DuPont™ Kapton®

Summary of Properties

DuPont™ Kapton® is used in applications such as the solar array and for thermal management in the United States space program.

DUPONT™ KAPTON® SUMMARY OF PROPERTIES

GENERAL INFORMATION

Kapton® polyimide film possesses a unique combination of properties that make it ideal for a variety of applications in many different industries. The ability of Kapton® to maintain its excellent physical, electrical, and mechanical properties over a wide temperature range has opened new design and application areas to plastic films. Kapton® is synthesized by polymerizing an aromatic dianhydride and an aromatic diamine. It has excellent chemical resistance; there are no known organic solvents for the film. Kapton® is self extinguishing as it has the highest UL-94 flammability rating: V-0. The outstanding properties of Kapton® permit it to be used at both high and low temperature extremes where other organic polymeric materials would not be functional. Adhesives are available for bonding Kapton® to itself and to metals, various paper types, and other films. Kapton® polyimide film can be used in a variety of electrical and electronic insulation applications: wire and cable tapes, formed coil insulation, substrates for flexible printed circuits, motor slot liners, magnet wire insulation, transformer and capacitor insulation, magnetic and pressure-sensitive tapes, and tubing. Many of these applications are based on the excellent balance of electrical, thermal, mechanical, physical, and chemical properties of Kapton® over a wide range of temperatures. It is this combination of useful properties at temperature extremes that makes Kapton® a unique industrial material.

Three types of Kapton® are described in this bulletin:

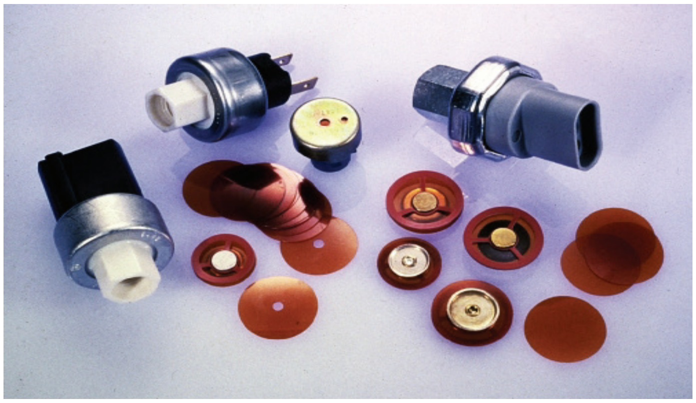
- Kapton® Type HN, all-polyimide film, has been used successfully in applications at temperatures as low as -269°C (-452°F) and as high as 400°C (752°F). Type HN film can be laminated, metallized, punched, formed, or adhesive coated. It is available as 7.5 µm (0.3 mil), 12.5 µm (0.5 mil), 25 µm (1 mil), 50 µm (2 mil), 75 µm (3 mil), and 125 µm (5 mil) films.
- Kapton® Type HPP-ST, all-polyimide film with all of the properties of Type HN, plus superior dimensional stability and modified surface for better adhesion. Type HPP-ST is available as 12.5 µm (0.5 mil), 25 µm (1 mil), 50 µm (2 mil), 75 µm (3 mil), and 125 µm (5 mil) films.
- Kapton® Type FN, a Type HN film coated or laminated on one or both sides with FEP fluoropolymer resin, imparts heat sealability, provides a moisture barrier, and enhances chemical resistance. Type FN is available in a number of combinations of polyimide and FEP thicknesses (see **Table 16**).

Note: In addition to these three types of Kapton®, films are available with the following attributes:

- Antistat
- Thermally conductive
- Polyimides for fine line circuitry
- Cryogenic insulation
- Corona resistant
- Pigmented for color
- Conformable
- Other films tailored to meet customers' needs

Data for these films are covered in separate product bulletins, which can be obtained from your DuPont representative.

Kapton® withstands the harsh chemical and physical demands on diaphragms used in automotive switches.



