the width of the film is made. If the range of these three determinations exceeds 2,0 mN/m, indicating that the polyolefin film has been unevenly treated, measurements, as described above, shall be made at three points spaced along the length of the roll (a total of nine measurements).

Extreme care shall be taken to prevent the surface of the film sample from being touched or handled in the areas upon which the test is to be made.

11.5 Conditioning

Standard atmosphere B according to IEC 60212 during testing (23 °C/50 % RH).

11.6 Procedure

Wet the extreme tip of a cotton applicator with one of the mixtures. Use only a minimum amount of liquid as an excess of reagent may affect the result.

Spread the liquid lightly over an area of approximately 6,5 cm^2 (~25 mm in diameter) of the test specimen at the selected location. Do not try to cover a larger area lest there be insufficient liquid to give complete coverage. Note the time required for the continuous liquid coverage formed on the film to break up into droplets. If the continuous liquid coverage holds for more than 2 s proceed to the next highest wetting tension mixture, but if the continuous liquid coverage breaks into droplets in less than 2 s, proceed to the next lowest wetting tension mixture. A clean, new cotton applicator shall be used each time to avoid contamination of the solution.

Proceed in the direction indicated above continuously repeating the prescribed steps until it is possible to select the right mixture according to 11.7.

Experience with the test has shown that occasionally erroneous results can be obtained by working progressively to lower surface tension mixtures. Therefore, it is recommended that the tester should check the wetting tension of the film by working progressively to higher surface tension mixtures.

11.7 Evaluation

The mixture is considered as wetting the test specimen when it remains intact as a continuous coverage of the liquid for 2 s as close as possible. Shrinkage of the periphery of the continuous liquid coverage does not indicate lack of wetting; only breaking into droplets within 2 s indicates lack of wetting. Severe peripheral shrinking may be caused by too much liquid being placed upon the film surface. The surface tension of the applied mixture in millinewtons per metre which remains intact for 2 s is called the wetting tension of the polyolefin film test specimen.

11.8 Report

If one specimen has been tested and the range of results is less than 2,0 mN/m, report the central value of the three wetting tension test results.

In case of an unevenly treated polyolefin film, for which nine determinations have been made, report the central value and the individual values.

12 Tensile properties

12.1 General

These are to be determined in accordance with ISO 527-3. Tensile properties generally to be specified are tensile stress and percentage elongation at break but sometimes 1 % secant modulus may be specified.

12.2 Test specimens

Test specimens shall be in accordance with 6.1.1 of ISO 527-3:1995, i.e. strips 10 mm to 25 mm wide, not less than 150 mm long, with gauge marks at least 50 mm apart.

Five specimens shall be tested in each of the directions specified in IEC 60674-3 (all parts).

12.3 Speed of testing

The speed of testing is the rate of separation of the grips of the testing machine during a test and shall be the speed specified in IEC 60674-3 (all parts).

12.4 Result

For each property and for each direction of test, the result is the central value of the five determinations, the highest and lowest values being reported.

13 Edge tearing resistance

13.1 General

The edge tearing resistance is to be determined in accordance with Clause 8 of IEC 60394-2:1972.

13.2 Principle

The test specimen is inserted into an inclined slot of a fixture which is clamped to a tensile testing machine. The force needed to initiate tearing of the edge is determined.

14 Tear resistance

The tear resistance shall be determined in accordance with ISO 6383-1 and ISO 6383-2. The method to be used will be specified in IEC 60674-3 (all parts).

15 Stiffness of film

Principle

This test method describes a means for determining the flexibility of a material by means of a fixed angle flexometer in which the test specimen bends under its own weight. A rectangular strip of material is supported on a horizontal platform in a direction perpendicular to one edge of the platform. The strip is placed on the platform with a specified length overhanging the platform and the time taken for this overhang to fall to an angle of 41° 30' below the horizontal is recorded.

16 Surface resistivity

The surface resistivity is to be determined according to IEC 62631-3-1 and 62631-3-2.

17 Volume resistivity

17.1 Method 1: Electrode method

The electrode method is to be determined according to IEC 62631-3-1 and IEC 62631-3-2, using a guarded electrode of 25 mm diameter and an unguarded one of at least 40 mm diameter.

Determinations to be made under the conditions specified in IEC 60674-3 (all parts) from the following:

- standard dry conditions of IEC 60212 (18 °C to 28 °C/< 1,5 % RH);
- standard atmosphere B of Table 2 of IEC 60212:2010 (23 °C/50 % RH);
- dry hot conditions selected from Table 2 of IEC 60212:2010.

17.2 Method 2: Method for wound capacitor dielectric films or films too thin for Method 1

17.2.1 Principle

This method uses the fact that the volume resistivity ρ of a capacitor dielectric may be calculated from the time constant ($t = CR$) by the relation:

$$\rho = \frac{C \times R}{\varepsilon_r \times \varepsilon_0}$$

where

C is the capacity in F;

R is the resistance in Ω;

ρ is the resistivity in Ω/m;

ε_r is the relative permittivity;

ε_0 is the permittivity of vacuum and is equal to $8,85 \times 10^{-12}$ F × m^{-1}.

