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Third edition
2007-06

**Pressure-sensitive adhesive tapes
for electrical purposes –**

**Part 2:
Methods of test**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**PRESSURE-SENSITIVE ADHESIVE TAPES
FOR ELECTRICAL PURPOSES –**
Part 2: Methods of test

FOREWORD

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International Standard IEC 60454-2 has been prepared by IEC technical committee 15: Solid electrical insulating materials.

This third edition cancels and replaces the second edition published in 1994, and constitutes a technical revision. This revision includes improved text regarding the flame test (Clause 20), the improved text on adhesion (Clause 11) and a new Figures 9a and 9b.

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

FDIS	Report on voting
15/377/FDIS	15/387/RVD

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

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

A list of all the parts in the IEC 60454 series, under the general title *Pressure-sensitive adhesive tapes for electrical purposes*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

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- withdrawn;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

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

PRESSURE-SENSITIVE ADHESIVE TAPES FOR ELECTRICAL PURPOSES –

Part 2: Methods of test

1 Scope

This part of IEC 60454 specifies methods of test for pressure-sensitive adhesive tapes for electrical purposes.

2 Normative references

The following referenced documents are indispensable for the application 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 60216-1:2001, *Electrical insulating materials – Properties of thermal endurance – Part 1: Ageing procedures and evaluation of test results*

IEC 60216-2:2005, *Electrical insulating materials – Thermal endurance properties – Part 2: Determination of thermal endurance properties of electrical insulating materials – Choice of test criteria*

IEC 60216-3:2006, *Electrical insulating materials – Thermal endurance properties – Part 3: Instructions for calculating thermal endurance characteristics*

IEC 60243-1:1998, *Electrical strength of insulating materials – Test methods – Part 1: Tests at power frequencies*

IEC 60426:2007, *Test methods for determining electrolytic corrosion with insulating materials*

IEC 60454-3 (all parts), *Pressure-sensitive adhesive tapes for electrical purposes – Part 3: Specifications for individual materials*

IEC 60589:1977, *Methods of test for the determination of ionic impurities in electrical insulating materials by extraction with liquids*

ISO 383: 1976, *Laboratory glassware – Interchangeable conical ground joints*

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

ISO 2194:1991, *Industrial screens – Woven wire cloth, perforated plate and electroformed sheet – Designation and nominal sizes of openings*

ISO 3071:2005, *Textiles – Determination of pH of the aqueous extract*

ISO 3599:1976, *Vernier callipers reading to 0,1 and 0,05 mm*

ISO 10093:1998, *Plastics – Fire tests – Standard ignition sources*

EN 1939:2003, *Self-adhesive tapes – Determination of peel adhesion properties* (The peel adhesion test method of Clause 11 is based on test method A of EN 1939:2003. This standard is the result of the harmonisation of AFERA 5001 and PSTC-1,2,3 and 4, ASTM 3330/D, ASTM 3330/M and agreed by JATMA.)

NOTE EN: European Norm (Europe) – AFERA: Association des fabricants européens de rubans auto-adhésifs – PSTC: Pressure sensitive tape council (USA) – ASTM: American society for testing and materials (USA) – JATMA: Japanese adhesive tapes manufacturers association.

3 Conditioning and specimen preparation

Unless otherwise specified, rolls are to be conditioned for at least 24 h at (23 ± 2) °C and (50 ± 5) % relative humidity and all test procedures are to be carried out in this atmosphere.

Remove and discard the three outer turns before taking any test specimens from the conditioned roll. Specimen preparation shall be done with care in a clean environment. Specific specimen preparation details will be included with the appropriate test method.

Further conditioning of test specimens may be required.

4 Determination of thickness

4.1 Test apparatus

A dead-weight thickness gauge having two ground and concentric circular surfaces, flat within 0,001 mm and parallel to within 0,003 mm. The upper surface shall be 6 mm to 8 mm in diameter and the lower surface larger than the upper one. The upper surface shall move on the axis perpendicular to the two faces.

The gauge shall be graduated to read directly to 0,002 mm. The frame of the thickness gauge shall be of such rigidity that a load of 15 N applied to the gauge housing, out of contact with either the weight or the pressure foot spindle, will produce a deflection of the frame not greater than 0,002 mm (as indicated on the thickness gauge). The pressure exerted on the specimen shall be (50 ± 5) kPa.

The accuracy of the thickness gauge shall be checked frequently by means of a set of steel gauges; the measuring errors of the thickness gauge shall not exceed 0,005 mm.

4.2 Test specimens

Five specimens, at least 75 mm long, are cut from the roll at intervals not less than 300 mm. The specimen shall be allowed to relax for at least 5 min.

4.3 Procedure

Place the test specimen between the jaws of the thickness gauge in contact with the fixed foot. Take care to ensure that no air bubbles are trapped. Lower the moving pressure foot gently on to the surface of the tape and take the reading on the gauge within 2 s. Read the measurement to the nearest 0,002 mm on the thickness gauge scale.

4.4 Results

Report the central value as well as the maximum and minimum values of the five readings of thickness in millimetres.

5 Determination of width

5.1 Method A

5.1.1 Use a steel rule graduated to 0,5 mm. The total measuring error of the rule shall not exceed 0,1 mm.

5.1.2 A specimen of tape, at least 450 mm long, is removed from the roll and placed adhesive side up on a smooth flat surface. The specimen shall be allowed to relax for at least 5 min.

The width of the relaxed specimen is measured with the adhesive side down to the nearest 0,5 mm using the rule. Ten measurements shall be made, uniformly distributed along the length of the specimen. The width shall be the mean value of the ten measurements.

5.2 Method B

5.2.1 Principle

The adhesive tape roll is placed between the jaws of a pair of calipers.

The width is the perpendicular distance, expressed in millimetres, between the opposite cut edges of the test specimen of adhesive tape. This method may not be suitable for slit or rewound rolls if the turns are not exactly coincident.

5.2.2 Apparatus

Vernier calipers with a scale length not less than the roll width according to ISO 3599.

5.2.3 Test specimen

One roll of tape.

5.2.4 Conditioning

Conditioning shall conform to Clause 3 with the exception that it is not necessary to remove any layers unless damaged.

5.2.5 Procedure

Hold the roll so that the cut edges are in a vertical plane. If the outer turns of the tape on the roll have crushed or damaged cut edges, these should be discarded prior to measurement.

Hold the calipers so that the scale shaft is in the horizontal plane.

Carefully close the caliper jaws so as to just touch the cut edges of the outer turns of the roll of tape, taking the following precautions:

- a) do not crush the roll edges;
- b) ensure that calliper jaws are perpendicular to cut edges.

Measure the roll width in millimetres to the nearest 0,1 mm.

Carry out two further measurements at equally spaced intervals around the circumference.

5.2.6 Results

Report the mean value as the width of tape in millimetres.

5.3 Method C

This method will only be used where a very high degree of accuracy is required.

Use a travelling microscope with a vernier control on one axis which has an accuracy of 0,001 mm. Using the specimen obtained and relaxed as in 5.1.2, measure the width to the nearest 0,01 mm, taking ten measurements. The width of the tape is taken as the mean value in millimetres.

6 Determination of roll length

6.1 Principle

The length can be calculated from a measurement of the number of turns of tape on the reel and a measurement of the outer circumference of the tape and the outer circumference of the core. Alternatively, length can be measured directly by using a length sensor that includes a rotating wheel that revolves on the roll of tape as it is being unwound.

For non-extensible tapes the length measured by these methods will be the same as the length after unrolling.

For extensible tapes the length after unrolling will be greater if the tape is stretched irreversibly by unrolling.

6.2 Method A – Measurement of turns method

6.2.1 Apparatus (see Figure 1)

- a) A measuring device capable of counting both whole revolutions and part revolutions, continuously driven by a spindle. The spindle has a suitable locking device by means of which a conical shaft can be quickly fitted to suit the internal diameters of cores for the rolls of tape. (For example, for a nominal 25 mm internal diameter core the conical shaft will give a 24,5 mm diameter to 26,5 mm diameter over a shaft length of 50 mm. Alternative size conical shafts would be needed for tapes on a core with significantly different nominal diameters, such as 76 mm.)
- b) Measuring tape. A narrow, flexible, steel tape (6 mm or narrower) calibrated in millimetres.

6.2.2 Test specimen

One roll of tape.

6.2.3 Procedure

Measure the circumference of the roll C_r in millimetres by means of a steel tape. Apply the tape to the roll like a belt.

Mount the roll on the conical shaft of the counter. Set the counter to zero and pull the tape from the roll in a direction perpendicular to the spindle. Remove all the tape from the core and record the number of revolutions (to the nearest tenth of a revolution) as read from the counter when the last turn of tape has left the core: N turns.

Measure the circumference of the core: C_o mm.

6.2.4 Results

Calculate the length (L) of the tape as follows:

$$L \text{ (metres)} = N \frac{C_r + C_o}{2000}$$

If the length of tape in contact with the core is not to be included in the total length, then

$$L \text{ (metres)} = N \frac{C_r + C_o}{2000} - \frac{C_o}{1000}$$

6.3 Method B – Length sensor method

6.3.1 Apparatus (see Figure 2)

A measuring device capable of measuring the length of a roll of tape in metres by using a calibrated rotating wheel which rolls, with low torque and contact pressure, against the circumference of the tape as it unwinds. The apparatus includes a spindle for mounting the tape, a length sensor, a read-out system and a rotating wind-up roll that can be used to unwind, either manually or automatically, the roll of tape.

6.3.2 Test specimen

One roll of tape.

6.3.3 Procedure

Mount the roll on the shaft adjacent to the sensor. Position the roll and length sensor so that the sensor is in contact with the circumference of roll and the leading end of the roll is directly under the sensor. Set the sensor to zero and manually pull the leading edge of the tape and fix it to the wind-up roll. At the start of unwinding, ensure that the length sensor maintains good contact with the roll and does not slip or bind. On completion of unwinding, take the reading of the length sensor.

