DuPont™ Kapton®

POLYIMIDE FILM

MOTOR AND MAGNET WIRE INDUSTRY 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 and procedures are included 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 incorrectly interpreted as being representative of "actual/typical" values. Therefore, if you require typical value data, please contact your DuPont marketing or technical representative for Kapton®. 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. In very thin sections, Kapton® conserves 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, and lubricants. 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 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, and 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 marketing representative for Kapton®.

Kapton® CR Film

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

Kapton® CR is available in standard thicknesses of 25, 50 and 75 µm (1, 2 and 3 mil). Additional thicknesses can be made available by special request. Please contact your DuPont Films marketing 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.

Although Kapton® WR is available in the standard thickness of 25 µm (1 mil), additional thicknesses can be made available by special request. Please contact your DuPont marketing representative for Kapton®.

Heat-Sealable Kapton® Films

Heat-sealable Kapton® films are used as primary insulation on magnet wire. These films are coated with or laminated to Teflon® FEP 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 to itself. The heat-sealable films are designated FN, FCR, FWN, and FWR. **Table 1** lists heat-sealable films typically used in this industry, which are UL listed as 240°C for electrical properties. Other types can be made available. Please consult your DuPont marketing representative for Kapton®.

Certification

Kapton® is certified to meet the requirements of specification ASTM D-5213 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 routinely 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 2** and **3** 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). This conforms to the "Elongation, %, after 2 hours 400°C (752°F)" requirement of MIL-P-46112B (MR). (See **Table 2**.)

Under their file number E 39505 for Kapton®, Underwriters Laboratory Inc. lists a thermal index of 220–240°C (428–464°F), depending on gauge and type, for electrical properties, and 200–220°C (392–428°F) for mechanical properties.

Thickness

Test Method

Table 4 lists thickness of Kapton® films, measured in accordance with ASTM D-374-94, Method A or C.

The average of ten randomly selected readings from a minimum area 77 cm^2 (12 in^2) 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)		
	Teflon® FEP	Kapton® HN	Teflon® FEP
120FN616B	3.8 (0.15)	25 (1.00)	3.8 (0.15)
150FN019		25 (1.00)	12.5 (0.50)
150FWN019		25 (1.00)	12.5 (0.50)
200FN919	12.5 (0.50)	25 (1.00)	12.5 (0.50)
250FN029		50 (2.00)	12.5 (0.50)
300FN929	12.5 (0.50)	50 (2.00)	12.5 (0.50)
	Teflon® FEP	Kapton® CR	Teflon® FEP
150FCR019		25 (1.00)	12.5 (0.50)
	Teflon® FEP	Kapton® WR	Teflon® FEP
150FWR019		25 (1.00)	12.5 (0.50)
200FWR919	12.5 (0.50)	25 (1.00)	12.5 (0.50)

* Commonly used in magnet wire and covered in this bulletin.
See General Product Bulletin for details regarding other Type FN films.

Table 2. Properties of Non-Heat-Sealable Kapton® Films

Property	Product Designation							Method
	100HN	200HN	300HN	100CR	200CR	300CR	100WR	
Minimum Machine Direction Ultimate Tensile Strength, MPa (kpsi)	179 (26)	179 (26)	179 (26)	110 (16)	117 (17.0)	117 (17.0)	179 (26)	ASTM D-882-91, Method A using a tensile tester (specimen size: 13 × 150 mm [1/2 × 6 in]; jaw separation: 100 mm [4 in]; jaw speed: 50 mm [2 in] min.). Calculate the average of five specimens based on original measured thickness at 23°C (73°F).
Minimum Machine Direction Ultimate Elongation, %	55	55	55	35	35	35	45	Same as above method.
Maximum Machine Direction Shrinkage, %	2.5	2.5	2.5	2.5	2.5	2.5	2.5	MIL-P-46112B (MR). The percent shrinkage is obtained by using the average of three measurements before and after conditioning. Prior to measurement, the 215 × 280 mm (8-1/2 × 11 in) specimen is conditioned by freely suspending for 2 hr in an oven controlled to 400 ±2°C (752 ±3.6°F).
Minimum Dielectric Strength, kV/mm (V/mil)	236 (6,000)	217 (5,500)	177 (4,500)	197 (5,000)	177 (4,500)	177 (4,500)	197 (5,000)	ASTM D-149-94. (Average of 10 specimens.) Flat sheets in air placed between 6.4 mm (1/4 in) diameter brass electrodes with 0.8 mm (1/32 in) edge radius subjected to 60 cycles AC voltage at 500 V/sec rate of rise to the breakdown voltage.
Minimum Volume Resistivity, ohm·cm at 200°C (392°F)	10^{12}	10^{12}	10^{12}	10^{12}	10^{12}	10^{12}	10^{12}	ASTM D-257-93
Typical Dielectric Constant	3.4	3.4	3.4	3.4	4.0	4.0	3.9	ASTM D-150-94. Use conducting silver paint electrodes, two terminal system of measurement at standard conditions. Results are based on an average of five tests using measured thickness of specimens. Measure at 1 kHz/sec.
Typical Dissipation Factor	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	Same as above method.

