Designation: D3664 – 16

Standard Specification for Biaxially Oriented Polymeric Resin Film for Capacitors in Electrical Equipment[1]

This standard is issued under the fixed designation D3664; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers thin biaxially oriented polymeric resin film for use in capacitors for electrical equipment. The material is biaxially oriented to improve the tensile properties in the machine (MD) and transverse (TD) directions.

1.2 The values stated in SI units are the standard. The values in parentheses are for information only.

NOTE 1—This standard resembles IEC 60674–3–2, Specification for plastic films for electrical use, in title only. The content is significantly different.

1.3 The following safety hazards caveat pertains only to the test methods section of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific warning statements see 9.3 and Table 1 footnote B.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies

D150 Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation

D202 Test Methods for Sampling and Testing Untreated Paper Used for Electrical Insulation

D257 Test Methods for DC Resistance or Conductance of Insulating Materials

D374 Test Methods for Thickness of Solid Electrical Insulation (Metric) D0374_D0374M

D543 Practices for Evaluating the Resistance of Plastics to Chemical Reagents

D570 Test Method for Water Absorption of Plastics

D756 Practice for Determination of Weight and Shape Changes of Plastics Under Accelerated Service Conditions (Withdrawn 1998)[3]

D774/D774M Test Method for Bursting Strength of Paper (Withdrawn 2010)[3]

D882 Test Method for Tensile Properties of Thin Plastic Sheeting

D1004 Test Method for Tear Resistance (Graves Tear) of Plastic Film and Sheeting

D1204 Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature

D1434 Test Method for Determining Gas Permeability Characteristics of Plastic Film and Sheeting

D1435 Practice for Outdoor Weathering of Plastics

D1505 Test Method for Density of Plastics by the Density-Gradient Technique

D2176 Test Method for Folding Endurance of Paper and Plastics Film by the M.I.T. Tester

D2305 Test Methods for Polymeric Films Used for Electrical Insulation

D2863 Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)

D3417 Test Method for Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry (DSC) (Withdrawn 2004)[3]

D3420 Test Method for Pendulum Impact Resistance of Plastic Film

D3636 Practice for Sampling and Judging Quality of Solid Electrical Insulating Materials

D3755 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials Under Direct-Voltage Stress

D3985 Test Method for Oxygen Gas Transmission Rate Through Plastic Film and Sheeting Using a Coulometric Sensor

[1] This specification is under the jurisdiction of ASTM Committee D09 on Electrical and Electronic Insulating Materials and is the direct responsibility of Subcommittee D09.07 on Electrical Insulating Materials.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

D6054 Practice for Conditioning Electrical Insulating Materials for Testing (Withdrawn 2012)[3]

E96/E96M Test Methods for Water Vapor Transmission of Materials

E252 Test Method for Thickness of Foil, Thin Sheet, and Film by Mass Measurement

2.2 *IEC Standards:*[4]

IEC 60674–3–2 Specification for plastic films for electrical purposes—Part 3: Specifications for individual materials—Sheet 2: Requirements for balanced biaxially oriented polyethylene phthalate (PET) films used for electrical insulation

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *shiner, n—as related to dielectric films*, a protrusion of material beyond the plane of either edge of the roll.

3.1.2 *space factor, n— as related to dielectric films*, a measure of surface roughness of film.

TABLE 1 Physical, Mechanical, and Electrical Requirements for Biaxially Oriented Polyethylene Terephthalate Capacitor Film (25.4 µm or less in thickness)[A]

Tensile Properties				
Tensile strength modulus, and elongation, MD and TD:				
Nominal Thickness, µm	Tensile Strength, min, MPA MD and TD	Break Elongation, % min		Tensile Modulus min, MPa MD and TD
		MD	TD	
1.5	110	40	20	2410
1.8	110	40	20	2410
2.0	110	...	30	2410
2.5	117	...	35	2410
3.0	131	...	35	2410
3.5	131	...	35	2716
4.0	131	45		2716
5.0	138	...	40	3103
6.0	138	...	40	3103
8.0	145	...	45	3103
10.0	145	...	50	3103
12.0	145	...	60	3103
19.0	145	...	60	2759
23.0	145	...	65	2759