6.3.4 Results

Report the length in metres as recorded on the read-out.

7 Corrosion-related properties

7.1 General

The requirements for individual products are given in IEC 60454-3. The test methods will be selected from those given in this part. When electrolytic corrosion is of significance, i.e. when fine wire approximately 1 mm in diameter or finer is used, the determination is carried out according to IEC 60426.

Where required by IEC 60454-3, the test methods for the determination of conductivity, pH and corrosive sulphur shall be used.

7.2 Preparation of water extract for pH and conductivity determinations

7.2.1 Precautions

Avoid contamination of the material during storage, sampling, preparation of test pieces and testing.

Ensure that the sample roll and the material taken therefrom are not contaminated by the atmosphere, particularly the atmosphere of a chemical laboratory, or by contact with bare hands, and that the implements used for cutting or handling the test piece are chemically clean.

7.2.2 Test piece

Cut strips of tape, each approximately 25 mm × 6 mm, from the sample roll.

If a strip is folded, it shall be folded adhesive surface outwards.

7.2.3 Method

Use water having a conductivity not greater than 0,2 mS/m. Make a blank test of the extraction vessel before each extraction, and if the resultant conductivity exceeds 0,2 mS/m repeat the test with the same extraction vessel. Change the vessel if the second result also exceeds this value.

Prepare the extract by putting a ratio of 1 g of tape to 100 ml of water into a borosilicate glass (high chemical resistance glass) or quartz flask fitted with a reflux condenser of the same quality glass or quartz. Use an apparatus with interchangeable conical ground-glass joints complying with the requirements of ISO 383.

Boil the water gently for 60 min, except in the case of cellulose acetate film tape for which the period should be 10 min, taking care that the material is not charred. Allow it to cool as rapidly as possible, taking precautions against admission of carbon dioxide (e.g. CO₂ trap).

7.2.4 Quantity

Sufficient quantity of extracts should be prepared so that pH and conductivity are measured on separate portions of the extracts.

7.3 Determination of pH value of water extract

Determine the pH value at a temperature of (23 ± 2) °C according to 8.2 of ISO 3071.

7.4 Determination of conductivity of water extract

7.4.1 Apparatus

The following apparatus is required.

7.4.1.1 A suitable conductivity cell which may consist of two inert electrodes, e.g., platinized platinum maintained at a fixed distance apart and adequately insulated from each other.

7.4.1.2 A measuring instrument capable of measuring conductance or admittance with an accuracy of 5 % and a minimum reading of 1 μS in the frequency range 50 Hz to 3 000 Hz at a voltage not exceeding 100 V; alternatively, resistance may be measured to the same accuracy.

NOTE 1 It is important that any insulation immersed in the test liquid should not be water absorbent or subject to contamination by aqueous electrolytes.

NOTE 2 The conductivity cell should be easy to clean and free from recesses where impurities can be retained.

NOTE 3 Care should be taken to ensure that the electrodes do not become polarized.

NOTE 4 Platinized platinum electrodes are platinum-coated with platinum black.

7.4.2 Determination of electrical conductivity

7.4.2.1 General

Determination of the conductivity cell constant. If not known, determine the conductivity cell constant K (m^{-1}) using the method specified in IEC 60589.

NOTE For test apparatus, where the cell constant is calibrated into the apparatus electronics, this step is not necessary.

7.4.2.2 Determination of the conductivity of the blank

After thoroughly cleaning the conductivity cell with water as specified in 7.2.3, fill it with water obtained as a result of the blank extraction test, and measure its conductivity G_1 in mS/m at $(23 \pm 2)^\circ\text{C}$. The conductivity of the blank in mS/m is then KG_1 .

7.4.2.3 Determination of the conductivity of the water extract

Thoroughly rinse the conductivity cell with the extract to be tested, and then fill with the extract. Adjust the temperature to $(23 \pm 2)^\circ\text{C}$, maintain for 15 min and then measure the conductivity G_2 in mS/m at that temperature.

The conductivity of the water extract in mS/m is then calculated as $K(G_2 - G_1)$.

NOTE For most purposes, where it is not convenient to test the water extract at $(23 \pm 2)^\circ\text{C}$, it is sufficiently accurate to apply the following correction:

$$\text{Conductivity at } 23^\circ\text{C} = \frac{G}{1 + 0,02(t - 23)}$$

where G is the conductivity obtained when the measurement is made at $t^\circ\text{C}$.

7.4.3 Results

Express the conductivity in mS/m at a temperature of 23°C .

7.5 Detection of corrosive sulfur

7.5.1 Test specimens

Cut two test specimens, each 100 mm long, from the sample roll.

7.5.2 Apparatus

Three smooth copper rods are required, each approximately 6 mm in diameter and 75 mm long, cleaned and polished with water and silicon carbide powder size $90\ \mu\text{m}$ to $125\ \mu\text{m}$ and wiped clean and dried with cotton wool or filter paper. Finally the rods are washed with a volatile sulfur-free solvent, such as diethyl ether, and allowed to dry.

7.5.3 Method

Handle the copper rods with clean, dry metal forceps. Wind two of the copper rods centrally with approximately 100 mm of tape so that succeeding layers are superimposed one on another. Leave at least 12 mm at each end of the copper rods clear of tape.

NOTE Tapes above 50 mm in width should be slit to allow the copper rods to be bare at each end for the required 12 mm.

Apply the tape to the first rod, adhesive side downwards in contact with the copper, and to the second rod, adhesive side upwards with the tape backing in contact with the copper. Leave the third rod bare to act as a control.

Place each rod in a separate glass-stoppered, chemically cleaned glass tube and maintain them at a temperature of $(100 \pm 2) ^\circ\text{C}$ for 16 h. Take the rods out of the tubes after they have cooled to room temperature.

Remove the tapes, together with any exudations that may have occurred, from the rods. Removal of exudation may be assisted by the use of a solvent but no mechanical abrasive aids shall be employed.

Visually examine the copper rods for signs of blue-black staining, characteristic of copper sulfide. If blue-black staining of the test rods is more intense or extensive than that of the control rod, such staining is an indication of the presence of corrosive sulfur.

7.5.4 Report

Report whether blue-black staining of the test rods is greater than that of the control rod.

7.6 Insulation resistance method

7.6.1 General

The test shall be performed in accordance with the requirements of Clause 14 of IEC 60426 with the following exceptions.

7.6.2 Test specimens

Samples shall be taken from the roll at intervals of not less than 300 mm.

7.6.3 Electrodes

The electrodes shall have corners rounded to 1 mm radius and shall be constructed from an inert high conductivity metal, e.g. nickel-plated brass.

7.6.4 Equipment

A means for measuring resistance up to $10^6 \text{ M}\Omega$ ($1 \text{ T}\Omega$) to an accuracy of $\pm 20\%$ shall be used. Screened leads, with the screens connected to the guard circuit, should be used for all connecting purposes.

7.6.5 Results

For tapes less than 25 mm in width, calculate the resistance in $\Omega/25 \text{ mm}$ assuming that resistance is inversely proportional to width.

7.7 Visual method

The test shall be performed in accordance with the requirements of Clause 3 of IEC 60426.

7.8 Wire tensile strength method

7.8.1 General

The test shall be performed in accordance with the requirements of Clause 9 of IEC 60426 with the following exception.

7.8.2 Test specimens

At least ten specimens shall be tested.

7.8.3 Tensile strength of test wire

The mean value of the breaking load for unexposed wire must be in the range of 7 N to 9 N.

7.8.4 Cleaning of apparatus

Metal parts shall be cleaned with pure, clean methanol followed by distilled water.

7.8.5 Tensile test equipment

The rate of grip separation shall be the same for the test on exposed and unexposed wires.

8 Tensile strength and elongation at break

8.1 Apparatus

As described in Clause 5 of ISO 527-3.

8.2 Test specimens

Cut five strips of tape, each of sufficient length to give the required initial test length, from the sample roll at intervals of not less than 300 mm. For tapes having an elongation at break of 50 % or less, the initial test length shall be 200 mm. For tapes having an elongation >50 %, the test length shall be 100 mm.

The width of the test piece shall be equal to or less than 50 mm.

In the case of tapes wider than 50 mm, cut the test pieces out of the middle of the tape to a width of 25 mm, using a sharp tool to produce clean-cut edges. For tapes less than 6 mm wide, edge effects can have a significant effect on these determinations. For tapes below this width the results should not be used for specification purposes.

8.3 Procedure

Insert the test specimens into the equipment so that the load is applied evenly across the width of the tape. The test shall be carried out at (300 ± 30) mm/min, unless otherwise specified in IEC 60454-3. Different speeds of separation shall be selected from Clause 9 of ISO 527-3. Make five valid determinations, disregarding any test in which the break occurs within 10 mm of either grip (or jaw). During the test ensure that the tape does not slip in the grips of the testing equipment.

8.4 Results

Report the breaking strength measurements as the central value of the five determinations in N/10 mm width and the elongation at break as the central value of increase in distance between the grips at the moment of break as a percentage of the original distance between the grips. Where a tape has been cut down from a large width, this shall be reported.

9 Low-temperature properties

9.1 Principle

A copper conductor is covered by the tape under test and then subjected to a flexing procedure after conditioning at low temperature. The specimen is tested for the presence of cracking or unwinding.

9.2 Test specimen

The copper conductor of a 300 mm length of thermoplastic insulated cable (of a type suitable for exposed wiring in wet locations) with a solid conductor approximately 1,6 mm in diameter (giving maximum allowable conductor temperature of 75 °C) shall be bared for 50 mm at the middle. The bared portion shall then be wrapped with 3 layers of tape (using one piece of tape), half-lapped, with the layers extending a minimum of a full lap beyond the bared portion at each end so that the insulation is covered. The tape shall be applied smoothly with a minimum tension in a manner so as to conform to the splice area.