17.2.2 Test specimens

Each test specimen is a wound capacitor on a rigid insulating core, of extended foil construction, with an active electrode width of 40 mm to 70 mm and an edge margin of 3 mm. The dielectric is a single layer of the film under test and the capacitance (measured at 1 kHz) is 0,5 µF ± 0,1 µF. If preliminary heat or vacuum treatment is required, this will be indicated in IEC 60674-3 (all parts).

17.2.3 Procedure

Three test specimens are wound as above and subjected to any necessary treatment. After further conditioning for 6 h in standard dry conditions (18 °C to 28 °C and <1,5 % RH) the two-minute resistance ((100 ± 10) V or (25 ± 4) V/µm for films of thickness 4 µm or less) is measured and then the capacitance at a frequency below 1,6 kHz.

The permittivity is measured as indicated in Clause 18. Alternatively the theoretical value may be sufficiently accurate.

The values of ρ are calculated from the equation shown in 17.2.1.

17.2.4 Result

The volume resistivity is the central value of the three measurements. The report should state the temperature of measurement and whether the permittivity was measured or assumed.

In order to reduce the error caused by the charging current of the capacitor to acceptable proportions, it is necessary for the time constant of the capacitance C of the test specimen and the input resistance r of the current measuring device to be small compared to both the time of application of voltage and the time constant of decay of the apparent leakage current. Where the application time is 2 min apply the $C \times R$ value less than 2 s for most films. Where the test specimen is 0,5 µF, the value of R is selected accordingly less than 4 MΩ.

Some direct reading megohmmeters may not be satisfactory in this respect.

18 Dissipation factor and permittivity

18.1 General

A frequency range of 50 Hz to 100 MHz is covered and two methods are available.

18.2 Method 1

18.2.1 General

The test shall be made on a flat specimen in accordance with IEC 60250, modified by the instructions of this clause, at a frequency to be agreed between purchaser and supplier and at a temperature of 23 °C ± 2 K unless otherwise specified in the relevant material specification of IEC 60674-3 (all parts).

At low frequencies and for thick films, it is usual to make the measurements on specimens made from one layer of film. However, it has been found that at a frequency higher than 1 MHz very thin films may be measured more conveniently and accurately by using a large number of layers (sheets) of the material being measured. Air shall be excluded from this stack of sheets by pressing. The average specimen thickness is determined from the density of the material, the area of the stack and the mass of the stack.

18.2.2 Sample and specimen handling

Sampling shall be carried out in accordance with the material specification. The state and condition of the material shall not be altered.

The sample and test specimens shall be handled with care to avoid contamination, scratches and finger-prints.

A minimum number of three test specimens shall be used unless otherwise specified in the material specification.

18.2.3 Sample conditioning prior to measurement

Any conditioning prior to measurement shall be in accordance with the material specification, or otherwise agreed between purchaser and supplier.

NOTE 1 The properties of film materials can be substantially affected by moisture. Standard conditions for use prior to, and during, the testing of solid electrical insulating materials are given in IEC 60212. The relative humidities associated with various salt solutions are given in IEC 60260.

NOTE 2 The properties of film materials can also be substantially affected by heat, mechanical stress, nuclear radiation, X-rays, etc. The methods described can be used to assess the magnitude of these effects.

NOTE 3 Specimens are measured in the 'as received' state and after conditioning in a dry atmosphere unless otherwise specified.

Samples with painted, evaporated or sputtered electrode shall be conditioned after the electrodes have been applied, as painting and vacuum treatment will greatly influence the moisture content of the material. Electrodes of these types are somewhat permeable moisture, but, if such electrodes are used, checks should be made to see that the specimens have reached substantial equilibrium with the conditioning atmosphere within the time laid down in the relevant material specification.

NOTE 4 This can be achieved by a series of comparative measurements made after further periods of conditioning.

18.2.4 Measurements with contacting electrodes

18.2.4.1 General

For measurement of thin films with frequencies up to approximately 50 kHz, a three terminal electrode arrangement shall be used. A typical example is given in Figure 4.

For measurements at higher frequencies, a two-terminal system shall be used (Figure 5).

The intimate electrodes shall be composed of a material that allows good contact with the specimen surface and introduces no appreciable error because of electrode resistance or contamination of the specimen.

NOTE Dissipation factor measurements at high frequencies can be more accurately made using non-contacting electrode methods because the errors arising from dielectric loss in intimate electrode increase with frequency.

The electrode material should be corrosion resistant under the conditions of the test. They shall be used with suitable backing electrodes.

If very thin films (2 μm or less) are to be measured, the backing electrode may be lines with an aluminium foil in order to avoid damage to the sample during positioning of the backing electrode.

