

DuPont™ Kapton®

Polyimide Film

Motor and Magnet Wire Technical Bulletin

Introduction

This bulletin describes the values and tolerances for Kapton® polyimide film properties and characteristics known to be of significance in the motor and magnet wire industry.

For a more thorough understanding, test methods are provided and values are expressed in both SI and Imperial units.

Minimum and/or maximum values are provided as a guide to those requiring a better understanding of current product test limits for design purposes. These values should not be interpreted as being representative of “actual/typical” values. Therefore, if you require typical value data, please contact your DuPont sales or technical representative for Kapton®. Additional information can be found at www.kapton.com. Data provided herein should not be used alone as the basis of design. Because the many different uses and conditions of use cannot be anticipated, users should conduct their own tests to determine the appropriateness of the products for their particular purposes.

Any aspects of the data requiring further interpretation or clarification should be discussed with your DuPont technical representative for Kapton®.

Applications

The unique properties of Kapton® allow it to be used extensively in the motor and magnet wire industry. The electrical & mechanical strengths of Kapton® film enable thinner insulation designs, conserving space for conductors, which ultimately yields more power without increasing motor size. Kapton® provides exceptional overload protection and long motor life, even in the most demanding applications and environments. Kapton® has superior chemical resistance to most solvents, hydrocarbons, lubricants, resins, and varnishes. Kapton® also carries the UL 94-V0 flammability rating and will not melt, ignite, or propagate flame.

Typical motor applications include magnet wire, turn-to-turn, strand, coil, slot liner, and ground insulation.

Kapton® is routinely used in laminations with other insulating materials, such as DuPont™ Nomex® paper or mica, as well as in pressure-sensitive adhesive tape.

Types of Kapton® Film

- DuPont offers a variety of Kapton® films for use in motors, generators and transformers.

Non-Heat-Sealable Kapton® Films

Kapton® HN Film

Kapton® HN is an aromatic polyimide film exhibiting an exceptional and unique balance of physical, chemical, and electrical properties over a wide temperature range, particularly at high temperatures.

Kapton® HN film is available in standard thicknesses: 25, 50, 75, and 125 μm (1, 2, 3, and 5 mil). Additional thicknesses can be made available by special request. Please consult your DuPont sales representative for Kapton®.

Kapton® CRC Film

Corona-resistant Kapton® CRC has been developed specifically to withstand the damaging effect of partial discharge, which can cause the eventual breakdown of an insulation material or system. Kapton® CRC has a corona resistance or voltage endurance that is significantly higher than standard Kapton® HN. Kapton® CRC provides a thermal conductivity that is greater than standard Kapton® HN, allowing better dissipation of heat in motors and other electrical equipment.

Kapton® CRC is available in standard thicknesses of 25 and 50 μm (1 & 2 mil). Additional thicknesses can be made available by special request. Please contact your DuPont sales representative for Kapton®.

Kapton® WR Film

Continuous exposure to hot water can affect the tensile strength, elongation, and dielectric strength of standard Kapton® HN. Water-resistant Kapton® WR has been developed specifically to combat the effect of water on insulation systems and for applications where hydrolytic stability is important.

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Heat-Sealable Kapton® Films

Heat-sealable Kapton® films are used as primary insulation on magnet wire. These films are coated with or laminated to a fluoropolymer which acts as a high temperature adhesive. The film is applied in tape form by helically wrapping it over and heat-sealing it to the conductor and itself. The heat-sealable films are designated FN, FCRC, FWN, FWR, PRN, PRT, and XP. **Table 1** lists heat-sealable films typically used in this industry.

Certification

Kapton® is certified to meet the requirements of specification ASTM D5213 as well as the items listed in this bulletin. Product certification is available with each delivery upon request.

Thermal Durability

The thermal durability of Kapton® polyimide film depends on the environmental conditions under which it is aged and tested, and lifetime depends on the criteria of failure. Films are tested at the manufacturing site in the following manner.

Sheets of film 215 × 280 mm (8-1/2 × 11 in) are freely suspended in an oven at 400°C (752°F). The temperature of the oven is

monitored with a thermocouple to ensure a temperature accuracy of ±2°C (±3.6°F). Sheets are removed after 2 hours and tested on a tensile tester as described in **Tables 3 and 4** under “Elongation.” The elongation (at 23°C [73°F]) of the film shall not be less than 10% after aging at 400°C (752°F).

Under the file number E39505, Underwriters Laboratory Inc. characterizes Kapton® polyimide film with a thermal index of 220-240°C (428-464°F) for electrical properties and 200-220°C (392-428°F) for mechanical properties.