Note: If your product is not shown in this table, please contact your local representative.

Table 3. Properties of Heat-Sealable Kapton® Films

Property	Product Designation									Method
	120FN 616B	150FN 019	150FWN 019	200FN 919	250FN 029	300FN 929	150FCR 019	150FWR 019	200FWR 919	
Minimum Machine Direction Ultimate Elongation, %	55	55	55	55	55	55	35	45	45	ASTM D-882-91, Method A using a tensile tester (specimen size: 13 × 150 mm [1/2 × 6 in]; jaw separation: 100 mm [4 in]; jaw speed: 50 mm [2 in] min.). Calculate the average of five specimens based on original measured thickness at 23°C (73°F).
Minimum Dielectric Strength, kV/mm (V/mil)	197 (5,000)	157 (4,000)	157 (4,000)	130 (3,300)	110 (2,800)	108 (2,750)	130 (3,300)	157 (4,000)	130 (3,300)	ASTM D-149-94. (Average of 10 specimens.) Flat sheets in air placed between 6.4 mm (1/4 in) diameter brass electrodes with 0.8 mm (1/32 in) edge radius subjected to 60 cycles AC voltage at 500 V/sec rate of rise to the breakdown voltage.
Minimum Heat Seal Peel Strength, N·cm (lb·in) Teflon® to Teflon® N·cm (lb·in) Teflon® to Kapton® N·cm (lb·in)	 2.3 (1.32) NA	 NA 2.3 (1.32)	 NA 2.3 (1.32)	 3.5 (1.98) NA	 NA 3.5 (1.98)	 3.5 (1.98) NA	 NA 2.1 (1.20)	 NA 2.3 (1.32)	 3.5 (1.98) NA	The heat seal peel strength between the coated and uncoated side of one-side coated Kapton® or the coated to coated side of one or two-sided coated Kapton® is measured in the following manner. Seals are made in a jaw sealer at 350°C (662°F), 138 kPa (20 psi), 20 sec dwell time. After cooling, the seals are cut to 25 mm (1 in) wide strips using a Thwing-Albert JDC sample cutter or equivalent. The strength of the seal is measured with a tensile tester. Seal strength is defined as the peak instantaneous strength occurring in each seal. Five specimen values are averaged.
As-Received Seal Peel Strength, N·cm (lb·in)	NA	0.98 (0.55)	0.98 (0.55)	0.98 (0.55)	0.98 (0.55)	0.98 (0.55)	0.80 (0.45)	0.98 (0.55)	0.98 (0.55)	180° peel in a tensile tester at 23°C (73°F).

Note: If your product is not shown in this table, please contact your local representative.

Table 4. Thickness of Kapton® Films

Thickness	Product Designation														
	100HN	200HN	300HN	120FN 616B	150FN 019	200FN 919	250FN 029	300FN 929	100CR	200CR	300CR	150FCR 019	100WR	150FWR 019	200FWR 919
Nominal, µm (mil)	25.4 (1.0)	50.8 (2.0)	76.2 (3.0)	33.0 (1.3)	38.1 (1.5)	50.8 (2.0)	63.5 (2.5)	76.2 (3.0)	25.4 (1.0)	50.8 (2.0)	76.2 (3.0)	38.1 (1.5)	25.4 (1.0)	38.1 (1.5)	50.8 (2.0)
Minimum, µm (mil)	22.8 (0.90)	47.0 (1.85)	69.8 (2.75)	31.0 (1.22)	34.3 (1.35)	45.7 (1.80)	60.4 (2.38)	69.8 (2.75)	22.8 (0.90)	47.0 (1.85)	69.8 (2.75)	34.3 (1.35)	22.8 (0.90)	34.3 (1.35)	45.7 (1.80)
Maximum, µm (mil)	28.7 (1.13)	55.9 (2.20)	82.6 (3.25)	34.8 (1.37)	41.9 (1.65)	55.9 (2.20)	66.5 (2.26)	82.6 (3.25)	28.7 (1.13)	55.9 (2.20)	82.6 (3.25)	41.9 (1.65)	28.7 (1.13)	41.9 (1.65)	55.9 (2.20)