It should be determined whether the electrode influences the results. This can be achieved by comparison of the result of tests made using two different types of electrodes.

18.2.4.2 Electrode materials

18.2.4.2.1 Evaporated or sputtered metal

The most recommended types of electrodes are of evaporated or sputtered metals as long as the sample material is not significantly affected by vacuum treatment or ion bombardment. Aluminium, silver or gold may be used as electrode materials. Metal films of about 150 nm in thickness show the best results in view of electrical properties and lowest stress to the sample material during metal deposition. The use of masks produces electrodes with highly defined edges and reproducible area.

Before evaporation, the vacuum in the chamber should be 0,05 μbar or better. During evaporation, the rate of film growth should be about 1 nm/s. The electrode deposition via vaporization of the electrode supply material, aided by the capacitor discharge going through it, is normally of an uncontrolled, short duration.

The stress on the sample during sputtering, quality, and properties of sputter electrodes depends on the choice of gas, gas pressure inside the reaction chamber, voltage used and position of the sample inside the reaction chamber. Conditions shall be optimized according to the selected sputter equipment.

Where metallized specimens cannot be measured immediately after metallizing, for example because of exposure to a conditioning atmosphere for a period of time, care shall be taken to minimize the effects of electrode corrosion. In this instance, evaporated gold electrodes are recommended. This is particularly important for materials with a low dissipation factor such as polypropylene.

18.2.4.2.2 Conductive silver paint

Commercially available high conductive silver paints may be used as electrodes, but it should be established that the solvent in the paint does not affect the properties of the sample. The use of masks gives electrodes of reproducible areas.

18.2.4.2.3 Metal foil

Electrodes of thin metal foil can be made from lead, tin, aluminium, silver or gold. They can be attached to the sample surface by a small quantity of petroleum or grease.

Silicone greases are not recommended for measurements on materials with low dissipation factors because they exhibit a very high dissipation factor at some frequencies and temperatures. Their major use is at elevated temperatures where petroleum has too low a viscosity. Higher molecular weight, low-loss olefinic greases have been found to be more suitable.

The electrodes shall be applied with a smooth pressure to eliminate all air and wrinkles. Excess grease may be wiped off with a tissue. The film of grease shall be as thin as possible and its thickness shall be insignificant compared to the sample thickness.

18.2.5 Measurements with non-contacting electrodes

For measurements made close to ambient temperature, specimens that are very thin or low loss, or measured at high frequencies are more accurately measured with either fixed or micrometre controlled non-contacting electrodes.

a) In air

   Measure according to IEC 60250:1969, 4.1.2.2.1, for dissipation factor at room temperature. Specimen electrodes are not required.

b) Fluid displacement

   Measure according to IEC 60250:1969, 4.1.2.2.2, for permittivity at room temperature.

18.2.6 Test procedure

The test procedure is as follows:

a) apply electrodes in relevant condition for the specimen prior to measurement as specified 18.2.1;
b) the measurement of permittivity and dielectric dissipation factor shall be made in accordance with the material specification and the specification of the measuring method used;
c) the specimen shall be measured inside a screened enclosure;
d) calculations of the dielectric permittivity and dissipation factor shall be made according to the specification of the measuring method used;
e) preferred test frequencies are 48 Hz to 62 Hz; 1 kHz; 10 kHz; 1 MHz;
f) calculate the mean value of the test measurements as the result.

18.2.7 Report

The report shall include the following information:

a) the manufacturer's description and identification of the material, including details of any surface treatment;
b) thickness of samples;
c) type of electrodes;
d) details of any conditioning prior to measurement, including any cleaning procedures;
e) test conditions, i.e. temperature and relative humidity;
f) applied voltage;
g) frequency;
h) permittivity;
i) dissipation factor.

18.3 Method 2

18.3.1 General

The dissipation factor and permittivity shall be determined on a wound capacitor at a frequency to be agreed between purchaser and supplier and at a temperature of 23 °C ± 2 K, the actual temperature being reported. Wound capacitors are only suitable for the measurement of the dissipation factor on thin (up to 25 µm) films. To obtain a more accurate result, it may be necessary to remove entrapped air from the capacitor winding by a heat, and or vacuum treatment.

Sample conditioning, electrode materials, electrode shape, test procedure and test report shall be according to 17.2.

18.3.2 Dissipation factor at or above 5×10^{-4}

Prepare the test specimen according to 17.2.

18.3.3 Dissipation factor below 5×10^{-4}

By agreement between supplier and purchaser, a capacitor construction incorporating the following features may be used:

a) after winding on a large mandrel, the capacitor should be removed from the mandrel and pressed so that the varying pressure does not alter the dissipation factor. The extension of foil at each end shall be sufficient to allow for sufficiently heavy bolted connections;

b) before the capacitor is clamped into its final configuration, it should be vacuum dried for 3 h to 4 h at room temperature to remove absorbed moisture.

