

INTERNATIONAL STANDARD



**Plastic films for electrical purposes –
Part 3: Specifications for individual materials – Sheet 1: Biaxially oriented
polypropylene (PP) films for capacitors**



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IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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polypropylene (PP) films for capacitors**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

PLASTIC FILMS FOR ELECTRICAL PURPOSES –

**Part 3: Specifications for individual materials –
Sheet 1: Biaxially oriented polypropylene (PP) films for capacitors**

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 60674-3-1:1998+AMD1:2011 CSV. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC 60674-3-1 has been prepared by IEC technical committee 15: Solid electrical insulating materials.

This second edition cancels and replaces the first edition published in 1998 and Amendment 1:2011. This edition constitutes a technical revision.

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

- a) this document has been completely revised editorially and technically and included in the IEC 60674 series of standards;
- b) the test methods have been updated to reflect today's state of the art.

The text of this International Standard is based on the following documents:

Draft	Report on voting
15/909/CDV	15/925/RVC

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under 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.

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INTRODUCTION

This standard is one of a series which deals with plastic films for electrical purposes. The series will consist 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).

This standard contains one of the sheets comprising Part 3, as follows:

Sheet 1: Biaxially oriented (PP) polypropylene films for capacitors.

PLASTIC FILMS FOR ELECTRICAL PURPOSES –

Part 3: Specifications for individual materials – Sheet 1: Biaxially oriented polypropylene (PP) films for capacitors

~~1~~ General

1 Scope

This sheet of IEC 60674-3 gives the requirements for biaxially oriented polypropylene film having a smooth or rough surface, corona treated when required for vacuum metallization. The films are for use as dielectric in capacitors.

Materials which conform to this specification meet established levels of performance. However, the selection of a material by a user for a specific application ~~should be~~ is based on the actual requirements necessary for adequate performance in that application and not based on this specification alone.

Safety warning: It is the responsibility of the user of the methods contained or referred to in this document to ensure that they are used in a safe manner.

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 60674-1:1980, *Specification for plastic films for electrical purposes – Part 1: Definitions and general requirements*

IEC 60674-2:~~1988~~2016, *Specification for plastic films for electrical purposes – Part 2: Methods of test*

~~IEC 61074:1991, *Determination of heats and temperatures of melting and crystallization of electrically insulating materials by differential scanning calorimetry*~~

~~ISO 534:1988, *Paper and board – Determination of thickness and apparent bulk density or apparent sheet density*~~

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

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

4 Classification

The polypropylene film shall be of the following types:

- Type 1: having smooth surfaces (space factor <5 %, see 8.9);
- Type 1a: not corona treated;
- Type 1b: one side pre-treated to facilitate the vacuum deposition of metal;
- Type 1c: both sides pre-treated;
- Type 2: having at least one rough surface (space factor ≥ 5 %, see 8.9);
- Type 2a: not corona treated;
- Type 2b: one side pre-treated to facilitate the vacuum deposition of metal;
- Type 2c: both sides pre-treated.
- Type 3: having high electric strength for thin film (film thickness $\leq 3,5 \mu\text{m}$);
- Type 3a: not corona treated;
- Type 3b: one side pre-treated to facilitate the vacuum deposition of metal;
- Type 3c: both sides pre-treated.

5 Designation

The plastic film shall be identified by the following designation:

Designation of the film – IEC 60674-3-1 – PP – type – thickness in micrometres – width in millimetres – length in metres.

EXAMPLE

Polypropylene film – IEC 60674-3-1 – PP – 1a – 6 – 100 – 3000.

6 General requirements

The materials shall be made essentially from isotactic type polypropylene homopolymer and shall conform to the requirements laid down in IEC 60674-1.

7 Dimensions

7.1 Thickness

The film thickness shall be measured in accordance with the requirements of 4.3.2 of IEC 60674-2:2016. This is in general the gravimetric thickness, but for type 2 distinction shall be made between thickness determined by weighing (t_g = gravimetric thickness) and thickness measured by micrometer method (t_b = bulking thickness).

Gravimetric thickness shall be measured in accordance with the requirements of 4.3.2 of IEC 60674-2:2016.

~~Bulking (micrometric) thickness shall be measured in accordance with ISO 534, except that 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 blanket of film about 0,5 mm thick taken from the outer surface of the roll being sampled. Discard the first and last layer of each pack or test piece just prior to imposing the pack between the open pressure faces of the micrometer.~~

Bulking (micrometric) thickness shall be measured according to 4.2.3 of IEC 60674-2:2016.