9.3 Procedure

The prepared specimen shall be placed in a cold chamber and conditioned for a period of 3 h at a temperature specified in Table 1. After this conditioning the specimen, while still at the conditioning temperature, shall be subjected to the flexibility test specified in 9.4. Following the flexibility test, the specimen shall be conditioned for 4 h at (23 ± 2) °C and shall withstand, without breakdown, the dielectric strength tests specified in 9.5.

9.4 Flexibility

The taped portion shall be bent 180° around a mandrel having a diameter of 8 mm, and then straightened. This procedure shall be repeated one and a half times, with each bend being made in the reverse direction (see Figure 3). The test shall be completed within 30 s. The layers of tape shall then be examined for cracking and unwinding.

9.5 Electric strength

Following the flexibility test, the bent portion of the specimen shall be immersed, except for the ends, in tap water at (23 ± 2) °C for a period of 1 h (see Figure 4). Then an a.c. voltage of 1 500 V shall be applied for 1 min between the copper conductor and the water. The electrical apparatus is specified in Clause 4 of IEC 60243-1.

9.6 Results

Report any cracking, unwinding or electrical breakdown.

Table 1 – Conditioning for low temperature properties

Low temperature rating of tape °C	Conditioning temperature °C
+10	+3 ± 1
0	-3 ± 1
-7	-10 ± 1
-10	-18 ± 1
-18	-26 ± 1
-26	-33 ± 1
-33	-40 ± 1

10 Resistance to penetration at elevated temperatures

10.1 Apparatus

Any apparatus can be used which detects penetration when a $(1,5 \pm 0,1)$ mm diameter steel ball is pressed under prescribed conditions into the surface of the tape placed on a corrosion-resistant steel plate, 100 mm long by 30 mm wide by 3 mm thick.

An oven capable of raising the temperature of the apparatus at a rate of (30 ± 5) °C/h.

The apparatus described hereinafter (see Figure 5) is an example of an apparatus that gives good results.

A magnetized steel rod, recessed at one end, holds the 1,5 mm diameter steel ball. A new ball shall be used for each determination. This rod is fixed in a C-clamp which further contains a counter-balance and is mounted in such a way that the necessary freedom of rotation exists.

The counter-balance consists of an adjustable rider capable of neutralizing the pressure of the steel ball against the steel plate when there is no load on the lower leg of the C-clamp. In use, the lower leg of this C-clamp is equipped to exert a force of 10 N vertically downwards against the corrosion-resistant steel plate lying in a horizontal plate.

The apparatus is equipped with a device to indicate electrical contact between the steel ball and the steel plate. A low-voltage source of electricity is to be used. The temperature of the steel plate shall be measured at a point as near as possible to the point where the pressure is exerted. The use of a thermocouple is suggested.

10.2 Test specimens

Take five strips of tape, each 25 mm long, from the roll at intervals of not less than 300 mm. Take care to remove the tape from the roll in manner that minimizes stretching. The specimens shall be allowed to relax prior to testing: tapes with elongation <5 % shall be allowed to relax for at least 5 min, tapes with elongation 5-50 % shall be allowed to relax for at least 30 min and tapes with elongation >50 % shall be allowed to relax for 2 h to 3 h.

10.3 Procedure

With no load on the penetration sphere, each specimen shall be placed smoothly on the steel plate (not pressed on and not rolled on) under the sphere at room temperature with the adhesive surface facing the steel plate. Place the apparatus cautiously in the oven. Allow the sample to dwell for 10 min at (23 ± 2) °C and then load the sphere, so that a compressive load of 10 N is exerted on the specimen. The temperature of the apparatus shall then be raised at a uniform rate of (30 ± 5) °C/h until penetration occurs.

10.4 Results

Report the central value as well as the maximum and minimum values of the five measured temperatures at penetration in degrees Celsius.

11 Adhesion

11.1 Principle

A length of adhesive tape is applied to a standard plate (see Figure 6), which is then fixed vertically in one clamp of a tensile testing machine. The other clamp of the machine pulls the free end of the adhesive tape at an angle of 180° to the plate (see Figure 7).

The adhesive strength is measured by the force required to peel the adhesive tape continuously from the plate (see 11.1.1 Test method A), or from the backing of the tape (see 11.1.2 Adhesion to backing), the line of separation being perpendicular to the direction of the applied force.

11.1.1 Test Method A – Single-coated tapes, peel adhesion at 180° angle – A strip of tape is applied to a standard test panel (or other surface of interest) with controlled pressure. The tape is peeled from the panel at a 180° angle at a specified rate, during which time the force required to effect peel is measured. This method is consistent with the method contained in EN 1939:2003.

11.1.2 Test Method B – Adhesion to backing, single-coated tapes – A strip of the tape under test is applied to a rigid panel. A strip of the tape under test is applied to the backing of the first strip and tested for peel adhesion as described in Method A.

11.2 Materials

11.2.1 Absorbent cleaning material

Surgical gauze, cotton wool or tissue. To be suitable, materials must be lint free during use, absorbent, contain no additives that are soluble in the solvents listed in 11.2.2 and made exclusively from virgin materials.

11.2.2 One or more of the following solvents

Diacetone alcohol, non-residual grade

Methanol;

Methyl ethyl ketone;

Acetone;

n-heptane.

Solvents shall be of general-purpose chemical grade and held in a suitable dispensing system.

11.3 Apparatus

11.3.1 Test piece cutter

An appropriate test piece cutter shall hold two single edge razor blades in parallel planes a precise distance apart, to form a cutter of exact specimen width; two cutters, 12 mm and 24 mm cutting width, shall be available or appropriate alternatives which will not cause edge damage. The precision on the razor blade separation shall be the nominal width $\pm 0,10$ mm.

11.3.2 Tensile testing machine

A constant rate of extension (CRE) tension tester shall be used. It is proposed to use an electronic machine taking at least one reading per millimetre of tape peeled. The tester shall have two clamps with centres in the same plane, parallel with the direction of the motion on the same plane, parallel with the direction of the motion on the stressing clamp and so aligned that they will hold the specimen wholly in the same plane; a means of moving the stressing clamp at a uniform rate of 5 mm/s $\pm 0,2$ mm/s and a device for recording load. The instrument shall be calibrated in such a way that a maximum error of 2 % is allowed on the reading.

11.3.3 Stainless steel panels

These shall be perfectly flat, at least 125 mm long and 50 mm wide and at least 1,1 mm thick, stainless steel type 1.4301 in accordance with the 2 R quality defined in EN 10088-2, having a bright annealed finish with a surface roughness of $50 \text{ nm} \pm 25 \text{ nm}$. Panels showing stains, discoloration or many scratches are not acceptable. New panels shall be cleaned prior to use as described in NOTE 1 to 11.5.2 except with ten washes of the final solvent. Between uses, the panel test surface shall be protected from scratches and contamination.

11.3.4 Mechanical or hand-operated roller

The roller used for all adhesion tests is as described in Annex A (normative).

11.3.4.1 A steel roller ($85 \pm 2,5$) mm in diameter and ($45 \pm 1,5$) mm in width, covered with rubber approximately 6 mm in thickness, having a Shore A durometer hardness of 80 ± 5 . The surface shall be a true cylinder, void of any convex or concave deviations. The mass of the roller shall be ($2 \pm 0,1$) kg.

11.3.4.2 No part of the apparatus shall increase the mass of the roller during use. The roller shall move either mechanically or by hand at the rate of ($10 \pm 0,5$) mm/s.

11.4 Test samples and test pieces

11.4.1 Conditioning

Condition the sample rolls of tape in the standard conditions of $23 \text{ °C} \pm 1 \text{ K}$ and (50 ± 5) % RH. Test at these conditions, unless otherwise specified in IEC 60454-3. If these tolerances cannot be maintained, the closest possible tolerances shall be used and these revised tolerances quoted in the report.

11.4.2 The test piece shall be 24 mm wide. A tolerance of a 0,5 mm shall be allowed. The length shall be approximately 300 mm.

NOTE Where the width of the specimen is less than 24 mm, apply one or more additional strips of the tape to give an equivalent width of 24 mm for rolling purposes. Alternatively acceptable rolling pressure may be obtained with a 1 kg roller on samples with width 8,5 mm – 17 mm or with 2 kg roller on samples with widths greater than 17 mm to a maximum of 34 mm.

11.4.3 Discard at least three but no more than six outer wraps of tape from the sample roll before taking the test pieces for testing.

11.4.4 Remove one test piece for each of the five tests to be performed. Remove the test piece from a freely rotating roll at the rate of 500 mm/s to 750 mm/s. Where high unwind force makes it impossible to remove the test piece at the prescribed rate, remove it at a rate as close to 500 mm/s as possible.

11.4.5 When the tape is wider than 24 mm, test pieces of the widest specified width are to be cut with an apparatus as described in 11.3.1 from the centre of a strip removed from the roll in accordance with 11.4.4.

11.4.6 Apply the test pieces within 5 min after unwinding.

NOTE double-sided tapes shall be tested by removing the interleaving material and covering the adhesive surface, not to be tested, with 23 µm polyester film.

11.5 Procedure

11.5.1 Standard test conditions

Standard test conditions shall be the same as in 11.4.1 for test pieces and test samples conditioning.

11.5.2 Preparation of the panel

Dispense one of the solvents listed in 11.2.2 on to the panel, wiping it to dryness with fresh absorbent cleaning material. Repeat for a total of three washes with this solvent.

Final wipe shall be with methyl ethyl ketone or acetone. The panel should be allowed to dry for at least 10 min. Panels not used within 10 h should be re-cleaned.

NOTE 1 In order to obtain consistent results, a new panel shall be wiped at least ten times with final solvent before use.

NOTE 2 Discard plates showing stains, discoloration, or many scratches. Avoid contacting panel surface with fingers. During storage panel should be protected from damage or contamination.