19 Dissipation factor under impregnated conditions

This document gives no requirement for this test. The details of this test will be a matter of contract.

20 Electric strength

20.1 AC and DC tests of film sheet sandwiched by metal electrodes

Electric strength under AC or DC voltage shall be tested in accordance with IEC 60243-1 and IEC 60243-2, in oil or in air. A mode of increase at voltage application shall be as indicated in 10.1 “short time test” in IEC 60243-1:2013.

The electrode shall be selected from following configurations; unequal electrodes in 5.2.1.1 of IEC 60243-1:2013, sphere and plate electrodes in 5.2.1.3 of IEC 60243-1:2013, and rod and rod electrodes in 5.2.2 of IEC 60243-1:2013. A diameter of the upper electrode in the unequal electrodes can be changed to 6 mm, if necessary.

The electrode configuration used for test of an individual kind of plastic film will be specified in IEC 60674-3. The same electrode configuration should be used in AC and DC tests.

20.2 DC test using a wound capacitor

Unless otherwise specified in IEC 60674-3, test capacitors are wound as for 17.2.2 but with an edge margin of 1 mm/kV of expected breakdown voltage. Each is subjected to an increasing direct voltage by means of a charging current of 100 µA ± 20 µA.

The maximum value of voltage reached is indicated and preferably retained by an indicator capable of indicating within an error less than 1 % of the full-scale deflection at the rate of rise specified. This may conveniently take the form of a voltage divider feeding a self-balancing recording instrument.

Twenty-one tests are made. Report the central value of the twenty-one results and the number of breakdowns which occur at or below the voltage given in IEC 60674-3.

21 Electrical weak spots

21.1 General

The methods given involve the counting of weak spots. In interpreting the result of these counts, it is important to be aware of the statistics involved. Experience has shown that the number of counts follow the Poisson type distribution law. When selecting limits for use in

IEC 60674-3, due attention will be paid to the different statistical treatments required by tests which use a count as a result rather than measured magnitudes.

21.2 Method A: Testing narrow strips of film in long lengths

21.2.1 Test equipment

The test equipment is shown in a schematic diagram (Figure 6). It shall allow the strip of film to be tested to be drawn at a constant rate of 5 m/min at a circumferential angle of approximately 90° over a reliably earthed and readily rotatable roller which serves as one of the two electrodes. The roller has a diameter of 15 mm and is of corrosion-resistant steel with a polished surface. The second electrode is a soft aluminium foil with a width of 10 mm to 20 mm and a thickness of 0,006 mm. The aluminium foil curves around the roller at the smallest possible angle (approximately 10°) and is loaded with about 40 g for each 10 mm width of the aluminium foil, preferably by a weight in the form of a clip. This presses the aluminium foil close to the strip of film to be tested. The aluminium foil shall be narrower than the strip of film to be tested and arranged so that the strip of film overlaps beyond the aluminium foil by at least 2,5 mm on both sides. A direct voltage of 100 V per 0,001 mm thickness of the film to be tested shall be applied between the aluminium foil and the roller. It shall be possible for the test voltage to be set whilst the strip of film is running. (The voltage set when the strip of film is motionless drops if the strip of film is moved, due to the removal of charge by the strip of film.)

The apparatus for producing the direct current shall be designed so that the full test voltage is reached again after about 0,1 s following a breakdown, so that faults following each other closely can be detected. A suitable counting mechanism shall be used for counting the electrical impulses (weak spots).

21.2.2 Procedure

The strip of film to be tested is drawn between the roller and the aluminium foil as described in 21.2.1, and the electrical impulses (weak spots) counted.

21.2.3 Results

The weak spots counted are divided by the tested area and stated as the fault count per m^2 by Method A.

The following particulars shall be stated:

- width in millimetres of the aluminium foil;
- length in metres of the tested strips of film.

21.3 Method B: Testing wide strips of film

21.3.1 General

Hazard note: The energy stored in this test specimen may be approximately 1 J.

21.3.2 Test equipment

A schematic diagram of the test equipment is given in Figure 7. On an electric insulating support of approximately 270 mm × 160 mm lies a metallized plastic foil [1] measuring 250 mm × 140 mm with the metal covering uppermost. A test specimen measuring 180 mm × 180 mm taken from the film to be tested is placed on the metal covering so that it overlaps by 20 mm on each of the 250 mm long sides of the metallized plastic foil and terminates at one of the 140 mm long sides of the foil. Another metallized plastic foil 140 mm

1 For example, a 0,03 mm thick polyethyleneterephthalate (PETP) film vacuum metallized with aluminium.

wide is placed on the test specimen with the metal covering side downwards and on top of this a soft rubber sheet measuring 140 mm × 140 mm and about 4 mm thick. After folding the upper metallized plastic foil round the soft rubber sheet, the whole is loaded with a metal plate measuring 140 mm × 140 mm weighing approximately 650 g. The test voltage is applied to the metal plate. The free end of the metallized plastic foil lying underneath is connected to earth. The test voltage (DC or peak AC) is 100 V per 0,001 mm thickness of the test specimen.