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
	152 mm (6 in)	Paper or Plastic

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

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 (±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.
- Roll face depression, the difference between the highest and lowest points unstressed, shall not exceed 4.8 mm (3/16 in).
- 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 (±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.
- Roll face depression, the difference between the highest and lowest points unstressed, shall not exceed 4.8 mm (3/16 in).
- 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
Step-Pac®	76 mm (3 in)	152 mm (6 in)*
	76 mm (3 in)	203 mm (8 in)*
	76 mm (3 in)	292 mm (11.5 in)*
Universal	76 mm (3 in)	152 mm (6 in)*
	76 mm (3 in)	203 mm (8 in)*
	76 mm (3 in)	292 mm (11.5 in)*
Pad	76 mm (3 in)	152 mm (6 in)
	76 mm (3 in)	241 mm (9.5 in)
	152 mm (6 in)	280 mm (11 in)

*depending on width

Other put-ups can be made available upon request. Please consult your DuPont™ marketing 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	
<38 mm (1-1/2 in)	± 0.18 mm (7 mil)
38 to 102 mm (1-1/2–4 in)	± 0.76 mm (30 mil)
>102 mm (4 in)	± 1.52 mm (60 mil)
Universal	± 0.20 mm (8 mil)

Weight Tolerance

Weight Ordered	Tolerance
0.4536–4.536 kg (1–10 lb)	±20%
4.536–45.36 kg (10–100 lb)	±10%
>45.36 kg (>100 lb)	±5%

Splice Options

A variety of splices is 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.

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

Roll Type	Core ID	Roll OD	Product Designation			
			100HN 100CR 100WR	150FN019 150FCR019 150FWR019 150FWN019	200HN 200CR	300HN 300CR
	mm	mm	Meters			
Step-Pac®	76	152	610	610	304	152
		203	610	610	304	152
		305	610	610	304	152
Universal	76	152	610	610	304	152
		203	610	610	304	152
		305	610	610	304	152
Pad	76	152	154	50	61	61
		240	195	107	102	102
	in	in	Feet			
Step-Pac®	3	6	2,000	2,000	1,000	500
		8	2,000	2,000	1,000	500
		12	2,000	2,000	1,000	500
Universal	3	6	2,000	2,000	1,000	500
		8	2,000	2,000	1,000	500
		12	2,000	2,000	1,000	500
Pad	3	6	505	165	200	200
		9-1/2	640	350	335	335

Heat seal splices shall be made as follows: On all films but Kapton® 250FN029, the splice is an overlap splice a minimum of 10 mm (3/8 in) long. On 250FN029, a butt splice is made using Kapton® 120FN616 as the joining tape applied on the FEP surface.

- 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.
- 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® 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

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

Table 8. Information Contained on Labels

	Container	Shipping Package	Core Label[1]
Scheduled Date	X	X	X
Customer Order Number	X	X	X[2]
DuPont Order Number	X	X	X
Gauge	X	X	X
Type	X	X	X
Width	X	X	X
No. of Rolls per Container	X	X	
Net Weight	X	X	
Footage			X
Mill Roll Number	X	X	
ID and OD[3]	X	X	

[1] Affixed to the core on all cores, 57 mm (2-1/4 in) wide and over; include with the package on all cores less than 57 mm (2-1/4 in) wide.

[2] Available for up to 12 characters.

[3] Inside diameter of core and nominal outside diameter of roll.

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 100CR 100WR	150FN019 150FCR019 150FWR019 150FWN019	200HN 200CR	300HN 300CR
	mm	mm	Meters			
Step-Pac®	76	152	30	46	30	30
		203	30	46	30	30
		305	30	46	30	30
Universal	76	152	30	46	30	30
		203	30	46	30	30
		305	30	46	30	30
Pad	76	152	30	30	30	30
		240	30	30	30	30
	in	in	Feet			
Step-Pac®	3	6	100	150	100	100
		8	100	150	100	100
		12	100	150	100	100
Universal	3	6	100	150	100	100
		8	100	150	100	100
		12	100	150	100	100
Pad	3	6	100	100	100	100
		9-1/2	100	100	100	100

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