11.5.3 Peel adhesion

11.5.3.1 Remove a 300 mm test piece of the tape to be tested, as described in 11.4.4. Fold 12 mm at one end, adhesive-to-adhesive to form a tab. Touch the other end of the test piece to an end of the test panel. Holding the tab end of the test piece so that it does not make contact with the panel but is positioned loosely above it, roll mechanically or by hand twice in each lengthways direction, causing the roller to apply the tape to the panel. This prevents entrapment of air between the adhesive and the panel. Should this occur, discard the test piece.

Individually prepare each test piece and test within 1 min.

NOTE Longer dwell time will give different results. Peel adhesion increases with dwell time at different rates for various tapes. A longer dwell time may be chosen purposely.

11.5.3.2 Stripping the test piece. Double back the folded end of the tape at an angle of 180° and peel 25 mm of the tape from the panel. Clamp that end of the panel into one of the jaws of the tensile testing machine and the tape into the other jaw. Operate the tester at $(5,0 \pm 0,2)$ mm/s.

After the movable jaw is started in motion disregard the values obtained while the first 25 mm of tape are mechanically peeled. Use the average force obtained, during peeling of the next 50 mm of adhesive tape from the panel, as the adhesion value.

NOTE The tester should know that by prolonged handling, heat is transmitted to the stainless steel test panel. Therefore during and after application of the adhesive tape to the test panel, the panel should be handled as little as possible.

11.6 Expression of results

11.6.1 General

Express the peel adhesion in Newtons per 10 mm (to the nearest 0,1 N/10 mm), if necessary first converting the observed force to Newtons.

11.6.2 Test report

The test report shall include the following information:

- a) a reference to this standard;

- b) statement that this test method was used and indicating if the test was performed on the panel (test method A) or on the backing (test method B) and indicating any deviations from the method as written;
- c) identification of each roll of tape tested;
- d) anomalous behaviour during testing (such as adhesive transfer or splitting);
- e) peel adhesion value in Newtons per 10 mm.

12 Adhesion to backing at low temperatures

12.1 Test specimens

Use the same type of specimen as described in 11.4.4, but the number of specimens shall be three.

An additional three strips are needed to serve as backing.

12.2 Procedure

Before the specimens are applied to the plate as described in 11.5.3.1, the three plates and the six strips shall be stored for 2 h in a low-temperature environment at the temperature prescribed in IEC 60454-3. The roller shall be at the same temperature. Storage of the roller may need a longer time at the prescribed temperature, due to its mass. The specimens shall be applied to the plate under the same low-temperature conditions. Use the same method of application as described under 11.5.3.1. Leave the prepared plates for 16 h to 24 h in the low-temperature environment. Proceed with stripping according to 11.5.3.2 in the low-temperature environment.

12.3 Results

Record the results for each of the three test specimens and treat them as in 11.6.1.

13 Shear adhesion to backing after liquid immersion

13.1 Apparatus

A tensile testing machine as described in Clause 5 of ISO 527-3.

A roller as from Annex A.

13.2 Test specimens

Out of each of five rolls, two strips 150 mm in length are removed from the roll by pulling radially, at a rate of approximately 300 mm/s, at intervals of 300 mm. The width of the strip to prepare a test specimen shall be (12 ± 1) mm.

If the width of the tape is greater than 12 mm, the specimen shall be cut out of the middle of the tape to a width of 12 mm.

The specimen shall be cut with a sharp tool to avoid tearing at the edges.

Five test specimens are formed by pressing the adhesive side of one strip to the back of the other strip in such a way that a 12 mm overlap is formed on the 12 mm width strip. There shall be no visual lateral offset of the strips. Lay the specimens, adhesive side down, on a firm, easy-release surface. Place the roller centrally across the specimen and pass it (taking care not to apply any additional pressure) by hand at a constant speed, four times over the specimen, twice in each direction, at a rate of 10 mm/s.

13.3 Procedure

In the case of thermosetting tapes, the test specimens are cured according to the instructions of the manufacturer. These conditions shall be reported. The specimens are then cooled to $(23 \pm 2) ^\circ\text{C}$ and stored at that temperature for $(16 \pm 0,5)$ h in the liquid specified in the relevant sheet of IEC 60454-3. Then, the test specimens are blotted between filter papers to remove adhering liquid. Determine the apparent breaking strength of each test specimen in accordance with 8.3. Determinations are to be completed at least 5 min and not more than 10 min after removal from the liquid.

13.4 Results

Report:

- a) the central value of the five measurements and the minimum and the maximum shearing loads in Newtons;
- b) the liquid in which the specimen has been immersed;
- c) the curing conditions, if applicable.

14 Curing properties of thermosetting adhesive tapes

14.1 Bond separation during thermal treatment (adhesive to backing)

14.1.1 Apparatus

- A roller as from Annex A.
- A clean, flat, metal or glass plate approximately 600 mm × 200 mm.
- Weights having a mass of (50 ± 1) g provided with clamps.

14.1.2 Test specimens

Six strips 150 mm in length are removed from the roll by pulling radially, at a rate of approximately 300 mm/s, at intervals of 300 mm.

If the width of the tape is greater than 12 mm, the specimen shall be cut out of the middle of the tape to a width of 12 mm. The specimen shall be cut with a sharp tool to avoid tearing at the edges.

Three test specimens are formed by lightly pressing the adhesive side of one strip to the back of another strip in such a way that an overlap is formed of 12 mm × 12 mm with a tolerance of +1 mm. Without the application of additional pressure, pass the roller twice backwards and forwards over the joint at a speed of approximately 10 mm/s.

14.1.3 Procedure

A weight of 50 g is attached to each of the test specimens, which are then suspended freely in an oven at the temperature specified in IEC 60454-3. The test is considered satisfactory if, at the end of 20 min, there has been no complete bond separation.

14.1.4 Results

Report the number of passes or failures.

14.2 Bond separation after thermal treatment (adhesion to backing)

14.2.1 Apparatus

- A roller as from Annex A.

- A clean, flat, metal or glass plate approximately 600 mm × 200 mm.
- Weights having a mass of (500 ± 10) g provided with clamps.

14.2.2 Test specimens

Three test specimens prepared as for 14.1.2.

14.2.3 Procedure

The three specimens are suspended freely in an oven at the temperature and for the time specified in IEC 60454-3. Remove the assemblies from the oven after the specified time and allow them to cool for 5 min. Then attach a mass of 500 g to each test specimen and place them in the oven. (The time and temperature are normally those recommended by the manufacturer for curing the tape.)

Before being attached, the weights shall have been stored in the oven at the prescribed temperature for sufficient time to ensure temperature equilibrium of the weights and the oven.

Immediately after the attachment of the weights, the oven is closed and the 20 min period starts.

At the end of the 20 min period, it is noted whether or not the weight is still suspended by the specimen.

14.2.4 Results

Report the number of passes or failures.

15 Flagging tests

15.1 Principle

Flagging is the lifting of an exposed end of a wrapping of tape after application of the method described and subsequent test conditioning, thus forming a flag or tab tangential to the contour of the wrap, or a partial or complete unwinding.

15.2 Apparatus

A simple winding jig designed to hold a rod at each end with a means of rotating the rod so that the test specimen is wound thereon. The winding jig should be attached to a rigid support with the rod held in a horizontal position.

Rods of any suitable metal or glass of 6 mm nominal diameter or any other diameter as specified in relevant sheets of IEC 60454-3.

Suitable attachable masses.

A suitable method of measuring 2 mm to the nearest 0,5 mm.

15.3 Test specimens

Three strips of tape at least 100 mm long are removed from the roll by pulling radially, at a rate of approximately 300 mm/s, at intervals of 300 mm.

If the width of the tape is greater than 19 mm, the specimens shall be cut out of the middle of the tape to a width of 12 mm. The specimen shall be cut with a sharp tool to avoid tearing the edges.

NOTE It is important to protect the adhesive surface from dust and to avoid touching it with the fingers or any other foreign body.

15.4 Preparation of specimens for test

A rod of 6 mm in diameter, unless otherwise specified in IEC 60454-3, is mounted in a horizontal position on the jig. A mass in the ratio of (100 ± 2) g to 3 mm tape width, for example 300 g for 9 mm width, is attached to one end of the tape specimen. The tape is held by the other end so that it is vertical and the adhesive side is brought into contact with the side of the rod (see Figure 8a). The rod is rotated through 90° until the original point of contact A of the tape with the rod is at the top (see Figure 8b). The tape is cut with a sharp tool at this point and the mass left suspended.

The rod is then rotated one complete turn. The mass is removed and the tape cut at D by placing a sharp tool tangentially to the rod (see Figure 8c) and tearing the tape against the rod. This gives an overlap of a quarter turn (see Figure 8d).

15.5 Test conditions

15.5.1 Conditioning

The prepared specimen shall be conditioned in the vertical position for 7 days at (23 ± 2) °C and (50 ± 5) % relative humidity.

15.5.2 Curing properties of thermosetting tapes

The prepared specimens shall be conditioned in the vertical position at the temperature and for the time prescribed by the manufacturer or as specified in IEC 60454-3.

15.5.3 Resistance to immersion in liquids

The prepared specimen, cured if necessary, shall be totally immersed in the vertical position in the liquid specified in the relevant sheet of IEC 60454-3 for 15 min at (23 ± 2) °C. After removal from the prescribed liquid, specimens should be allowed to dry before measuring the unwound length.

Thermosetting tapes shall be cured for the time and at the temperature prescribed and shall be allowed to cool to (23 ± 2) °C before immersion in the liquid.

15.6 Results

The flag, for example the length of tape unwound (see Figure 8d) shall be measured to the nearest 1 mm. Should uneven flagging occur, the greatest distance is measured.

The central value of the three readings shall be recorded as the amount of flagging. Report the diameter of the rod. Report the liquid used.

16 Water vapor permeability

16.1 Apparatus

A box made of non-corrodible metal, with external dimensions of approximately 95 mm × 25 mm × 20 mm and weighing not more than 90 g when empty, which is closed completely except for a centrally placed rectangular 80 mm × 10 mm opening in the top, and the inside of which is coated with a suitable glazed lacquer.