Insulation resistance and conducting paths:		
Nominal Thickness, µm	Insulation Resistance, min MΩ at 125°C	Conducting Paths, max No. per m^2
1.5	1000	...
1.8	1000	...
2.0	1000	...
2.5	850	...
3.0	850	...
3.5	850	128
4.0	825	107
5.0	825	86
6.0	800	64
8.0	600	53
10.0	600	43
12.0	600	22
19.0	500	11
23.0	400	11

Permittivity, 23°C, 50 % RH:		
60 Hz	3.2 ± 0.1	
1 kHz	3.2 ± 0.1	
Dissipation factor, max 23°C:	60 Hz	1 kHz
2.0 to 4.0 µm thick	0.006	0.008
5.0 to 25.0 µm thick	0.004	0.006

Thickness, µm:				
Nominal Thickness,	Average Thickness per Single-Slit Roll			
	Based on Roll Weight		Ten-Sheet Stack	
µm	min	max	min	max
1.5	1.48	1.62	...	...
1.8	1.61	1.89	...	...
2.0	1.79	2.11	1.50	3.00
2.5	2.30	2.70	2.03	3.56
3.0	2.71	3.19	2.54	4.06
3.5	3.10	3.69	3.05	4.57
4.0	3.72	4.28	3.81	5.33
5.0	4.65	5.25	4.57	6.10
6.0	5.64	6.36	5.59	7.11
8.0	7.52	8.48	7.62	9.14

Nominal Thickness, μm	Average Thickness per Single-Slit Roll, μm			
	Based on Roll Weight		Ten-Sheet Stack	
	min	max	min	max
10.0	9.40	10.60	9.40	11.43
12.0	11.28	12.72	11.43	13.46
19.0	18.05	19.95	17.78	20.32
23.0	21.85	24.15	21.84	24.89

Width tolerance, variation from nominal, mm:	
less than 76 mm	±0.2
76 to 152 mm	±0.4
over 152 to 456 mm	±0.8
over 456 mm	±1.6
Density, 23/23°C, g/cm^3[B]	1.385 to 1.410
Melting point, min, °C	252
Shrinkage, max, MD and TD at 150 ± 1°C, %	3.0 MD, 2.0 TD

Dielectric breakdown voltage, dc:

Critical test voltage, V	Number of capacitors that must survive the critical test voltage per 20 capacitors[C]													
	Thickness, μm													
	1.5	1.8	2.0	2.5	3.0	3.5	4.0	5.0	6.0	8.0	10.0	12.0	19.0	23.0
100			18											
200				17		18	18							
300					17			18						
400						17								
500							17		19					
600								17		19	19			
800												19		
1000									18				19	
1200										18				
1600											18			
1800												18		
2200													18	19
Min avg dc voltage of 20 capacitors	100	175	200	300	500	600	700	900	1500	2000	2400	2800	3700	4000

[A] See Section 9 for Test Methods.
[B] Use 1,3-dibromopropane and n-heptane for preparing density gradient tube. **Warning** —n-heptane is flammable and volatile.
[C] This number has been statistically determined. Normally it will be met by any group of 20 capacitors. However, to definitely prove statistically that the specified number has been met for any mill roll lot of materials, it will be necessary to wind 60 capacitors from 3 slit rolls (20 from rolls A and B, 20 from rolls B and C, and 20 from A and C). If the average of the 3 groups is lower than the allowable number, the material is rejectable.

Aqueous extract conductivity, max, μS/cm	2
Acidity, max, milliequivalents/g	0.002

4. Classification

4.1 This specification covers the following:

4.1.1 *Type I*—having smooth surfaces (space factor <5 %, see 4.3);

4.1.1.1 *Grade 1*—not pre-treated,

4.1.1.2 *Grade 2*—one side pre-treated to facilitate the vacuum deposition of metal, and

4.1.1.3 *Grade 3*—both sides pre-treated.