21.3.3 Procedure

Starting at nil, the test voltage is increased at 0,5 kV/s to the calculated value and then maintained at this calculated value for 1 min, after which the specimen is removed from the test equipment and the number of weak spots, which are recognizable by their brownish specks, are counted on an area of 100 cm^2 which is at least 20 mm from the edge of the tested area.

The testing is carried out on 10 test specimens taken from and evenly distributed over the width of the roll of film.

21.3.4 Results

The number of weak spots determined on the 10 test specimens is divided by the film area and stated as the fault count per square meter by Method B. The type of test voltage shall also be stated.

21.4 Method C: Testing of film in rolls

21.4.1 General

Many types of apparatuses for film in rolls are used by manufacturers and customers to evaluate weak spots. The results obtained by each apparatus have been used for the evaluation to meet the criteria which are agreed upon between supplier and purchaser. In this part of IEC 60674, three types of apparatus for the testing of film in rolls are presented as typical examples.

Method C1: an apparatus where the unmetallized film being tested runs between layers of cleaned aluminium foil electrodes. One aluminium foil electrode is connected to ground potential. The other is connected to high voltage (HV).

Method C2: an apparatus where film, metalized on one surface is used as an electrode in contact with the film under test. The metallized film is connected to the ground electrode. One side of the film to be tested is placed in contact with the metallized film, the other side being placed in contact with the HV roller.

Method C3: an apparatus where the earthed roller is in contact with film surface. The HV electrode is not in contact with the film surface.

It should be noted that these testing methodologies should not be compared because results are not the same even using the same grade of film.

21.4.2 Unreeling system

21.4.2.1 General

The complete unreeling system is housed in a suitable cabinet to protect it against dust. A switch is provided to cut off the test voltage whenever the door of the cabinet is opened.

21.4.2.2 Method C1

A diagram of the apparatus is given in Figure 8. The film under test is unreeled at the same speed as two aluminium foil electrodes 1 and 2 by two rubber-covered rollers R4 and R5. The thickness of these electrodes is 5 μm to 6 μm, and electrode 1 is narrower than electrode 2 by about 20 mm; they are electrically connected to the fault measuring system by the two metal rollers R1 and R2 respectively. Fault detection takes place on the quartz roller R3, which has a diameter of 24 mm. The aluminium foil electrode 1 is tangential to this roller, while electrode 2 passes round it through 180°, so that the film under test is only subjected to the test voltage at the line of contact.

21.4.2.3 Method C2

A diagram of the apparatus is given in Figure 9. The film under test is unreeled at the same speed as the metalized film. The thickness of the metalized film is 2 μm, and the metalized film is narrower than the film under the test by about 20 mm. The metalized surface of the film is electrically connected to the ground potential by touching the grounded roller (R1). HV is connected to metal roller R2.

21.4.2.4 Method C3

A diagram of the apparatus is given in Figure 10a). The film under the test runs through the air gap between HV electrode and the grounded metal roller. As shown in Figure 10b), the gap between HV electrode edge and the grounded metal roller is 0,10 mm ± 0,05 mm. A typical shape of a HV electrode is a metal plate of 4 mm thick and the edge of the plate is finished to a curvature of 2 mm radius, unless otherwise specified in IEC 60674-3 (all parts). The central angle (α), formed by a circular arc between a contact point and a separate point of the film is larger than 120 °.

21.4.3 Fault counter

The counting system comprises:

- a DC HV generator which can supply an adjustable voltage. The breakdown current is limited by a 10 kΩ resistor, irrespective of the test voltage. When breakdown occurs, the voltage should return to its initial value in less than 0,5 s;
- a suitable detector of pulses due to the breakdown current, and a suitable pulse counter;
- optionally, a time-switch to stop the apparatus once a given length of film has been tested.

21.4.4 Procedure

Determine the unreeling speed, the electric field strength applied to the film and an inspection area (width and length) of the film before the test. These parameters are specified in IEC 60674-3 (all parts).

21.4.5 Results

The number of faults is divided by the area in square metres and expressed as the faults count per square metre by Method C1, Method C2 or Method C3.

In addition, the following shall be noted:

- unreeling speed;
- value of the electric field in kilovolts per millimetre or in volts per micrometre.
- width and length of the inspected film;

22 Resistance to breakdown by surface discharges

This is to be determined according to IEC 60343.

23 Electrolytic corrosion

The electrolytic corrosion is to be determined according to one of the methods given in IEC 60426. The particular method will be stated in IEC 60674-3 (all parts).

24 Melting point

Melting point shall be measured by DSC method in accordance with ISO 11357-3.