Kapton® polyimide films retain their physical properties over a wide temperature range. They have been used in field applications where the environmental temperatures were as low as -269°C (-52°F) and as high as 400°C (752°F). Complete data are not available at these extreme conditions, and the majority of technical data presented in this section falls in the 23 to 200°C (73 to 392°F) range.

DUPONT™ KAPTON® SUMMARY OF PROPERTIES

Table 1. Physical Properties of Kapton® Type 100 HN Film, 25µm (1 mil)

Physical Property	Typical Value at 23°C (73°F)	Typical Value at 200°C (392°F)	Test Method
Ultimate Tensile Strength, MPa (psi)	231 (33,500)	138 (20,000)	ASTM D-882-91, Method A*
Yield Point at 3%, MPa (psi)	69 (10,000)	41 (6000)	ASTM D-882
Stress to Produce 5% Elongation, MPa (psi)	90 (13,000)	62 (9,000)	ASTM D-882
Ultimate Elongation, %	72	83	ASTM D-882
Tensile Modulus, GPa (psi)	2.76 (400,000)	2.0 (290,000)	ASTM D-882
Impact Strength, N•cm (ft•lb)	78		(0.58) DuPont Pneumatic Impact Test
Folding Endurance (MIT), cycles	285,000		ASTM D-2176
Tear Strength—Propagating (Elmendorf), N (lbf)	0.07 (0.02)		ASTM D-1922
Tear Strength—Initial (Graves), N (lbf)	7.2 (1.6)		ASTM D-1004
Density, g/cc or g/mL	1.42		ASTM D-1505
Coefficient of Friction—Kinetic (Film-to-Film)	0.48		ASTM D-1894
Coefficient of Friction—Static (Film-to-Film)	0.63		ASTM D-1894
Refractive Index (Sodium D Line)	1.70		ASTM D-542
Poisson's Ratio	0.34		Avg. Three Samples Elongated at 5%, 7%, 10%
Low Temperature Flex Life	Pass		IPC TM 650, Method 2.6.18

*Specimen Size: 225 x 150 mm (1 x 6 in); Jaw Separation: 100 mm (4 in); Jaw Speed: 50 mm/min (2 in/min); Ultimate refers to the tensile strength and elongation measured at break.

Table 2. Thermal Properties of Kapton® Type 100 HN Film, 25 µm (1 mil)

Thermal Property	Typical Value	Test Condition	Test Method
Melting Point	None	None	ASTM E-794 (1989)
Thermal Coefficient of Linear Expansion	20 ppm/°C (11 ppm/°F)	-14 to 38°C (7 to 100°F)	ASTM D-696
Coefficient of Thermal Conductivity, W/m•K (cal/sec-cm-°C)	0.20 (4.8×10^{-4})	296 K (23°C)	ASTM D5470
Specific Heat, J/g•K (cal/g•°C)	1.09 (0.261)		Differential Calorimetry
Flammability	94V-0		UL-94 (2-8-85)
Shrinkage, %	0.17 1.25	30 min at 150°C 120 min at 400°C	IPC TM 650, Method 2.2.4A ASTM D-5214
Heat Sealability	Not Heat Sealable		
Limiting Oxygen Index, %	37		ASTM D-2863
Solder Float	Pass		IPC TM 650, Method 2.4.13A
Smoke Generation	DM = <1	NBS Smoke Chamber	NFPA-258
Glass Transition Temperature (T_g)	A second order transition occurs in Kapton® between 360°C (680°F) and 410°C (770°F) and is assumed to be the glass transition temperature. Different measurement techniques produce different results within the above temperature range.		