There are no requirements for thickness in this document, but preferred gravimetric thicknesses are as follows:

Type 1: 4,0 μm ; 5,0 μm ; 6,0 μm ; 7,0 μm ; 8,0 μm ; 10,0 μm ; 12,0 μm ; 15,0 μm ; 18,0 μm ; 20,0 μm and 25 μm .

Type 2: 7,4 μm ; 9,0 μm ; 10,1; 11,0 μm ; 12,0 μm ; 12,7 μm ; 13,6 μm ; 14,4 μm ; 15,2 μm ; 16,2 μm and 17,8 μm .

Type 3: 2,5 μm ; 2,8 μm ; 3,0 μm and 3,5 μm .

The thickness tolerance shall comply with the requirements of 4.1 of IEC 60674-1:1980 unless otherwise specified.

7.2 Width

The film width shall be measured in accordance with the requirements of Clause 6 of IEC 60674-2:2016.

Preferred widths cannot be given on account of the great variety of applications and different requirements throughout the capacitor industry.

The tolerance on the width shall comply with the requirements of 4.2 of IEC 60674-1:1980.

7.3 Length/diameter

There are no requirements in this document for length or diameters of rolls. These should be subject to purchase contract.

8 Properties

8.1 Physical properties

See Table 1.

Table 1 – Physical properties

Property	Test method	Unit	Requirement	Remarks
Density	IEC 60674-2, clause 4, method D ISO 1183-2:2019	Mg/m³ kg/dm ³ (g/cm ³)	0,91 ± 0,01	This method is only suitable for film thickness >12 µm. The recommended mixture is methanol/ethylene glycol
Melting point	IEC 61074 ISO 11357-3:2018	°C	165 to 175	DSC method
Tensile strength (either direction)	IEC 60674-2:2016, Clause 12	MPa	Minimum Type 1: 120 Type 2: 90 Type 3: 120	Specimen width (15 ± 3) mm, rate of extension (100 ± 2) mm/min, reference lines with the initial grip separation (100 ± 2) mm apart
Elongation at break (either direction)		%	Minimum Type 1: 40 Type 2: 30 Type 3: 30	
Surface resistivity	IEC 60674-2:2016, Clause 16 ^a	Ω	≥10 ¹⁴	The test voltages are 100 V for thicknesses >10 µm and 10 V for thicknesses ≤10 µm The test voltages are (100 ± 10) V for thicknesses >10 µm and (10 ± 1) V for thicknesses ≤10 µm
Volume resistivity	IEC 60674-2:2016, Clause 17 ^a	Ωm	>10 ¹⁵	
Dissipation factor at 23 °C and 48 Hz – 62 Hz: 1 kHz:	IEC 60674-2:2016, 18.2 or 18.3		≤3 × 10 ⁻⁴ ≤3 × 10 ⁻⁴	Use evaporated metal electrodes or non-contacting electrodes (18.2.4 or 18.2.5)
Permittivity	IEC 60674-2:2016, 18.2		2,2 ± 0,1	Use evaporated metal electrodes or non-contacting electrodes (18.2.4 or 18.2.5)
Dimensional change for shrinkage: – Machine direction – Transverse direction	IEC 60674-2:2016, Clause 25	% %		Shrinkage shall be agreed between buyer supplier and seller purchaser
NOTE Although the potential effects of certain properties such as crystallinity, orientation and isotactic/ atactic content on the performance of the film are recognized, no recommendations regarding the determination of these parameters have been made, particularly as no suitable test methods are available in IEC 60674-2.				
^a Measurement conditions: (23 ± 2) °C and (50 ± 5) % relative humidity after at least 24 h exposure.				

8.2 Electric strength (DC test)

Electric strength shall be measured according to 20.2 of IEC 60674-2:2016. The central value shall be not less than the value given in Table 2. The winding tension shall 2,5 N/mm² ± 0,5 N/mm².