A digital copy of this report can be found at ul.com under the online certifications directory.

Thickness

Test Method

Table 2 lists thickness of Kapton® films, measured in accordance with ASTM D374.

The average of ten randomly selected readings from a minimum area 77 cm² (12 in²) is obtained and rechecked before rejecting any slit roll. Abnormal readings may occasionally result from dust particles or spot surface imperfections.

Table 1. Constructions of Heat-Sealable Kapton® Types

Film Designation	Film Constructions,* µm (mil)		
	Fluoropolymer	Kapton® HN	Fluoropolymer
120FWN616B	3.8 (0.15)	25 (1.00)	3.8 (0.15)
150FN019		25 (1.00)	12.7 (0.50)
150FWN019		25 (1.00)	12.7 (0.50)
150PRN411	10 (0.40)	25 (1.00)	2.5 (0.10)
150XP019		25 (1.00)	12.7 (0.50)
200FN919	12.7 (0.50)	25 (1.00)	12.7 (0.50)
250FN029		50 (2.00)	12.7 (0.50)
300FN929	12.7 (0.50)	50 (2.00)	12.7 (0.50)
		Kapton® CRC	
150FCRC019		25 (1.00)	12.7 (0.50)
		Kapton® WR	
150FWR019		25 (1.00)	12.7 (0.50)
200FWR919	12.7 (0.50)	25 (1.00)	12.7 (0.50)
200PRT919	12.7 (0.50)	25 (1.00)	12.7 (0.50)

* Commonly used in magnet wire and covered in this bulletin.
See General Specifications for Kapton® Polyimide Films for details regarding other type FN films.

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Table 2. Thickness of Kapton® Films

		Product Designation																
		100HN	200HN	300HN	100CRC	200CRC	120FWN616B	150FN019	150FCRC019	150FWN019	150FWR019	150PRN411	150XP019	200FN919	200FWR919	200PRT919	250FN029	300FN929
Nominal	µm (mil)	25.4 (1.0)	50.8 (2.0)	76.2 (3.0)	25.4 (1.0)	50.8 (2.0)	33 (1.3)	38.1 (1.5)	38.1 (1.5)	38.1 (1.5)	38.1 (1.5)	38.1 (1.5)	38.1 (1.5)	50.8 (2.0)	50.8 (2.0)	50.8 (2.0)	63.5 (2.5)	76.2 (3.0)
Minimum		22.8 (0.90)	47 (1.85)	69.8 (2.75)	22.8 (0.90)	47 (1.85)	31 (1.22)	34.3 (1.35)	34.3 (1.35)	34.3 (1.35)	34.3 (1.35)	34.3 (1.35)	34.3 (1.35)	45.7 (1.80)	45.7 (1.80)	45.7 (1.80)	60.4 (2.38)	69.8 (2.75)
Maximum		28.7 (1.13)	55.9 (2.20)	82.6 (3.25)	28.7 (1.13)	55.9 (2.20)	34.8 (1.37)	41.9 (1.65)	41.9 (1.65)	41.9 (1.65)	41.9 (1.65)	41.9 (1.65)	41.9 (1.65)	55.9 (2.20)	55.9 (2.20)	55.9 (2.20)	66.5 (2.62)	82.6 (3.25)

Table 3. Properties of Non-Heat-Sealable Kapton® Films

Property	Product Designation					Method
	100HN	200HN	300HN	100CRC	200CRC	
Minimum MD Ultimate Tensile Strength, kpsi (Mpa)	26 (179)	27 (186)	26 (179)	26 (179)	17 (117)	ASTM D882
Minimum MD Ultimate Elongation, %	55	55	55	55	35	ASTM D882
Minimum Dielectric Strength, V/mil (kV/mm)	6200 (244)	5000 (197)	4000 (157)	6000 (236)	4500 (177)	ASTM D149 6.4 mm (1/4 in) electrodes
Typical Volume Resistivity, ohm·cm	10 ¹⁷	10 ¹⁷	10 ¹⁷	10 ¹⁷	10 ¹⁵	ASTM D257
Typical Dielectric Constant (@ 1 kHz)	3.4	3.4	3.5	3.4	4	ASTM D150
Typical Dissipation Factor (@ 1 kHz)	0.002	0.002	0.002	0.003	0.003	ASTM D150

Note: If your product is not shown in this table, please contact your local DuPont™ Kapton® film representative.

