



Standard Specification for Polymeric Resin Film for Electrical Insulation and Dielectric Applications¹

This standard is issued under the fixed designation D 5213; 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 requirements for the material, dimensions and tolerances, and property values of film, in sheet or strip form, with or without heat-sealable coatings.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

NOTE 1—This document is similar to IEC 60674, Part 3, Sheets 2, 4, 5, 6, and 7.

2. Referenced Documents

2.1 ASTM Standards:

D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies²

D 883 Terminology Relating to Plastics³

D 1711 Terminology Relating to Electrical Insulation²

D 2305 Test Methods for Polymeric Films Used for Electrical Insulation²

D 3636 Practice for Sampling and Judging Quality of Solid Electrical Insulating Materials⁴

D 4088 Practice for Preparation for Shipment of Solid Electrical Insulating Materials⁴

2.2 IEC Standards:

Publication 60674-3 Specification for Electrical Films for Electrical Purposes⁵

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminologies D 1711 and D 883 unless otherwise specified.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *sheet, n*—material greater than 75 mm in width.

3.2.2 *strip, n*—material 75 mm or less in width.

4. Classification

4.1 This specification covers the following:

4.1.1 *Type I*—General purpose,

4.1.2 *Type II*—Heat sealable,

4.1.2.1 *Grade 1*—One side coated, and

4.1.2.2 *Grade 2*—Two sides coated.

4.2 *Materials:*

4.2.1 *Item A*—Poly(N,N'-p,p'-oxydiphenylene pyromellitimide),

4.2.2 *Item B*—Poly(N,N'-p,p'-oxydiphenylene biphenyltetracarboxylimide),

4.2.3 *Item C*—Poly(N,N'-p-phenylene biphenyltetracarboxylimide),

4.2.4 *Item D*—FEP-fluorocarbon, and

4.2.5 *Item E*—Polyethylene terephthalate.

4.2.6 *Item F*—Polyethylene naphthalate.

5. Ordering Information

5.1 Order the film covered by this specification stating the type, grade, class, thickness, width, and roll dimensions.

6. Materials

6.1 Type I material is flexible, unsupported film.

6.2 Type II material is film meeting all of the requirements of Type I, and having a heat-sealable coating on one or both sides.

7. Requirements

7.1 The film covered by this specification shall meet the property requirements given in Tables 1-6 and Table 7 when tested by the methods given in Test Methods D 2305.

7.1.1 Type II films, prior to coating, shall meet all of the requirements given in Table 1 for films of the thicknesses given in Table 8.

7.1.2 Type II films, after coating, shall meet all of the requirements given in Table 1 for elongation, before and after heating, and for shrinkage as given in Table 1 for films of the thicknesses given in Table 8.

7.2 *Roll Diameters:*

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² *Annual Book of ASTM Standards*, Vol 10.01.

³ *Annual Book of ASTM Standards*, Vol 08.01.

⁴ *Annual Book of ASTM Standards*, Vol 10.02.

⁵ Available from American National Standards Institute, 4 W. 42nd St., New York, NY 10036.

TABLE 1 Property Values for Type I, Class A Film poly(N,N'-p-p'-oxydiphenylene pyromellitimide)

	Average Property Value							
	Nominal Thickness, μm (mils)							
	7.5 (0.3)	13 (0.5)	20 (0.8)	25 (1.0)	50 (2.0)	75 (3.0)	100 (4.0)	130 (5.0)
Tensile strength, min MPa (psi), machine direction and transverse direction	69 (10 000)	97 (14 000)	138 (20 000)	138 (20 000)	138 (20 000)	138 (20 000)	138 (20 000)	138 (20 000)
Elongation, min percent, machine and transverse direction	10	20	35	35	40	45	45	45
Shrinkage, max percent, after exposure to 200°C (392°F), machine and transverse direction	...	...	0.30	0.30	0.35	0.35	0.35	0.35
Moisture absorption, max percent, 100 % RH	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Dielectric strength, min kV/mm (V/mil), 60 Hz ^{A,B}	120 (3000)	120 (3000)	180 (4500)	180 (4500)	150 (3800)	140 (3600)	100 (2500)	100 (2500)
Volume resistivity, min $\Omega\text{-cm}$, ^{B,C}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}
Permittivity, max at 1 kHz ^B	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Dissipation factor, max at 1 kHz ^B	0.007	0.005	0.005	0.004	0.004	0.004	0.004	0.004

^A Use Type 3 electrodes in air of Table 1 of Test Method D 149 (opposing 6.4-mm diameter rods).