Table 2 – Electric strength (DC test) for types 1, 2 and 3

Nominal film thickness μm	Type	Electric strength (central value) $\text{V}/\mu\text{m}$		Not more than 1 of 21 results shall be below $\text{V}/\mu\text{m}$	
		23 °C	105 °C	23 °C	105 °C
2,5	3	250	125	150	75
2,8		250	125	150	75
3,0		250	125	150	75
3,5		250	125	150	75
4	1 and 2	120	-	40	-
5		150	-	60	-
6		190	-	80	-
7 and 7,4		230	-	100	-
8		250	-	120	-
9		270	-	145	-
10 and 10,1		290	-	165	-
11		300	-	175	-
12		310	-	185	-
12,7		315	-	195	-
>12,7 to 25		320	-	200	-

8.3 Electrical weak spots

Electrical weak spots shall be measured according to 21.4 of IEC 60674-2:2016 ~~with a test voltage of 150 V/ μm for types 1 and 2, and 250 V/ μm for type 3, based on the nominal thickness of the film.~~

The number of faults counted shall not exceed the numbers given in Table 3. A minimum surface area of 5 m² is to be tested.

Compliance with any one of two method criteria shall constitute compliance with this document.

Table 3 – Electrical weak spots for types 1, 2 and 3

Nominal thickness μm	Type	Fault count/ m^2
2,5	3	2,6
2,8		2,6
3,0		2,6
3,5		2,6
4	1 and 2	2,6
5		2,3
6		1,8
7 and 7,4		1,7
8		1,5
9		1,3
10 and 10,1		1,2
11		1,1
≥ 12		1,0

Nominal thickness μm	Type	Method C1 (Aluminium foil electrodes) 21.4.2.2 of IEC 60674-2:2016		Method C3 (Metal electrode with air gap) 21.4.2.4 of IEC 60674-2:2016	
		Fault count/ m^2	Test voltage $\text{V}/\mu\text{m}$	Fault count/ m^2	Test voltage $\text{V}/\mu\text{m}$
2,5 2,8 3,0 3,5	3	2,6	250	2,0	200
4 5 6 7 and 7,4 8 9 10 and 10,1 11 ≥ 12	1 and 2	2,6 2,3 1,8 1,7 1,5 1,3 1,2 1,1 1,0	150	1,0 0,5	350 300 300 250 250 230 230 220 200

8.4 Thermal endurance

There is no requirement in this document for thermal endurance.

8.5 Wetting tension (types 1b + 1c, 2b + 2c and 3b + 3c only)

When tested in accordance with Clause 11 of IEC 60674-2:2016, the wetting tension of the tested surface shall not be less than $35 \text{ mN}\cdot\text{m}^{-1}$.

8.6 Liquid absorption

For satisfactory construction of impregnated capacitors, the absorption of the impregnant by the film may need to be controlled within certain limits. If required, the method of measurement

the time and the temperature used and the absorption limits shall be agreed between supplier and purchaser¹.

The preferred method shall conform with Clause 33 of IEC 60674-2:2016.

8.7 Compatibility with impregnants

The compatibility of the film with selected dielectric fluids shall be determined using a method agreed upon between the supplier and the purchaser. This method may, for example, be based on swelling or solubility of the film in the fluid, or on contamination of the fluid or the film¹.

8.8 Dissipation factor under impregnated conditions

The impregnants and the methods of testing used throughout the capacitor industry vary widely and many of the materials and procedures are proprietary. Where the dissipation factor of the film under impregnated conditions must be to an agreed standard, the limiting values and the method of measurement should be agreed between supplier and purchaser¹.

8.9 Space factor

Space factor: Caused by surface roughness, space factor is the percentage increase in bulking (micrometric) thickness over gravimetric thickness.

Space factor shall be measured according to Clause 9 of IEC 60674-2:2016.

There are no requirements for space factor in this document but the preferred space factor value of type 2 is $SF = (10 \pm 5) \%$.

Space factor is calculated using the following formula:

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

where

t_b is the bulking thickness in micrometres;

t_g is the gravimetric thickness in micrometres.

9 Roll characteristics

9.1 Windability

The windability shall be measured according to Clause 7 of IEC 60674-2:2016.

Two methods exist:

a) for reels of width less than 150 mm, method A shall be used.

Bias/camber <10 mm

Sag (tension 5 MN/m²) <2 mm

b) for reels of width 150 mm and above, method B shall be used.

Bias/camber <10 mm

¹ In view of the wide variety of impregnants available today and under development for capacitor application, no specific tests and/or limits can be given in this document for liquid absorption (8.6), compatibility with dielectric fluids (8.7) and dissipation factor under impregnated conditions (8.8).