4.1.2 *Type II*—having at least one rough surface (space factor ≥5 %, see 3.1.2);

4.1.2.1 *Grade 1*—not pre-treated,

4.1.2.2 *Grade 2*—one side pre-treated to facilitate the vacuum deposition of metal, and

4.1.2.3 *Grade 3*—both sides pre-treated.

4.2 *Materials:*

4.2.1 *Class A*—polyethylene terephthalate (PET).

4.2.2 *Class B*—polypropylene (PP).

4.3 Space factor, as related to dielectric films (see 3.1.2), shall be expressed as % and shall be calculated by the following equation:

$$\text{Space factor} = 100\left[T_b - T_g\right]\left[T_g\right]^{-1} \quad (1)$$

where:

T_b = bulking thickness determined using Test Methods D374, and

T_g = gravimetric thickness determined using Test Method E252.

5. General Requirements

5.1 The material shall be of uniform composition, and as free from metal particles, contamination, blisters, holes, and other imperfections as commercially feasible.

5.2 Information of general engineering interest is given in the Appendix.

6. Detail Requirements

6.1 The material shall conform to requirements prescribed in Table 1 or Table 2.

7. Sampling

7.1 For purposes of sampling, and inspection lot for examination shall consist of all film of the same type, grade, class, and nominal thickness submitted for inspection at one time. If a single shipment contains film having different lot numbers assigned by the film manufacturer, sample each lot number separately.

TABLE 2 Physical, Mechanical, and Electrical Requirements for Biaxially Oriented Polypropylene Capacitor Film (25.4 µm or less in thickness)[A]

Property		Value
Tensile strength, min, MPA (MD or TD)	Type I	120
	Type II	90
Elongation, min, % (MD or TD)	Type I	40
	Type II	30

Conducting Paths Nominal Thickness, µm	Conducting Paths, max per m^2
4.0	2.6
5.0	2.3
6.0	1.8
7.0	1.7
7.4	1.7
8.0	1.5
9.0	1.3
10.0	1.2
10.1	1.2
11.0	1.1
12.0 or greater	1.0

Permittivity, 23°C, 50% RH	
60 Hz	2.2 ± 0.1
1 kHz	2.2 ± 0.1
Dissipation Factor, 23°C, 50 % RH	
60 Hz	0.003
1 kHz	0.0002
Thickness Tolerance, µm	±10 %
Width Tolerance, mm	
up to 50 mm	±0.5 mm
over 50 mm to 300 mm	±1.0 mm
over 300 mm to 450 mm	±2.0 mm
over 450 mm to 750 mm	±4.0 mm
Density, 23°C, g/cm[3][B]	0.91 ± 0.01
Melting Point, min, °C	165
Shrinkage, max	To be agreed upon by purchaser and manufacturer

Dielectric Breakdown Voltage, dc:		
Nominal Film Thickness	Average Breakdown Voltage, V	Not more than 1 of 21 results shall be below, V
4.0	480	160
5.0	750	300
6.0	1140	480
7.0	1610	700
7.4	1700	740
8.0	2000	960
9.0	2430	1305
10.0	2900	1650
10.1	2930	1665
11.0	3300	1925
12.0	3720	2220
12.7	4000	2475
25.0	8000	5000

[A] See Section 9 for Test Methods.
[B] Use methanol and ethylene-glycol for preparing density gradient tube.

7.2 Unless otherwise agreed upon between the purchaser and seller, sample material for test according to Practice D3636. Set inspection levels and acceptable quality levels (AQL) as agreed upon between the purchaser and seller.

8. Conditioning

8.1 If required, condition the test specimens in accordance with Procedure A of Practice D6054 and Test Methods D2305.

8.2 Use test conditions in accordance with Practice D6054, unless otherwise specified.

9. Test Methods

9.1 *Tensile Strength, Modulus, and Elongation*—Test Method D882, Method A. Test at 50 mm/min (2 in./min) with an initial jaw separation of 50 mm (2 in.). Test a 25-mm (1-in.) width or the width as received, if less.

9.2 *Density*—Test Method D1505.