Table 4. Properties of Heat-Sealable Kapton® Films

Property	Product Designation												Method
	120FWN616B	150FN019	150FCRC019	150FWN019	150FWR019	150PRN411	150XP019	200FN919	200PRT919	200FWR919	250FN029	300FN929	
Minimum Machine Direction Ultimate Elongation, %	60	60	55	65	45	60	60	60	50	45	50	60	ASTM D882
Minimum Dielectric Strength, V/mil (kV/mm)	5300 (209)	4300 (169)	3600 (142)	4400 (173)	4400 (173)	4300 (169)	3800 (150)	3600 (142)	4000 (157)	3600 (142)	3100 (122)	3300 (108)	ASTM D149 1/4 in (6.4 mm) electrodes
Minimum Heat Seal Peel Strength, Fluoropolymer to Fluoropolymer gm/in (N/cm)	750 (2.9)	800 (3.1)	-	-	-	-	800 (3.1)	800 (3.1)	800 (3.1)	750 (2.9)	-	800 (3.1)	ASTM D5213
Minimum Heat Seal Peel Strength Fluoropolymer to Kapton® gm/in (N/cm)	-	650 (2.5)	700 (2.7)	700 (2.7)	750 (2.9)	500* (1.9)	650 (2.5)	-	-	-	725 (2.8)	-	

*Minimum Heat Seal Peel Strength Fluoropolymer to Copper gm/in (N/cm)

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Cores

Cores shall be of sufficient strength to prevent collapsing during normal handling.

Core Type

	ID	Core Material
Pad	38 mm (1.5 in)	Plastic
	76 mm (3 in)	Paper or Plastic

	ID	Core Width	Core Material
Universal & Step-Pac®	76 mm (3 in)	70 mm (2-3/4 in)	Paper or Plastic
	76 mm (3 in)	111 mm (4-3/8 in)	Paper or Plastic

Core Width Tolerance

Roll Width	Tolerance
2 to 102 mm (5/64 to 4 in)	-0 to +0.8 mm (-0 to +1/32 in)
103 mm to max. (4-1/16 in to max.)	-0 to +1.6 mm (-0 to +1/16 in)

Roll Configurations

Kapton® polyimide film is supplied in three types of put-ups: Step-Pac®, universal wind, and pad wind, described below.

Step-Pac®

- Film shall be centered on the core to ± 4.8 mm ($\pm 3/16$ in).
- Film shall not project from the main body of the roll more than 3 mm (1/8 in).
- The outside and starting ends of the film shall be fastened in such a manner as to prevent unwinding.
- Width of traverse can be either 65 mm (2-1/2 in) or 105 mm (4-1/8 in).

Universal Wind

- Film shall be centered on the core to ± 4.8 mm ($\pm 3/16$ in).
- Film shall not project from the main body of the roll more than 3 mm (1/8 in).
- The outside and starting ends of the film shall be fastened in such a manner as to prevent unwinding.
- Width of traverse can be either 44 mm (1-3/4 in) or 100 mm (4 in).

Pad Wind

- Core width shall be film width +3 mm (+1/8 in), -0 mm (-0 in).
- Core edges shall not project more than 1.6 mm (1/16 in) beyond roll face on either side.
- Core shall not be recessed on either side.
- The outside and starting ends of the film shall be fastened in such a manner as to prevent unwinding.
- "Dishing" or "cupping" shall not exceed 1.6 mm (1/16 in), measured with a straight edge across the diameter of the roll.

Standard Put-Ups

- Standard put-ups for different roll types are given in **Table 5**.

Table 5. Put-Ups for Different Roll Types

Roll type	ID	OD
Pad	76 mm (3 in)	241 mm (9.5 in)
Universal	76 mm (3 in)	152 mm (6 in)*
		203 mm (8 in)*
		292 mm (11.5 in)*
Step-Pac®	76 mm (3 in)	152 mm (6 in)*
		203 mm (8 in)*
		292 mm (11.5 in)*

* depending on width

Other put-ups can be made available upon request. Please consult your DuPont sales representative for Kapton®.

Film Width

The minimum width of film wound on pads is 9.5 mm (3/8 in). Universal winding is available for film widths from 3.2 mm (1/8 in) to 22.2 mm (7/8 in).

The Step-Pac® is available for film widths from 3.2 mm (1/8 in) to 38.1 mm (1-1/2 in).

The increments in width are 1.6 mm (1/16 in).