^BAt 23°C (73.4°F), 50 % RH.

^CThe median value of 5 measurements should be used for compliance.

TABLE 2 Property Values for Type I, Class B Film poly(N,N'-p-p'-oxydiphenylene biphenyltetracarboxylimide)

	Average Property Value								
	Nominal Thickness, μm (mils)								
	7.5 (0.3)	13 (0.5)	20 (0.8)	25 (1.0)	40 (1.6)	50 (2.0)	75 (3.0)	100 (4.0)	130 (5.0)
Tensile strength, min MPa (psi), machine direction and transverse direction	110 (15 000)	138 (20 000)	196 (28 000)	196 (28 000)	196 (28 000)	196 (28 000)	196 (28 000)	196 (28 000)	196 (28 000)
Elongation, min percent, machine and transverse direction	24	40	80	80	80	80	80	80	80
Shrinkage, max percent, after exposure to 200°C (392°F), machine and transverse direction	...	...	0.30	0.30	0.35	0.35	0.35	0.35	0.35
Moisture absorption, max percent, 100 % RH	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Dielectric strength, min kV/mm (V/mil), 60 Hz ^{A,B}	120 (3000)	120 (3000)	180 (4500)	180 (4500)	150 (3800)	140 (3500)	130 (3300)	100 (2500)	95 (2400)
Volume resistivity, min $\Omega\text{-cm}$, ^{B,C}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}
Permittivity, max at 1 kHz ^B	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Dissipation factor, max at 1 kHz ^B	0.007	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

^A Use Type 3 electrodes in air of Table 1 of Test Method D 149 (opposing 6.4-mm diameter rods).

^BAt 23°C (73.4°F), 50 % RH.

^CThe median value of 5 measurements should be used for compliance.

TABLE 3 Property Values for Type I, Class C Film poly(N,N'-p-phenylene biphenyltetracarboxylimide)

	Average Property Value								
	Nominal Thickness, μm (mils)								
	7.5 (0.3)	13 (0.5)	20 (0.8)	25 (1.0)	40 (1.6)	50 (2.0)	75 (3.0)	100 (4.0)	130 (5.0)
Tensile strength, min MPa (psi), machine direction and transverse direction	133 (19 000)	176 (25 000)	241 (34 000)	241 (34 000)	241 (34 000)	241 (34 000)	241 (34 000)	241 (34 000)	241 (34 000)
Elongation, min percent, machine and transverse direction	25	25	25	25	25	25	25	25	25
Shrinkage, max percent, after exposure to 200°C (392°F), machine and transverse direction	...	...	0.15	0.15	0.15	0.20	0.20	0.20	0.20
Moisture absorption, max percent, 100 % RH	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Dielectric strength, min kV/mm (V/mil), 60 Hz ^{A,B}	120 (3000)	120 (3000)	180 (4500)	180 (4500)	150 (3800)	140 (3500)	120 (3000)	100 (2500)	95 (2400)
Volume resistivity, min $\Omega\text{-cm}$, ^{B,C}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}
Permittivity, max at 1 kHz ^B	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Dissipation factor, max at 1 kHz ^B	0.007	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

^A Use Type 3 electrodes in air of Table 1 of Test Method D 149 (opposing 6.4-mm diameter rods).

^BAt 23°C (73.4°F), 50 % RH.

^CThe median value of 5 measurements should be used for compliance.

7.2.1 The outside diameters of rolls of film shall not vary from the value specified on the purchase order by more than ± 6 mm (0.25 in.).

7.2.2 The inside diameters of cores of standard rolls of film shall not vary from the value specified on the purchase order by more than ± 1.5 mm (0.060 in.).