16.2 Test specimens

A strip of tape from the sample roll, of sufficient length to cover the top of the apparatus.

16.3 Procedure

Place $(5 \pm 0,2)$ g of granular anhydrous calcium chloride in the box, of a size such that they just pass a mesh approximating to a 2,00 mm sieve and are retained on a 600 μ m sieve, both complying with the requirements of ISO 2194.

Press the test piece down firmly over the top of the box so that the opening is fully covered. (If the tape under test is less in width than the top of the box, press supplementary strips of tape on to the top of the box at each side of the first specimen, so as to cover the box completely and overlap lengthways the first specimen by 2 mm. Ensure that the edges of the first specimen are sealed by running a fingernail along the supplementary strips on the line of the edges of the original strip.) Trim off any tape overlapping the top of the box.

Weigh the sealed box to $\pm 0,005$ g. Place it in a humidity cabinet and maintain it in an atmosphere of (90 ± 2) % relative humidity and at a temperature of $(38 \pm 0,5)$ °C.

After 24 h, remove the box from the cabinet, allow to cool, wipe off any adherent moisture with a clean cloth and reweigh it.

16.4 Results

From the water vapor permeability per 24 h per 8 cm² of tape thus determined, calculate and report the permeability in grams per square meter per 24 h.

17 Electric strength

17.1 General

This test shall be carried out according to IEC 60243-1 using the electrodes in accordance with 4.1.2 of that standard.

17.2 Test specimens

Five strips approximately 300 mm long taken at intervals of not less than 300 mm.

17.3 Procedure

According to Clause 9 of IEC 60243-1, using a 500 V/s rate-of-rise.

17.4 Results

The test report shall include the following:

- a) average thickness of each test specimen calculated on at least three individual measurements each;
- b) width of the specimen; indication of overlapping the edges, gaskets or dielectric fluid in order to prevent flashover around the edges;
- c) temperature and humidity of conditioning before test; temperature and humidity during tests;
- d) the breakdown voltage at each puncture;
- e) the central value of the five breakdown voltages for each specimen. Arrange the five central values in ascending order and take the central value of these as the breakdown voltage;
- f) electric strength, in kV/mm, calculated from the central value of the breakdown voltage according to e) and the average thickness according to a).

18 Electric strength after humid conditioning

This test is carried out as described in Clause 17 after storage of the test specimens for 24 h in the standard atmosphere of (23 ± 2) °C and (93 ± 2) % relative humidity unless otherwise specified in IEC 60454-3.

19 Resistance to flame propagation

19.1 Principle

The following measurements are made on specimens of definite size and under defined conditions:

- the time elapsing between the instant when the tape specimen catches fire and the instant when it extinguishes itself;
- the length of tape burnt during the test.

19.2 Apparatus

a) A protective device, comprising a rectangular metal box 250 mm x 250 mm and 750 mm high (see Figure 9a). The box shall be open at the top and shall have 12 holes, 12 mm in diameter, uniformly spaced along a horizontal line 25 mm from the base. One vertical side shall be fitted with a sliding glass panel.

- A detachable clip shall be fixed centrally, 30 mm from the top of the box, parallel to the glass panel, to act as a means of attachment for the test specimen so that it can be suspended vertically. If necessary, one of the side walls may be provided with a semi-circular hole, 25 mm in diameter, through which the Bunsen burner hose(s) may be passed (see Figure 9b).
- A sliding horizontal metal tray (diaphragm) may be placed on the box, at 1 cm above the height of the burner. The sliding diaphragm will have a hole, 1,5 cm in diameter which, upon sliding, will coincide with the tip of the cellulose primer in the upper side, and with the burner flame in the lower side, causing ignition of the primer, when opened for a very short time (see Figure 9b).

NOTE The plate is a means of applying the flame for a very short time (see 19.4); the flame can be applied by hand, provided that the flame application remains very short.

- An horizontal metal rod, 2–3 mm in diameter, to serve as support for the specimen, may be placed centrally on the box, parallel to the front wall (sliding glass panel). The position of the rod in the vertical direction shall be such that it allows a minimum of 6 cm of the specimen (which should be with the adhesive side facing the opposite direction) to hang freely below it.

NOTE The utilization of this supporting rod significantly decreases the tendency of the specimen to move during the testing due to the strong convection currents generated by the flame when trying to ignite the cellulose primer. This random movement of the specimen can severely affect the reproducibility of the test since more than one ignition attempt may be required which could result in direct ignition of the tape by the burner flame rather than ignition by the primer as intended in this test.

- b) A stop-watch with an accuracy of $\pm 0,2$ s.
- c) A source of ignition, such as a match or Bunsen burner, equipped with a pilot light flame, which simulates the flame intensity of a lit match.
- d) A primer in the form of an isosceles triangle with base 25 mm and 30 mm high, cut from untreated and uncoated cellulose film with a mass per unit area of 50 g/m² to 60 g/m².

19.3 Test specimen

The test shall be made within 5 min after the removal of the specimens from the roll.

Five test specimens 300 mm in length are removed from the roll by pulling radially, at a rate of approximately 300 mm/s, at intervals of not less than 300 mm.

If the width of the tape is 25 mm or less, the width of the specimen is the width of the tape.

If the width of the tape is greater than 25 mm, the specimen shall be cut out of the middle of the tape to a width of 25 mm. The specimen shall be cut with a sharp tool to avoid tearing at the edges.

Using ink or any other suitable medium, a line perpendicular to the longer sides is drawn 50 mm from one end of the test specimen.

NOTE When testing tapes of widths different than 25 mm, the primer triangle base should be adjusted to match the width of tape. With tapes narrower than 25 mm, different levels of flammability may be obtained.

19.4 Procedure

The apparatus shall be placed during test in a draught-free atmosphere.

The base of the primer is fixed to the adhesive side of the tape at the end of the test specimen from which the 50 mm mark is measured, with a maximum overlap of 5 mm.

The detachable clip is placed at the other end of the test specimen and the whole is then suspended inside the metal box so that the tape hangs freely and vertically. Slightly raise the sliding glass panel and bring the source of ignition to the lower end of the primer. Ignite the primer and quickly lower the sliding panel. If using the Bunsen burner, light the Bunsen pilot light and slide out the metal plate, so that the primer is ignited and the metal plate is slid back into position thus removing the source of flame. As soon as the primer has ignited, the source of flame is removed and the stopwatch started.

19.5 Results

- a) The product is described as "non-ignitable" under the terms of this standard if at least four of the test specimens do not burn at all.
- b) The product is described as "self-extinguishing" if for at least four of the five burning test specimens the length burnt does not exceed 50 mm. Since the burning front on the test specimen will generally not be straight, the length burnt shall be defined as the average across the tape specimen. The central value as well as the maximum and minimum values of the burning times, in seconds, are reported together with the length burnt, in mm, in any one of the five tests.
- c) The product is described as "flammable" if at least four of the five test specimens burn, beyond the 50 mm mark. The definition given in b) for length burnt shall also be applied here. The central value as well as the maximum and minimum values of the five burning times, in seconds, are reported.
- d) Where the product cannot be described under a), b) or c), the individual results for each specimen shall be stated in the test report.

20 Flame test

20.1 Principle

Tape is wound round a steel mandrel and when a flame is applied by the method described, tape marked "flame retardant" shall not flame longer than 60 s following any of five applications of the test flame, the period of application being 15 s.

The flame is successively applied for a period of 15 s and removed for a period of 15 s until five successive applications have been made. In the event of the specimen continuing to flame 15 s after removal of the test flame, the re-application of the flame shall be delayed until the specimen has stopped flaming.

The tape shall not ignite combustible materials or damage 25 % of the indicator flag during, between, or after five applications of the test flame.

NOTE This test is the same as test method of UL 510 (Underwriters Laboratories USA).

20.2 Apparatus

- a) A protective device, comprising a three-sided metal enclosure, 305 mm wide, 355 mm deep and 610 mm high. The top and front of the enclosure are open.
- b) A means of securing the test specimen with longitudinal axis vertical to the centre of the enclosure (see Figure 10).
- c) A gas burner in accordance with 7.11 of ISO 10093, preferably fitted with a gas pilot light (under consideration).

A Tyrell gas burner (which differs from a Bunsen burner in that the air flow as well as the flow of gas is adjustable) with or without a gas pilot light attached to supply the flame. The barrel of the burner shall have an internal diameter of 9,5 mm and shall extend 102 mm above the air inlets. While the barrel is in the vertical position and the burner is well away from the specimen, the overall height of the flame shall be adjusted to approximately 100 mm to 125 mm. The inner blue cone shall be 38 mm high and the temperature at its tip shall be 816 °C or higher as measured using a chromel-alumel (nickel-chromium and nickel-manganese) thermocouple. Without disturbing the adjustments to the height of the flame, the valve supplying gas to the burner and the separate valve supplying gas to any pilot flame shall be closed.

- d) Untreated surgical cotton.
- e) A wedge to which the base of the burner can be secured at an angle of 20° from vertical (see Figure 11).
- f) A steel mandrel, 3,5 mm in diameter and 460 mm long.
- g) A winding jig to support the mandrel at each end in such a manner that the mandrel can be rotated so that the tape can be wound thereon. The winding jig is to be attached to a rigid support in such a manner that it can be rotated, tilting the major axis of the mandrel to the horizontal.
- h) A strip of un-reinforced 94 g/m² Kraft paper, 13 mm wide and approximately 0,1 mm thick.