Width Tolerance

	Slit Width Range	Tolerance
Pad Rolls	9.5 to 38 mm (3/8 to 1-1/2 in)	± 0.18 mm (7 mil)
	38 to 102 mm (1-1/2 to 4 in)	± 0.76 mm (30 mil)
	>102 mm (4 in)	± 1.52 mm (60 mil)
Universal	3.2 to 22.2mm (1/8 to 7/8 in)	± 0.20 mm (8 mil)
Step-Pac®	3.2 to 38.1mm (1/8 to 1-1/2 in)	± 0.20 mm (8 mil)

Weight Tolerance

Weight Ordered	Tolerance
0.45–4.54 kg (1–10 lb)	$\pm 20\%$
>4.54 kg (>10 lb)	$\pm 10\%$

Table 6. Minimum Average Splice Free Length for Common Kapton® Films

Roll Type	Core ID	Roll OD	Product Designation				
			100HN 100CRC	120FWN616B	150FN019 150FCRC019 150FWN019 150FWR019 150PRN411 150XP019	200HN 200CRC 200PRT919	300HN
	mm	mm	Meters				
Step-Pac®	76	152	610	610	610	304	152
		203	610	610	610	304	152
		292	610	610	610	304	152
Universal	76	152	610	610	610	304	152
		203	610	610	610	304	152
		292	610	610	610	304	152
Pad	76	240	195	107	107	102	102
	in	in	Feet				
Step-Pac®	3	6	2000	2000	2000	1000	500
		8	2000	2000	2000	1000	500
		11.5	2000	2000	2000	1000	500
Universal	3	6	2000	2000	2000	1000	500
		8	2000	2000	2000	1000	500
		11.5	2000	2000	2000	1000	500
Pad	3	9.5	640	350	350	335	335

Splice Options

A variety of splices are available:

- Heat seal (limited to 305 mm [12 in] width or less).
- Kapton® polyimide film-based pressure-sensitive tape.
- Mylar® polyester film-based pressure-sensitive tape.
- The minimum average distance between splices is shown in **Tables 6 and 7**. To calculate the maximum number of splices in a roll, divide the roll length by the minimum average length and subtract one.

Heat seal splices shall be made as follows: On all films but Kapton® 250FN029, the splice is an overlap splice a minimum of 15 mm (19/32 in) long. Overlap heat seal splices are oriented with the leading edge of the new film on the bottom for universal and pad rolls for two-sided FEP structures. Pad rolls of one-sided FEP composites have the leading edge on the top. On 250FN029, a butt splice is made using Kapton® 120FN616 as the joining tape applied on the FEP surface. The 250FN029 butt splice is oriented with the 120FN616 tape on the top of the film as it unwinds from universal or Step-Pac® rolls and on the bottom as it unwinds from pad rolls.

Pressure-sensitive splices shall be made as follows: A butt splice is made with the film ends covered on both sides with splice tape. For all films, a 50 mm (2 in) wide pressure-sensitive tape will be used.

Splices shall be sufficiently smooth and wrinkle-free, so that adjacent layers of film are not disturbed and approximately centered to ±6 mm (±1/4 in).

No splices will be made after the roll has reached minimum OD.

Packaging

Kapton® film shall be adequately packed to prevent loss of contents or damage during routine shipment. All film will be wrapped with a non-fibrous material.

Marking & Labeling

Kapton® is identified as described in **Table 8** to allow traceability back to the raw materials and processing conditions.

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Table 7. Minimum Length Between Splices and/or Beginning and End of Roll for Common Kapton® Films

Roll Type	Core ID	Roll OD	Product Designation				
			100HN 100CRC	120FWN616B	150FN019 150FCRC019 150FWN019 150FWR019 150PRN411 150XP019	200HN 200CRC 200PRT919	300HN
	mm	mm	Meters				
Step-Pac®	76	152	30	46	46	30	30
		203	30	46	46	30	30
		292	30	46	46	30	30
Universal	76	152	30	46	46	30	30
		203	30	46	46	30	30
		292	30	46	46	30	30
Pad	76	240	30	30	30	30	30
	in	in	Feet				
Step-Pac®	3	6	100	150	150	100	100
		8	100	150	150	100	100
		11.5	100	150	150	100	100
Universal	3	6	100	150	150	100	100
		8	100	150	150	100	100
		11.5	100	150	150	100	100
Pad	3	9.5	100	100	100	100	100

Table 8. Information Contained on Labels

	Label Type		
	Container / Pallet	Carton / Box	Roll / Core
Customer Reference No.	X	X	X ¹
DuPont Order No.	X	X	X
Gage & Type	X	X	X
Width	X	X	X
No. of Rolls	X	X	
Net Weight	X	X	
Effective Length		X	X
Roll Number		X ²	X
ID and OD ³	X	X	X

¹ Available upto 12 characters

² Maximum displayed 12 per carton

³ Nominal core ID & roll OD

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For more information on DuPont™ Kapton® polyimide films or other DuPont products, please visit our website.

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EI-10139 (7/20)