TABLE 4 Property Values for Type I, Class D Film (FEP—Fluorocarbon)

	Average Property Value												
	Nominal Thickness, μm (mils)												
	13 (0.50)	25 (1.0)	51 (2.0)	76 (3.0)	102 (4.0)	127 (5.0)	254 (10.0)	356 (14.0)	508 (20.0)	762 (30.0)	1016 (40.0)	1524 (60.0)	2413 (95.0)
Tensile strength, min MPa (psi), machine direction and transverse direction	13.8 (2000)	17.25 (2500)	17.25 (2500)	17.25 (2500)	17.25 (2500)	17.25 (2500)	17.25 (2500)	17.25 (2500)	17.25 (2500)	17.25 (2500)	17.25 (2500)	17.25 (2500)	17.25 (2500)
Elongation, min, %, machine direction and transverse direction	175	250	250	250	250	250	250	250	250	250	250	250	250
Shrinkage, max percent, after exposure to 200°C (392°F)	5.0	5.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0	4.0	4.0	4.0	5.0
Moisture absorption, max percent, 100 % RH	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Dielectric strength, min at 60 Hz kV/mm (V/mil) ^{A,B}	160 (4000)	160 (4000)	140 (3500)	120 (3000)	110 (2750)	100 (2500)	72 (1800)	64 (1600)	56 (1400)	...	...	...	...
Volume resistivity, min, $\Omega\text{-cm}^{B,C}$	10^{17}	10^{17}	10^{17}	10^{17}	10^{17}	10^{17}	10^{17}	10^{17}	10^{17}	10^{17}	10^{17}	10^{17}	10^{17}
Permittivity, max at 1 kHz ^B	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15
Dissipation factor, max at 1 kHz ^B	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003

^A Use Type 3 electrodes in air of Table 1 of Test Method D 149 (opposing 6.4-mm diameter rods).

^BAt 23°C (73.4°F), 50 % RH.

^CThe median value of 5 measurements should be used for compliance.

TABLE 5 Property Values for Type I, Class E Film (Polyethylene Terephthalate)

	Average Property Value								
	Nominal Thickness, μm (mils)								
	12 (0.48)	15 (0.60)	23 (0.92)	36 (1.42)	75 (3.00)	100 (4.00)	190 (7.50)	250 (10.00)	
		19 (0.75)		50 (2.00)		125 (5.00)	225 (9.00)	>250	
Tensile strength, min MPa (psi), machine direction and transverse direction	145 (21 000)	145 (21 000)	138 (20 000)	138 (20 000)	138 (20 000)	138 (20 000)	138 (20 000)	110 (16 000)	
Elongation, min % machine direction and transverse direction	60	60	65	70	70	70	70	70	
Shrinkage, max percent after exposure to 150°C (302°F), 30 min	3.5	3.0	3.0	3.0	3.0	3.0	3.0	2.0	
Moisture absorption, max %, 100 % RH	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	
Dielectric strength, min at 60 Hz, kV/mm (V/mil) ^{A,B}	208 (5300)	190 (4800)	174 (4400)	130 (3300)	105 (2700)	80 (2000)	60 (1500)	50 (1300)	
Volume resistivity, min, $\Omega\text{-cm}^{B,C}$	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	
Permittivity, max at 1 kHz ^B	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	
Dissipation factor, max at 1 kHz ^B	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	

^A Use Type 3 electrodes in air of Table 1 of Test Method D 149 (opposing 6.4-mm diameter rods).

^BAt 23°C (73.4°F), 50 % RH.

^CThe median value of 5 measurements should be used for compliance.

TABLE 6 Property Values for Type I, Class F Film (Polyethylene Naphthalate) Average Property Value

	Nominal Thickness, μm (mils)							
	12 (0.48)	16 (0.65)	25 (1.00)	38 (1.50)	50 (2.00)	75 (3.00)	100 (4.00)	250 (10.00)
Tensile strength, min MPa (psi), machine direction and transverse direction	172 (25 000)	172 (25 000)	172 (25 000)	172 (25 000)	172 (25 000)	172 (25 000)	172 (25 000)	172 (25 000)
Elongation, min percent, machine and transverse direction	50	50	50	50	50	50	50	50
Shrinkage, max percent, after exposure to 150°C (302°F), 30 min	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Moisture absorption, max %, at 100 % RH	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Dielectric strength, min at 60 Hz, kV/mm (V/mil) ^{A,B}	215 (5500)	215 (5500)	195 (5000)	145 (3700)	145 (3700)	120 (3000)	120 (3000)	
Volume resistivity, min, $\Omega\text{-cm}^{B,C}$	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	10^{15}	
Permittivity, max at 1 kHz ^B	3.4	3.4	3.4	3.4	3.4	3.4	3.4	
Dissipation factor, max at 1 kHz ^B	0.006	0.006	0.006	0.006	0.006	0.006	0.006	

^A Use Type 3 electrodes in air of Table 1 of Test Method D 149 (opposing 6.4-mm diameter rods).