20.3 Preparation of test specimen

The steel mandrel is supported in a winding jig. A 900 mm length of tape is cut from the roll. The tape is secured, by overlapping the first turn of the tape, to the mandrel held in the horizontal position. A mass of 2 kg ± 20 g is then attached to the free end of the tape to provide tension. After 1 min under tension, the mandrel is slowly rotated, and the fixture tilted so that the tape wraps with an overlap equal to one half the width of the tape. When wrapping is completed, the lower end of the tape is secured and the remaining tape cut off. A second wrapping shall be similarly applied with the direction of advance of the turns reversed from that of the first wrapping. Finally, a third wrapping shall be applied with the direction of advance opposite to that of the second wrapping, giving six thicknesses of tape at each point along the wrapped mandrel.

A strip of Kraft paper, gummed on one side, is to be used as an indicator flag. The gumming is moistened but not more than necessary to facilitate adhesion. With the gum towards the specimen, the strip is wrapped around the specimen once with its lower edge 255 mm above point B, the point at which the inner blue cone of the flame is to touch the specimen. The ends of the strip are pasted together evenly and trimmed to provide a flag that projects 19 mm from the specimen toward the rear of the enclosure (see Figure 10).

20.4 Procedure

The specimen is secured centrally within the enclosure and the lower clamp or support adjusted vertically to keep it from being any closer than 76 mm to point B. The burner is secured on to the wedge and the assembly placed on an adjustable support jig. A layer of untreated surgical cotton, 6 mm to 25 mm thick, is placed on the wedge and around the burner. In the absence of a gas pilot light on the burner, the support for the burner and wedge is arranged so as to enable the burner to be quickly removed from and precisely returned to the position described below. The jig is adjusted towards one side or the other of the enclosure to place the longitudinal axis of the (burner) barrel in the vertical plane that contains the longitudinal axis of the specimen. The plane is parallel to the sides of the enclosure. The jig is also adjusted towards the rear or front of the enclosure to position the point A, which is the intersection of the longitudinal axis of the burner barrel with the plane of the tip of the burner barrel, 38 mm from point B, at which the extended longitudinal axis of the barrel meets the outer surface of the specimen. Point B is the point at which the tip of the blue inner cone of the flame touches the centre of the front of the test specimen.

If the burner has a gas pilot light, the valve supplying the gas to the burner is opened to apply the flame automatically. The valve is held open for 15 s and then closed for 15 s for a total of five applications of the flame. In the event of the specimen continuing to flame 15 s after removal of the test flame, the re-application of the flame shall be delayed until the specimen has stopped flaming.

If the burner does not have a gas pilot light, the burner shall be moved into position to apply the gas flame to the specimen, kept there for 15 s and then removed for 15 s for a total of five applications of the flame. In the event of the specimen continuing to flame 15 s after removal of the test flame, the re-application of the flame shall be delayed until the specimen has stopped flaming.

20.5 Results

The results of this test are judged by the three following criteria, using a 19 mm width tape which is considered representative of the performance of all sizes (widths) of tape.

- a) If the specimen shows less than 25 % of the indicator flag burned or charred (soot that can be removed with a cloth or fingers and brown scorching is to be ignored), does not emit flaming or glowing particles or flaming drops at any time that ignite the cotton on the burner, wedge, or floor of the enclosure (flameless charring of the cotton shall be ignored) and continues to flame less than 60 s after application of the gas flame, the tape shall be judged flame retardant.
- b) If the specimen shows more than 25 % of the indicator flag burned or charred (soot that can be removed with a cloth or fingers and brown scorching is to be ignored) after any of the five applications of flame, the tape is to be judged capable of conveying flame along its length.
- c) If the specimen emits flaming or glowing particles or flaming drops at any time that ignites the cotton on the burner, wedge, or floor of the enclosure (flameless charring of the cotton shall be ignored), the tape is judged capable of conveying flame to combustible materials in its vicinity.

21 Thermal endurance

21.1 Determination of thermal endurance (based on IEC 60216-1 and IEC 60216-2)

The specification for individual tapes given in IEC 60454-3 shall specify which of the following methods is to be used, together with the end-point criterion and state that, when required by the purchaser, the manufacturer shall certify that the pressure sensitive adhesive tape has been made using the materials and processes that have been shown to give a product which will meet the requirements specified.

The described method is based on successful experience in some countries. Therefore, this method might be considered as a starting-point for the development of improved procedures. If evidence of such improvements can be shown and adequate data is available, they might be given ultimately in the specification sheets of IEC 60454-3.

21.2 Voltage breakdown

21.2.1 Test specimens

The width of tape to be used shall be in the range of 12 mm to 25 mm. Preferably a width of 25 mm shall be used.

Test specimens of tapes to be tested are prepared by wrapping the tapes spirally around clean brass (or copper for temperatures up to 150 °C, or stainless steel for temperatures above 200 °C) rods 8 mm in diameter over a length of 200 mm with overlap slightly less than 50 %. The rod should be sufficiently long so that one end may be left unwrapped and used for making an electrical connection.

Wrapping is to be done with adequate tension for the tape to conform smoothly to the rod.

Immediately after wrapping, thermosetting tapes shall be cured in accordance with the manufacturer's instructions.

The number of test specimens shall be not less than five for each test interval at each exposure temperature.

21.2.2 Procedure

The oven to be used shall be in accordance with 5.6 of IEC 60216-1.

Put the test specimens – the wrapped rods – vertically into the oven, the unwrapped end of the rods pointing downwards.

Instructions regarding exposure temperatures and time cycles are given in 5.5 of IEC 60216-1, and exposure temperatures for various types of pressure-sensitive adhesive tapes are given in IEC 60454-3. Since voltage breakdown is a destructive test method, the total number of specimens will depend on the number of test intervals necessary to exceed the end-point criterion. At the end of each test interval, specimens to be tested are removed from the oven and kept at room temperature for approximately 2 h.

As specified in IEC 60454-3, a conductive paint or a metal foil at the central portion of the test specimen will serve as one electrode having a length of 100 mm; the second connection will be applied to the unwrapped part of the rod.

In accordance with 9.1 of IEC 60243-1, an alternating current of 48 Hz to 62 Hz is applied. The voltage shall be raised at a uniform rate of 500 V/s (if not otherwise specified in the IEC 60454-3 sheet) until breakdown occurs.

21.2.3 Evaluation

Select the central value of five measured values for each exposure temperature and each test interval.

Prepare a graph in accordance with the instructions of 7.6.1 of IEC 60216-1 and determine, as in Figure 1 of IEC 60216-1, the exposure time for each exposure temperature. The crossing-points for the three different exposure temperatures are read as the times to failure.

Establish the thermal endurance graph in accordance with the instructions of 7.6.2 and Figure 4 of IEC 60216-1, by a graphical treatment of the results or, alternatively, by the method in accordance with Clauses 6 and 7 and relevant subclauses of IEC 60216-3. Deduce the temperature index from the graph at 20 000 h (IEC 60216-1).

21.3 Loss of mass

21.3.1 Specimens

Take 15 tape specimens having a preferred length of 100 mm and a preferred width of 25 mm. To establish the initial mass, the specimens shall be maintained (unless otherwise specified in the relevant sheet of IEC 60454-3) for 48 h at (23 ± 2) °C and (50 ± 5) % relative humidity; the mass is then determined with an accuracy of 0,1 mg. Precautions shall be taken to exclude the mass of the supporting means.

21.3.2 Procedure

For each of the three temperatures, five specimens are placed in a vertical position in each oven kept at one of the three temperatures specified in the relevant sheet of IEC 60454-3.

The ovens shall be as described in 21.2.2.

The specimens are suspended freely on a light metal frame, inside a test tube, where necessary. (The test tube is used to prevent specimens sticking together as a result of movement in air currents.)

Since loss of mass is a non-destructive test, test intervals may be adjusted according to 5.5 of IEC 60216-1. It may be useful to check the change in weight after a period of 7, 14, 28, 56 or more days, when ageing is carried out at the lowest exposure temperature. The test intervals at different temperatures shall be chosen accordingly.

After each test interval, remove the test specimens from the oven (and from the test tube if used), and maintain them for 2 h in an atmosphere of (23 ± 2) °C and (50 ± 5) % relative humidity; the mass is then determined with an accuracy of 0,1 mg. Continue ageing the specimens until the end-point, as specified in the relevant sheet of IEC 60454-3, is reached.

21.3.3 Evaluation

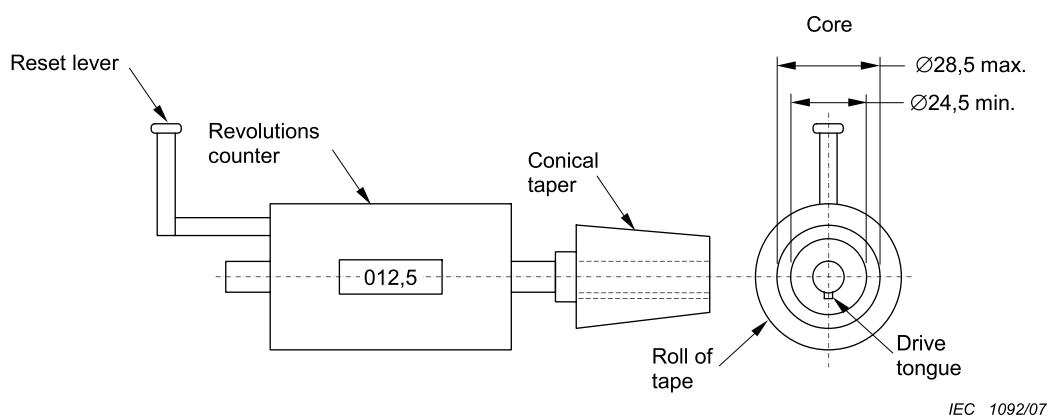
Convert the individual results obtained into the respective loss of mass as follows:

$$\text{loss of mass} = \frac{(\text{initial mass} - \text{mass after ageing})}{\text{initial mass}} \times 100 \%$$

Select the central value of the five measured values for each exposure temperature and each test interval.

Prepare a graph in accordance with the instructions of 7.6.1 of IEC 60216-1 and determine, as in Figure 1 of IEC 60216-1, the exposure time for each exposure temperature. The crossing-points for the three different temperatures are read as the times to failure.