25 Dimensional change

25.1 Test specimens

Two types of test specimen can be used, a square type or a strip type. The size for the square type is approximately 100 mm × 100 mm. The typical size for the strip type is 20 mm × 150 mm, although other sizes can be used.

In the case of the square type, cut two test specimens from the film. Mark each test specimen to show the machine or transverse direction. For materials narrower than 100 mm take the actual width and 100 mm length.

In the case of the strip type, cut ten test specimens from the film. The lengthwise direction of five specimens out of the ten shall be arranged to the same direction as the machine direction, and the lengthwise direction of the other five specimens, to the transverse direction. Mark two gauge lines separated by 100 mm ± 2 mm on the surface of the specimen so that the two lines are centered lengthwise on the strip.

25.2 Procedure

The length and width of the square type specimen are measured to an accuracy of 0,1 mm. The distance between the gauge lines of the strip type specimen are measured to an accuracy of 0,1 mm.

The test specimen of the either type is then suspended free in a hot cabinet with natural circulation of air, for the period of time and at the temperature specified in IEC 60674-3 (all parts).

After cooling to room temperature the length and the width are measured at the same points as previously measured. For the strip type, the distance between the two gauge lines at the same points is measured. The measurements in both types should be performed to an accuracy of 0,1 mm.

25.3 Results

The changes in dimensions of each test specimen are calculated in relation to the initial dimensions as a percentage of dimensional change in the machine and transverse direction.

In the case of the square type, the dimensional change in each direction is the mean value of the two determinations in that direction.

In the case of the strip type, the dimensional change in each direction is the mean value of each five determinations with the five specimens in that direction.

26 Dimensional stability under tension with rising temperature

26.1 Test specimens

Test specimens of 15 mm in width are cut from films in the machine and also, where applicable, in the transverse direction of the roll of film (care should be taken to obtain satisfactorily cut surfaces); from narrower tapes, film test specimens are taken in the delivered width. The length of the test specimens is according to the test equipment. The measured length of 20 mm is marked by two lines in approximately the middle of their length and over their entire width.

26.2 Procedure

The test specimen is suspended in a hot cabinet and loaded to a tension of 2,5 N/mm^2. Beyond (alongside, in the case of opaque film) the measured length of the test specimen, a scale is applied which permits the change in the measured length to be read off to within 1 mm accuracy.

A thermocouple is secured to the test specimen in the region of the measured length. The hot cabinet is heated so that the temperature measured at the temperature-measuring apparatus rises steadily by 50 °C ± 1 K/h, starting at not more than 30 °C. When the measured length has increased under load by 40 %, compared with the initial length or the test specimen tears, a reading of the temperature is taken. Tests in which the specimen is torn at the grips are not evaluated and shall be repeated.

Three specimens are tested in the machine direction and, where applicable, three in the transverse direction of the roll of film.

26.3 Results

The central value from the three individual values of the temperature is stated as dimensional stability under tensile stress with rising temperature in the direction concerned.

It is best to plot a graph of the change in the measured length relative to the temperature. If the test specimen tears before reaching an extension of 40 %, this shall be stated together with the temperature.

27 Dimensional stability under pressure with rising temperature

27.1 Test equipment

The specimen is held between two 1 mm diameter nickel wires which cross at an angle of 90° under a fixed load of 30 N. Penetration of the test specimen is indicated by electrical contact of the two wires.

27.2 Test specimens

Three test specimens 30 mm × 30 mm are cut from the film.

27.3 Procedure

The test equipment is placed in a vibration-free laboratory oven with air circulation, the test specimen is laid between the penetrating fins of the test equipment and loaded without shock to 30 N. A DC voltage of approximately 40 V is then connected via the signalling instrument to the two penetrating fins.

Starting form 30 °C, the temperature is increased uniformly at a rate of 50 °C ± 3 K/h until the signalling instrument indicates the destruction of the specimen. The temperature is measured in the immediate vicinity of the test specimen. As soon as the signalling instrument indicates destruction of the test specimen, the temperature is read.

27.4 Results

The central value of three individual values for the temperature is quoted in degrees Celsius as the dimensional stability under pressure and with rising temperature.

28 Resistance to penetration at elevated temperature

28.1 General

Resistance to penetration at elevated temperature shall be determined according to Clause 10 of IEC 60454-2:2007.

28.2 Principle

The method determines the temperature at which a 1,5 mm diameter sphere penetrates the film so as to make electrical contact through it.

29 Volatile content (loss of mass on heating)

29.1 Test specimens

Three specimens are tested. Each test specimen consists of sufficient pieces of film 50 mm × 50 mm to provide a specimen of mass not less than 300 mg. In the case of film less than 50 mm width, the test specimen shall be a length of film of mass not less than 300 mg.

29.2 Procedure

The test specimen is dried in an oven at the pre-conditioning temperature and for the time specified in IEC 60674-3 (all parts). During this and subsequent heating operations, the test specimen shall be arranged so as to allow free circulation of air over all surfaces.