^BAt 23°C (73.4°F), 50 % RH.

^CThe median value of 5 measurements should be used for compliance.

TABLE 7 Additional Property Values for Type II, Class A, B and C Films

Grade	Total Nominal Thickness μm (mils) ^A	Dielectric Strength, min kV/mm (V/mil)	Heat Seal Strength, min at 350°C ± 2°C (662 ± 3.6°F) g/25 mm (in.) width	
			Coated Side to Uncoated Side	Coated Side to Coated Side
			1	25 (1.0)
1	38 (1.5)	140 (3500)	450	800
1	50 (2.0)	120 (3000)	450	800
1	60 (2.5)	100 (2500)	450	800
1	75 (3.0)	100 (2500)	450	800
1	100 (4.0) ^B	80 (2000)	450	800
1	100 (4.0) ^C	105 (2700)	450	800
1	150 (6.0)	85 (2100)	450	800
2	30 (1.2)	155 (3900)	...	500
2	38 (1.5)	120 (3000)	...	800
2	50 (2.0)	120 (3000)	...	800
2	75 (3.0) ^D	100 (2500)	...	800
2	75 (3.0) ^C	80 (2000)	...	600
2	130 (5.0)	90 (2200)	...	800

^A See Table 3A for nominal thicknesses of polyimide and FEP-Fluorocarbon layers.

^B FEP-Fluorocarbon coating is 50 μm (2.0 mils) in nominal thickness.

^C FEP-Fluorocarbon coating is 25 μm (1.0 mils) in nominal thickness.

^D FEP-Fluorocarbon coating is 12 μm (0.5 mils) in nominal thickness.

TABLE 8 Thicknesses and Tolerances for Type II Class A, B and C Films

Grade	Nominal Thickness, μm (mils)				Tolerances on Total Thickness, ±μm (mils)
	Total	First FEP ^A Layer	Polyimide Layer	Second FEP ^A Layer	
1	25 (1)	None	13 (0.5)	13 (0.5)	6 (0.25)
1	38 (1.5)	None	25 (1)	13 (0.5)	6 (0.25)
1	50 (2)	None	25 (1)	25 (1)	8 (0.3)
1	62 (2.5)	None	50 (2)	13 (0.5)	3.3 (0.13)
1	75 (3)	None	50 (2)	25 (1.0)	10 (0.4)
1	100 (4)	None	50 (2)	50 (2)	10 (0.4)
1	100 (4)	None	75 (3)	25 (1)	10 (0.4)
1	150 (6)	None	130 (5)	25 (1)	15 (0.6)
2	30 (1.18)	2.5 (0.1)	25 (1)	25 (0.1)	2 (0.08)
2	38 (1.5)	13 (0.5)	13 (0.5)	13 (0.5)	7 (0.3)
2	50 (2)	13 (0.5)	25 (1)	13 (0.5)	8 (0.3)
2	75 (3)	13 (0.5)	50 (2)	13 (0.5)	10 (0.4)
2	75 (3)	25 (1)	25 (1)	25 (1)	10 (0.4)
2	130 (5)	25 (1)	75 (3)	25 (1)	12 (0.5)

^A The FEP-Fluorocarbon film shall conform to Specification D 5213, Class D.

7.2.3 Refer to Appendix X1 for the dimensions of rolls of film that are commercially available for the standard grades and thicknesses, and for the nominal lengths of film in these rolls.

7.3 The widths of film in rolls shall be within the following tolerances:

7.3.1 Twenty-five mm (1 in.) wide or less, ±0.4 mm (0.015 in.).

7.3.2 Over 25 to 100 mm (over 1 to 4 in.), ±0.8 mm (0.030 in.).

7.3.3 Over 100 mm (4 in.), ±1.6 mm (0.062 in.).

7.4 The number of splices in standard rolls shall not exceed the values given in Table 9 for Type I film or Table 10 and Table 11 for Type II films.