Establish the thermal endurance graph in accordance with the instructions of 7.6.2 and Figure 4 of IEC 60216-1, by a graphical treatment of the results or, alternatively, by the method in accordance with Clauses 6 and 7 and relevant subclauses of IEC 60216-3. Deduce the temperature index from the graph at 20 000 h (IEC 60216-1).



Dimensions in millimetres

Figure 1 – Measuring device for determination of roll length of tape (measurement of turns method)

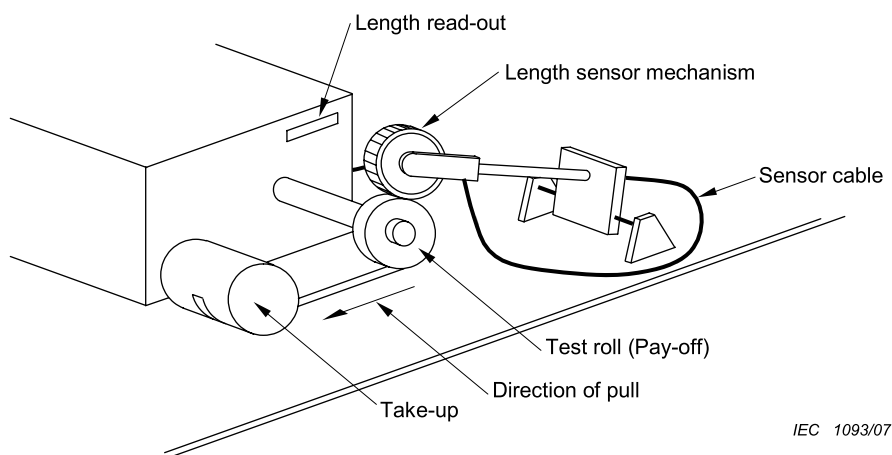


Figure 2 – Measuring device for determination of roll length of tape (length sensor method)

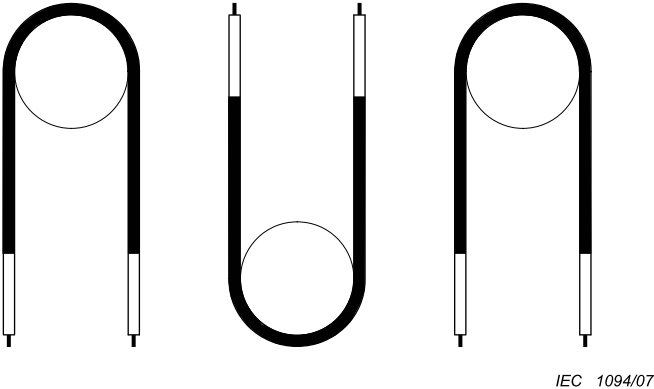


Figure 3 – Sequence of bends

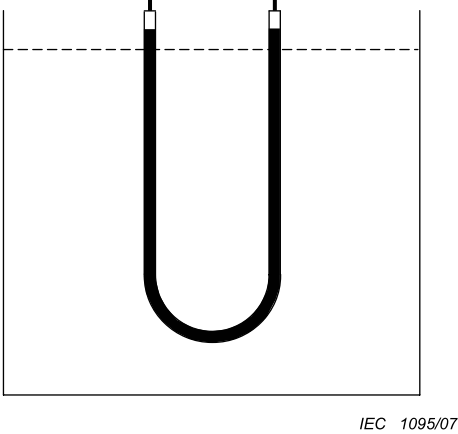
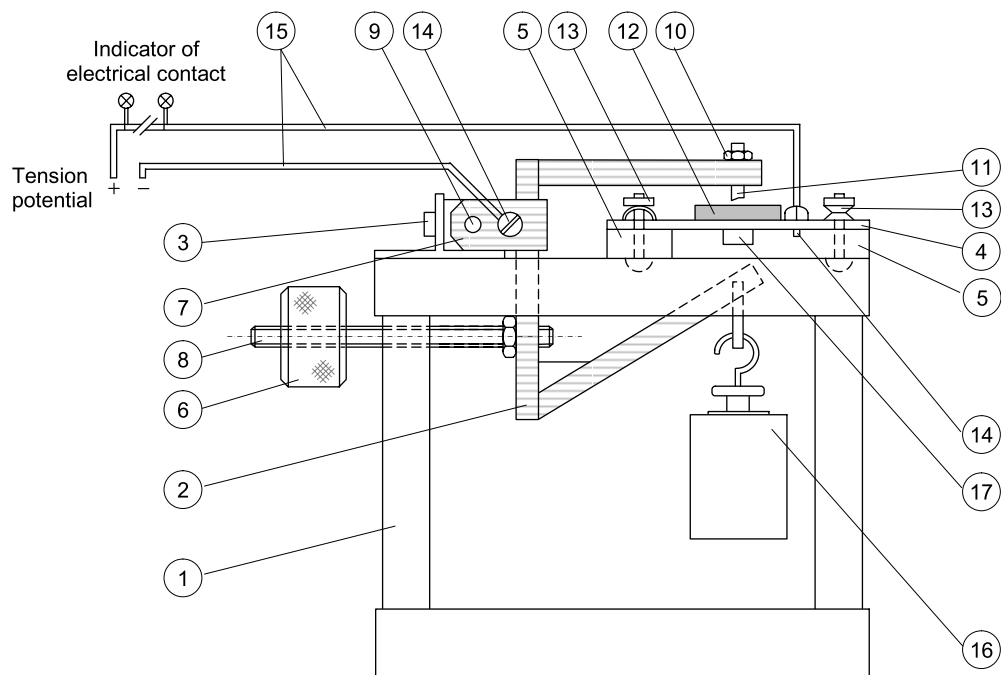


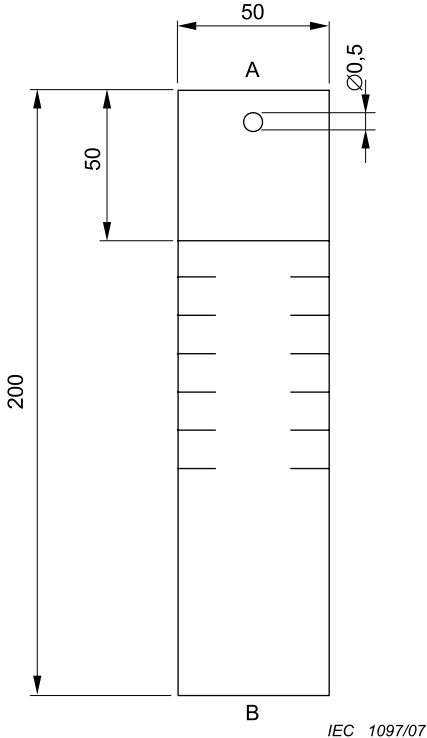
Figure 4 – Dielectric strength test in water



IEC 1096/07

- 1 Frame – steel
- 2 Pivot arm – steel
- 3 Screw holding pivot block to frame – steel
- 4 Plate-stainless steel (easily removable)
- 5 Insulating blocks – phenolic laminate – No electrical contact between plate and frame
- 6 Knob to balance pivot arm with weight removed – steel
- 7 Pivot block – steel
- 8 Pivot pin to adjust knob 6 – steel
- 9 Stud + nut – thread size to match adjusting knob (6)
- 10 Nut and mounting rod – steel
- 11 1,5 mm stainless steel ball affixed to mounting rod
- 12 Tape or film specimen to be tested
- 13 Studs to facilitate removal of stainless steel plate
- 14 Screws for making electrical connections
- 15 Electrical leads to outside of oven
- 16 1000 g weight
- 17 Hole for the thermocouple

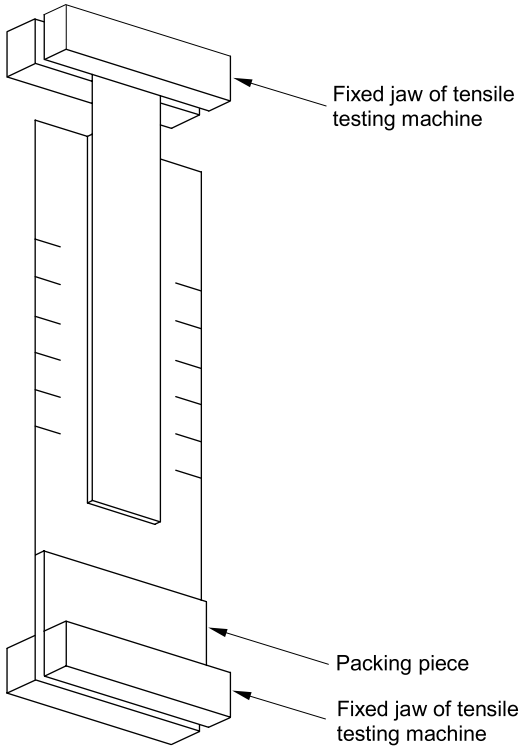
Figure 5 – Sketch of penetration tester



IEC 1097/07

Dimensions in millimetres

Figure 6 – Steel test plate



IEC 1098/07

Figure 7 – Arrangement for stripping the tape from the plate

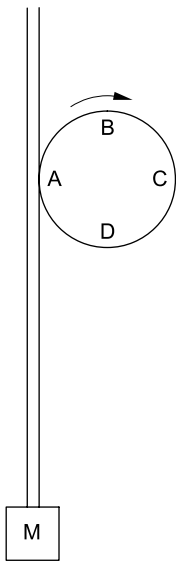


Figure 8 a)

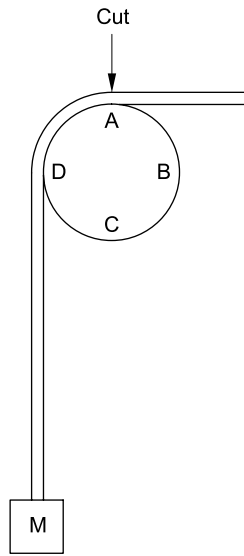


Figure 8 b)