9.3 *Permittivity and Dissipation Factor*—Test Methods D150. Use a maximum applied voltage of 30 V ac. Use the fluid-displacement method. Recommended fluids are air, *n*-heptane, or 1 or 5×10^{-6} m^2/s (cSt) silicone fluid having a dissipation factor less than 0.00001. Conducting paint, sprayed or evaporated metal electrodes, are acceptable if care is taken to avoid errors as outlined in Test Methods D150. In case of disagreement, use the fluid-displacement method as the referee method. (**Warning**—Heptane is readily flammable. Use proper precautions.

9.4 *Surface Resistivity and Volume Resistivity*—Test Methods D257 with electrification for 60 s at 100 V dc.

9.5 *Melting Point*—Test Method D3417.

9.6 *Shrinkage*—Test Method D1204.

9.7 *Thickness*—Test Methods D374, Procedures 6.2. See the Thickness Section of Test Methods D202 for directions for handling ten-sheet stack specimens.

9.8 *Bursting Strength*—Test Method D774/D774M.

9.9 *Tear Strength*—Test Method D1004.

9.10 *Impact Strength*—Test Method D3420.

9.11 *Fold Endurance*—Test Method D2176.

9.12 *Color or Clarity*—Visual observation.

9.13 *Moisture Absorption*—Test Method D570, 24 h at 23°C.

9.14 *Moisture Permeability*—Test Methods E96/E96M.

9.15 *Oxygen Index*—Test Method D2863.

9.16 *Oxygen Permeability*—Test Method D1434 or Test Method D3985.

9.17 *Resistance to Corrosive Agents*— Practices D543 for acids, alkalies, and organic solvents; Test Methods E96/E96M for water; Practice D1435 for sunlight.

9.18 Special requirements such as heat or solvent resistance and hygroscopic coefficient of expansion are subjects for individual negotiation.

9.19 *Aqueous Extract Conductivity*—Test Methods D202, except use a 5-g specimen and 200 mL of boiling distilled water. Omit stirring. After filtering, wash specimen with 50 mL of hot distilled water and add to filtrate. Adjust final volume to 250 mL with hot distilled water. Divide the calculated result by two. Save the solution to perform acidity test as in 8.21.

9.20 *Acidity*—Test Methods D202, except titrate extract as in 9.19.

9.21 *Conducting Paths*—Method A of Test Methods D202 using 100 V dc.

9.22 *Insulation Resistance*—Test Methods D257. Measure on 0.5-µF unimpregnated single-layer capacitors with 3-mm margins, 3-min total electrification at 100 V dc. Preheat

capacitors in oven at 125 ± 1°C for ½ h prior to test. Maintain temperature at 125 ± 1°C during measurement.

9.23 *Dielectric Breakdown Voltage* (*dc*)—See 9.3 for Warning. Test Method D3755. Measure on 0.5-µF unimpregnated single-layer capacitors subjected to dc voltage at 100-V/s rate of rise at room temperature and 50 % relative humidity. Conduct tests on "as-wound" units, using a 20-mm minimum or preferably 50-mm wide film with a 16-mm margin and a 3-mm arbor. Discard units failing a 6-V shorting test.

9.24 *Thickness of Capacitor Film:*

9.24.1 *Roll Weight Method*—Calculate the average thickness from the average density, and from the width, length, and net weight of the role.

9.24.2 *Ten–Sheet Stack Method*—Use Method A or C of Test Methods D374. Make measurements on a ten-sheet stack of film from a single-slit roll. Keep the micrometer foot more than 20 mm from any folded edge of a stack, as specified in Test Methods D202, or 6 mm from the edge of the sheet.

9.24.3 *Gravimetric Method*—Use Test Method E252.

10. Roll Requirements

10.1 The following requirements apply:

10.1.1 *Core*—Cores must not distort or collapse from the winding tension, nor flake or degrade the sheet.

NOTE 2—Current industry practice is to wrap the material on either 76 or 152-mm (3 or 6-in.) diameter cores. Film for film/foil capacitor use is also supplied on 29-mm diameter cores.

10.1.1.1 Details of whether the core shall be permitted to extend to the edge of the material or protrude beyond are subject to agreement between purchaser and manufacturer.

10.1.2 *Patching*—None is allowed.