The test specimen is then cooled to room temperature in a desiccator and weighed (m_1).

The test specimen shall then be heated at the temperature and for the time specified in IEC 60674-3 (all parts). It shall then be cooled to room temperature in a desiccator and weighed (m_2).

29.3 Result

The volatile content, V_C (%), of each specimen is:

$$V_C = \frac{m_1 - m_2}{m_1} \times 100$$

The result is the central value to the three determinations, the other two values being reported.

30 Thermal endurance

Thermal endurance, TI or RTE, shall be determined in accordance with IEC 60216 (all parts). The end-point criteria are specified in IEC 60674-3 (all parts).

31 Burning characteristics

31.1 Principle

This is a combustion test on test specimens in vertical position with the object of dividing materials into different classes according to the results obtained. The test is applicable to thin materials (thickness up to and including 0,25 mm), including those which shrink or distort at the side opposite the flame.

31.2 Apparatus

- Test chamber, enclosure or laboratory fume cupboard free from draughts;
- Bunsen or Tyrrel burner having a tube 100 mm long and an inside diameter of 9 mm;
- circular support with clips or other means of holding test specimens in a vertical position;
- supply of methane gas (technical grade) with regulator and meter to obtain a uniform rate of flow (natural gas having a calorific value of 9 000 kcal/m^3 (1 000 BThU per cubic foot) is considered capable of giving similar results);
- stop-watch or similar suitable device;
- absorbent surgical cotton;
- anhydrous calcium chloride desiccator;
- conditioning room or chamber at 23 °C ± 2 K and 50 % ± 5 % RH;
- ventilated oven at 70 °C ± 1 K;
- a mandrel 9,5 mm ± 0,5 mm in diameter.

31.3 Test specimens

Five test specimens shall be tested.

The test specimens shall be cut from the film under test and shall have the following dimensions: length 200 mm, width 50 mm.

The specimens tested by this method are limited to a maximum thickness of 0,25 mm.

The test specimens shall be prepared by drawing a line across the width of the sample at 125 mm from one of its ends.

The test specimen is then wound around a mandrel of diameter 9,5 mm ± 0,5 mm so as to form a cylinder 200 mm long, with the line marking the length of 125 mm on its outer face.

The end of the rolled test specimen is fixed by means of an adhesive tape 75 mm wide placed with one of its edges along the 125 mm line. The cylindrical test specimen is then removed from the mandrel.

31.4 Conditioning

Batches of test specimens shall be conditioned as follows:

a) batches of five test specimens each, conditioned for at least 48 h at 23 °C ± 2 K and 50 % ± 5 % RH before the test;

b) batches of five test specimens each, conditioned before testing in a ventilated oven for 168 h at 70 °C ± 1 K, and then allowed to cool for 4 h to the ambient temperature.

31.5 Procedure

The test shall be carried out in a room, enclosure or laboratory fume cupboard free from draughts.

A closed laboratory fume cupboard provided with a heat-resistant glass window and an extractor fan for removing combustion products after the test is recommended.

The circular support shall hold the test specimen over a length of 6,0 mm at its upper end, with its longitudinal axis vertical, and its lower end 9,5 mm above the top of the burner, and 300 mm above a horizontal layer of dry absorbent surgical cotton measuring 50 mm × 50 mm and 6,0 mm thick. The cylindrical test specimen so placed shall have its upper end open.

The burner is then held well away from the test specimen, lit and regulated so as to obtain a blue flame 20 mm ± 1 mm high. This flame may be obtained by adjusting both the gas flow and air inlet to obtain a flame 20 mm high with yellow tip, and then increasing the air until the yellow tip disappears. The height of the flame should then be re-measured and corrected if necessary.

The flame is then placed concentrically below the centre of the lower end of the specimen under test, and maintained there for 3 s. The flame is then removed from the test specimen to a distance of at least 150 mm, and the time for which the test specimen continues to burn is noted.

When the burning has stopped, the flame is immediately replaced under the test specimen. After 3 s, the flame is again removed and the duration of flames and burning is noted.

If the test specimen emits molten or flaming matter during one of the applications of the flame, the burner should be tilted at an angle of 45° and moved slightly towards the side of the test specimen to prevent particles of such matter from falling into the burner tube.

If the test specimen burns away from the flame during the test, the burner should be held in the hand, and the distance 9,5 mm between the bottom of the test specimen and the top of the burner tube maintained during application of the flame, ignoring any threads of molten material.

During the test, the following shall be observed and noted:

a) the duration of burning with flames after the first application of the burner;
b) the duration of burning with flames after the second application of the burner;
c) whether or not the test specimen gives off flaming particles which ignite the surgical cotton;
d) the duration of any combustion after the second application of the burner;
e) whether or not the test specimen burns right up to the 125 mm mark.