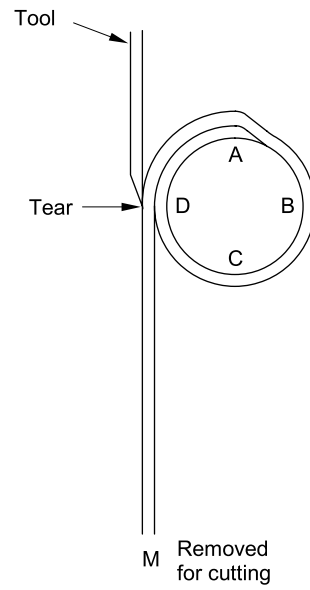


Figure 8 c)

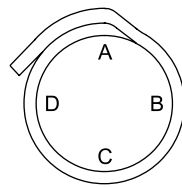
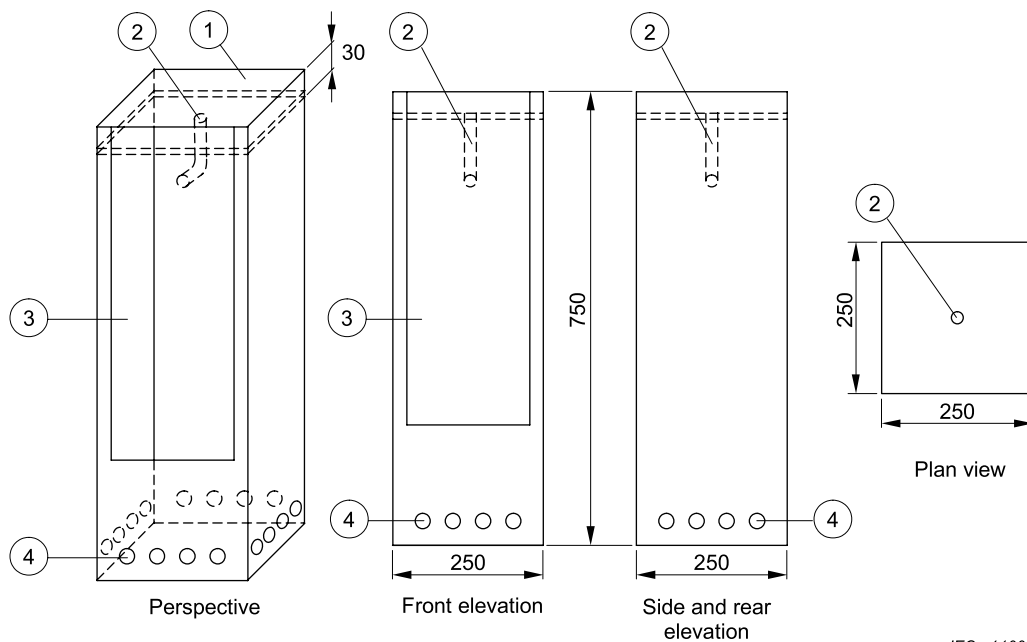


Figure 8 d)

IEC 1099/07

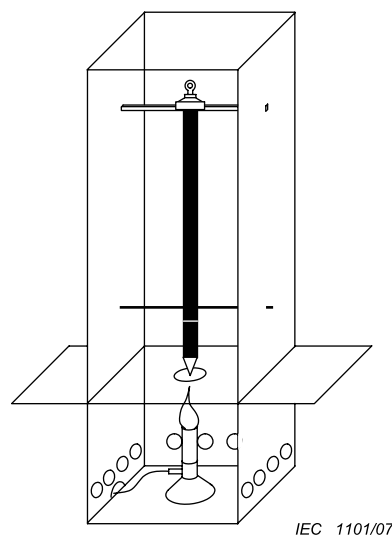
Figure 8 – Flagging test – Preparation of test specimen



IEC 1100/07

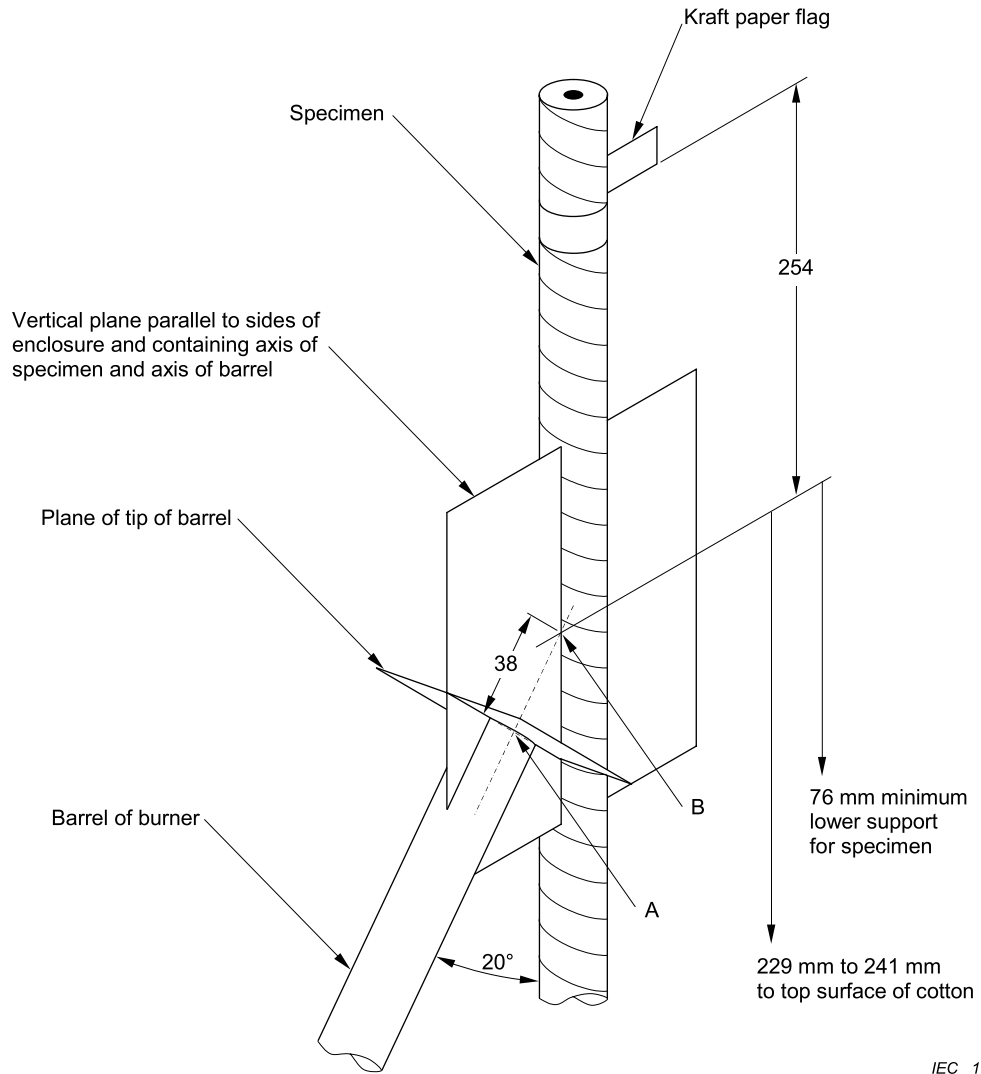
Dimensions in millimetres

- 1 Open side
- 2 Movable clip placed at the centre 30 mm below the upper edges
- 3 Sliding window
- 4 12 mm holes uniformly distributed around the four sides along a horizontal line at a height of 25 mm from the base

Figure 9a – Draught protection device

IEC 1101/07

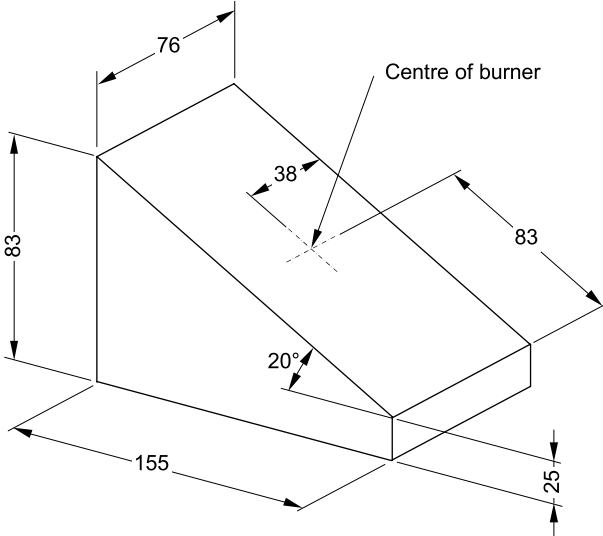
Figure 9b – Use of Bunsen burner and sliding plate with draught protection device**Figure 9 – Flame test enclosures**



IEC 1102/07

Dimensions in millimetres

**Figure 10 – Essential dimensions for flame test
(proportions exaggerated for clarity of details)**



IEC 1103/07

Dimensions in millimetres

Figure 11 – Dimensions of wedge

Annex A
(normative)

Rollers to be used in various tests

The roller to be used shall be:

A steel roller ($85 \pm 2,5$) mm in diameter and ($45 \pm 1,5$) mm in width, covered with rubber approximately 6 mm in thickness, having a Shore A durometer hardness of 80 ± 5 . The surface shall be a true cylinder, void of any convex or concave deviations. The mass of the roller shall be ($2 \pm 0,1$) kg.

No part of the apparatus shall increase the mass of the roller during use.

The roller shall move either mechanically or by hand at the rate of ($10 \pm 0,5$) mm/s.

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ISO 683-13:1986, *Heat-treatable steels, alloy steels and free-cutting steels – Part 13: Wrought stainless steels* (withdrawn standard)

EN 10088-2:2005, *Stainless steels*

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