10.1.3 *Shiners*—More than three per roll or those extending more than 1.6 mm (0.062 in.) are unacceptable.

10.1.4 *Splices*—The maximum number of splices permitted in a slit roll is given in Table 3. The minimum distance between splices, or from beginning or end of a slit roll is 162 m (500 ft), unless otherwise agreed upon between the purchaser and the supplier. Details of the splice, such as color, trailing tails at the top or bottom, sandwiched or overlapped, shall be agreed upon by the purchaser and supplier.

TABLE 3 Slit Roll Splice Frequency (Maximum Number Permitted)

Roll Inside Diameter 76 mm			
Film Thickness	Roll Outside Diameter		
	240 mm	330 mm	410 mm
1.5 – 23.0	2	3	4

Roll Inside Diameter 152 mm				
Film Thickness	Roll Outside Diameter			
	230 mm	280 mm	360 mm	455 mm
1.5 – 23.0	2	3	4	5

10.1.5 *Telescoping*—There shall be no more than 1.6-mm (0.062-in.) displacement from the plane of the edge of the roll.

10.1.6 *Wrinkles*—Permit no wrinkles that cause permanent deformation of the film.

10.1.7 *Marking*—Mark the following information on the core or on an accompanying label: mill roll number, footage, actual sheet thickness or gage, width, and the manufacturer's designation.

11. Packaging

11.1 Package the material in standard commercial containers designed to protect the roll from damage, and constructed to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the point of delivery, unless otherwise specified in the contract or order.

12. Marking

12.1 Identify shipping containers with the name and the specification number of the material, the thickness, the width, the footage, the roll and core diameters, the manufacturer's name, and the number of the contract or order.

13. Keywords

13.1 capacitor; polyethylene terephthalate; polymeric resin film; polypropylene

APPENDIX

(Nonmandatory Information)

X1. INFORMATION OF GENERAL ENGINEERING INTEREST 25 µm (0.001 in.), NOMINAL THICKNESS

TABLE X1.1 Information of General Engineering Interest (Biaxially Oriented Polyethylene Terephthalate Film)

Property[A, B]	Value
Bursting strength:	
kPa	>475
psi	>69
Tear strength:	
MPa	>12.4
psi	>1800
Impact strength:	
J/mm	96.4
J/mil	2.5
Fold endurance, cycles	>14 000
Color or clarity	clear to translucent
Moisture absorption, %	<0.6
Moisture permeability:	
g/m^2·24 h	<23.2
g/100 in^2·24 h	<1.5
Hygroscopic coefficient of expansion,%	
$(\Delta l/l)/\Delta$ % RH:	
mm/mm·% RH = in/in·% RH	0.6×10^{-5}
Oxygen index	20–25
Oxygen permeability:	
cm^3/m^2·24 h·atm·m	<3.66
cm^3/100 $in.^2$·24 h·atm·mil	<6.
Corona	[C]
Resistance to corrosive agents:	
Weak acids	excellent
Strong acids	fair
Weak alkali	poor
Strong alkali	poor
Organic solvents	excellent
Water	excellent
Sunlight	poor unless specifically treated
Moisture and heat (hydrolytic stability)	poor
Surface resistivity, typical, Ω (per square):	
23°C, 30 % RH	1×10^{16}
23°C, 80 % RH	1×10^{12}
Volume resistivity, typical, Ω-cm:	
25°C, 50 % RH	1×10^{18}
150°C, 50 % RH	1×10^{13}

[A] If these are to be specified, they are subject to agreement between the purchaser and the manufacturer.
[B] See Section 9 for test methods.
[C] Not recommended for use where continuous corona or electrical discharges are likely to occur.

TABLE X1.2 Information of General Engineering Interest (Biaxially Oriented Polypropylene Film)

Property[A, B]	Value
Surface resistivity, typical, Ω (per square):	≥10E14
23°C, 50 % RH	
Volume resistivity, typical, Ω-cm:	>10E15
23°C, 50 %RH	

[A] If these are to be specified, they are subject to agreement between the purchaser and the manufacturer.
[B] See Section 9 for test methods.