31.6 Interpretation of results

According to the results obtained from the tests described above, the materials are classified VTF 0, VTF 1 and VTF 2 as given in Table 2, if, during the tests:

- one of the 5 test specimens does not fulfil criteria A, C, D or E, or
- the total combustion time (criterion B) is exceeded by up to 5 s, a further test on a fresh batch of five test specimens is allowed.

The test specimens submitted to this second test shall fulfil the requirements for the class into which they are classified.

Table 2 – Classification of materials regarding self-extinguishing properties

	Criteria	VTF 0	VTF 1	VTF 2
A	Maximum duration of burning with flames after each application of the burner	10 s	30 s	30 s
B	Maximum total combustion time for 10 applications of the burner for all 5 test specimens	50 s	250 s	250 s
C	Number of test specimens capable of burning up to the 125 mm mark	0	0	0
D	Emission of flaming particles capable of igniting the surgical cotton placed 300 mm below the test specimen	0	0	[a]
E	Maximum duration of combustion without flame after removing the burner for the second time	30 s	60 s	60 s

[a] A few flaming particles burning for a short time, some of which may ignite the surgical cotton.

32 Water absorption in a damp atmosphere

32.1 Apparatus

- Balance with an accuracy ±0,1 mg;
- weighing bottles;
- oven, capable of maintaining a temperature as specified in IEC 60674-3 (all parts);
- desiccator;
- enclosure in which a relative humidity of 93 % ± 2 % can be maintained.

32.2 Test specimens

Three specimens are tested. Each test specimen consists of sufficient pieces of film 50 mm × 50 mm to provide a test specimen of mass not less than 300 mg. In the case of film less than 50 mm width, the test specimen shall be a length of film of mass not less than 300 mg.

32.3 Procedure

32.3.1 Water absorption of material as-received

The mass of three test specimens in the as-received condition is determined.

These pieces are placed in an atmosphere of 93 % ± 2 % RH for a period of time to be specified in IEC 60674-3 (all parts) and selected from Table 2 of IEC 60212:2010. After this period of time has elapsed, the mass (to the nearest mg) of each test specimen is determined immediately in a closed weighing bottle. The increase in mass of each test specimen is calculated.

32.3.2 Water absorption of dry material

Three test specimens are dried in an oven at the temperature given in IEC 60674-3 for a period of 24 h and then cooled to room temperature in a desiccator over phosphorus pentoxide for at least 1 h. Each of the test specimens is weighed in a closed weighing bottle (to the nearest mg).

These pieces are placed in an atmosphere of 93 % ± 2 % RH for a period of time to be specified in IEC 60674-3 (all parts) and selected from Table 2 of IEC 60212:2010. After this period of time has elapsed the mass (to the nearest mg) of each test specimen is determined immediately in a closed weighing bottle. The increase in mass of each test specimen is calculated.

32.4 Results

Take the central value of the three determinations and report the increase in mass as a percentage of the original mass either in the as-received condition or in the dry condition as required.

33 Absorption of liquid

33.1 Principle

The method detailed here is an indirect method based on the weight of liquid absorbed by the film, the volume increase due to the liquid absorbed being calculated using the density of the film and of the liquid.

33.2 Apparatus

- Knife-edged punch or template with a sharp knife or razor capable of cutting squares of the film approximately 50 mm × 50 mm;
- balance with an accuracy of 0,1 mg;
- oven, capable of controlling the temperature to within ±1 °C of the required test temperature specified in IEC 60674-3 (all parts);
- circular glass dish at least 100 mm in diameter and suitable glass cover;
- sheets of unglazed absorbent paper 0,1 mm to 0,15 mm thick, suitable for rapidly mopping liquid from the surface of the test specimens;
- weighing bottles;
- density bottle or pyknometer.

33.3 Test specimens

Three specimens are tested. Each test specimen consists of sufficient pieces of film 50 mm × 50 mm to provide a specimen of mass not less than 300 mg. In case of film less than 50 mm width the test specimen shall be a length of film not less than 300 mg.

33.4 Procedure

Place the glass dish containing a quantity of the impregnant liquid (depth 10 mm or more) in the oven at the required test temperature.

Determine the mass (m) of each of the three test specimens weighed to the nearest 0,1 mg, at a temperature of 23 °C ± 1 K.

When the impregnant liquid has attained the test temperature, immerse the three weighed test specimens in the liquid so that the squares remain separate and note the time.

After the time specified in IEC 60674-3 (all parts), remove the test specimens from the oven and immediately place the test squares separately between sheets of the absorbent paper to mop the liquid from both surfaces, wipe them rapidly, thoroughly and firmly several times on both surfaces with clean pieces of paper and weigh the test specimens at room temperature (m_0).

Wiping and weighing should be completed within 15 min [2]) of removal of the test specimens from the oven.

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2) Since some impregnant liquids have some volatility at room temperature, this time should not be exceeded.