7.5 The thicknesses shall be within the tolerances specified in Table 12 for Type I film or Table 3 for Type II film.

7.6 The color of the sheet or strip shall be uniform within a given lot, as determined by visual examination.

TABLE 9 Splice Tolerances for Standard Rolls of Type I Film

Roll Diameter, mm (in.)		Nominal Thickness, μm (mils)								
ID	OD	7.5 (0.3)	13 (0.5)	20 (0.8)	25 (1.0)	40 (1.6)	50 (2.0)	75 (3.0)	100 (4.0)	130 (5.0)
Number of Splices per Roll, max										
76 (3)	124 (4.88)	9	...	...	...	...	...	...	...	...
76 (3)	152 (6)	...	5	2	2	2	1	1	1	1
76 (3)	241 (9.5)	...	...	7	7	5	5	4	4	4
152 (6)	241 (9.5)	40	10	5	5	5	3	3	2	2
Length Between Splices or From End of Roll, m (ft), min										
76 (3)	152 (6)	...	30 (100)	30 (100)	30 (100)	30 (100)	30 (100)	30 (100)	23 (75)	23 (75)
76 (3)	241 (9.5)	...	...	30 (100)	30 (100)	30 (100)	30 (100)	30 (100)	23 (75)	23 (75)
152 (6)	241 (9.5)	23 (75)	30 (100)	30 (100)	30 (100)	30 (100)	30 (100)	30 (100)	23 (75)	23 (75)
Average Splice-Free Length per Roll, m (ft)^A, min										
76 (3)	152 (6)	...	150 (500)	150 (500)	150 (500)	115 (380)	115 (380)	75 (250)	45 (150)	45 (150)
76 (3)	241 (9.5)	...	...	195 (640)	195 (640)	130 (425)	130 (425)	105 (340)	60 (200)	60 (200)
152 (6)	241 (9.5)	90 (300)	170 (550)	150 (500)	150 (500)	115 (380)	115 (380)	75 (250)	60 (200)	60 (200)

^A Divide the length of the roll by the total number of splice-free segments.

TABLE 10 Splice Tolerances for Standard Rolls of Type II, Grade 1 Film

Roll Diameter, mm (in.)		Nominal Thickness, μm (mils)						
ID	OD	25 (1)	38 (1.5)	50 (2)	63 (2.5)	75 (3)	100 (4)	150 (6)
Number of Splices per Roll, max								
76 (3)	152 (6)	5	3	2	2	2	1	...
76 (3)	241 (9.5)	...	8	7	5	5	5	4
152 (6)	241 (9.5)	9	5	5	4	4	4	3
Length Between Splices or From End of Roll, m (ft), min								
76 (3)	152 (6)	30 (100)	30 (100)	30 (100)	30 (100)	30 (100)	30 (100)	...
76 (3)	241 (9.5)	...	30 (100)	30 (100)	30 (100)	30 (100)	30 (100)	23 (75)
152 (6)	241 (9.5)	30 (100)	30 (100)	30 (100)	30 (100)	30 (100)	30 (100)	23 (75)
Average Splice-Free Length per Roll, m (ft)^A, min								
76 (3)	152 (6)	75 (250)	75 (250)	75 (250)	60 (200)	50 (165)	55 (185)	...
76 (3)	241 (9.5)	...	115 (375)	95 (310)	100 (335)	85 (280)	60 (205)	50 (170)
152 (6)	241 (9.5)	90 (300)	115 (375)	75 (250)	60 (200)	65 (210)	45 (150)	38 (125)

^A Divide the nominal length of the roll by the total number of splice-free segments.

7.7 The film shall be uniform in appearance, as determined by visual examination. The film shall be clean and free from contamination, wrinkles, holes, scratches, and other defects that might affect either appearance or serviceability. The heat-sealable coating for Type II material shall be uniform in appearance.

8. Sampling

8.1 Sample in accordance with Practice D 3636, unless otherwise agreed upon between the supplier and the purchaser.