DUPONT™ KAPTON® SUMMARY OF PROPERTIES

Table 3. Physical and Thermal Properties of Kapton® Type HPP-ST Film

Property	Typical Value for Film Thickness				Test Method
	25 µm (1 mil)	50 µm (2 mil)	75 µm (3 mil)	125 µm (5 mil)	
Ultimate Tensile Strength, MPa (psi)	231 (33,500)	234 (34,000)	231 (33,500)	231 (33,500)	ASTM D-882
Ultimate Elongation, %	72	82	82	82	ASTM D-882
Tear Strength—Propagating (Elmendorf), N	0.07	0.21	0.38	0.58	ASTM D-1922
Tear Strength—Initial (Graves), N	7.2	16.3	26.3	46.9	ASTM D-1004
Folding Endurance (MIT), $\times 10^3$ cycles	285	55	6	5	ASTM D-2176
Density, g/cc or g/mL	1.42	1.42	1.42	1.42	ASTM D-1505
Flammability	94V-0	94V-0	94V-0	94V-0	UL-94 (2-8-85)
Shrinkage, %, 30 min at 150°C (302°F)	0.03	0.03	0.03	0.03	IPC TM 650 Method 2.2.4A
Limiting Oxygen Index, %	37	43	46	45	ASTM D-2863

Table 4. Physical Properties of Kapton® Type FN Film*

Property	Typical Value for Film Type**		
	120FN616	150FN019	250FN029
Ultimate Tensile Strength, MPa (psi) 23°C (73°F) 200°C (392°F)	 207 (30,000) 121 (17,500)	 162 (23,500) 89 (13,000)	 200 (29,000) 115 (17,000)
Yield Point at 3%, MPa (psi) 23°C (73°F) 200°C (392°F)	 61 (9000) 42 (6000)	 49 (7000) 43 (6000)	 58 (8500) 36 (5000)
Stress at 5% Elongation, MPa (psi) 23°C (73°F) 200°C (392°F)	 79 (11,500) 53 (8000)	 65 (9,500) 41 (6000)	 76 (11,000) 48 (7000)
Ultimate Elongation, % 23°C (73°F) 200°C (392°F)	 75 80	 70 75	 85 110
Tensile Modulus, GPa (psi) 23°C (73°F) 200°C (392°F)	 2.48 (360,000) 1.62 (235,000)	 2.28 (330,000) 1.14 (165,000)	 2.62 (380,000) 1.38 (200,000)
Impact Strength at 23°C (73°F), N•cm (ft•lb)	78 (0.58)	68.6 (0.51)	156.8 (1.16)
Tear Strength—Propagating (Elmendorf), N (lbf)	0.08 (0.02)	0.47 (0.11)	0.57 (0.13)
Tear Strength—Initial (Graves), N (lbf)	11.8 (2.6)	11.5 (2.6)	17.8 (4.0)
Polyimide, wt% FEP, wt%	80 20	57 43	73 27
Density, g/cc or g/mL	1.53	1.67	1.57

*Test methods for **Table 4** are the same as for **Table 1**.

**Because a number of combinations of polyimide film and fluorocarbon coating add up to the same total gauge, it is necessary to distinguish among them. A three-digit system is used in which the middle digit represents the nominal thickness of the base Kapton® film in mils. The first and third digits represent the nominal thickness of the coating of FEP fluoropolymer resin in mils. The symbol 9 is used to represent 13 µm (0.5 mil) and 6 to represent 2.5 µm (0.1 mil). Example: 120FN616 is a 120-gauge structure consisting of a 25 µm (1 mil) base film with a 2.5 µm (0.1 mil) coating on each side.

DUPONT™ KAPTON® SUMMARY OF PROPERTIES

MECHANICAL PROPERTIES

The usual values of tensile strength, tensile modulus, and ultimate elongation at various temperatures can be obtained from the typical stress–strain curves shown in **Figures 1 and 2**. Such properties as tensile strength and modulus are inversely proportional to temperature, whereas elongation reaches a maximum value at about 300°C (570°F). Other factors, such as humidity, film thickness, and tensile elongation rates, were found to have only a negligible effect on the shape of the 23°C (73°F) curve.

Figure 1. Tensile Stress–Strain Curves, Type HN Film, 25 µm (1 mil)

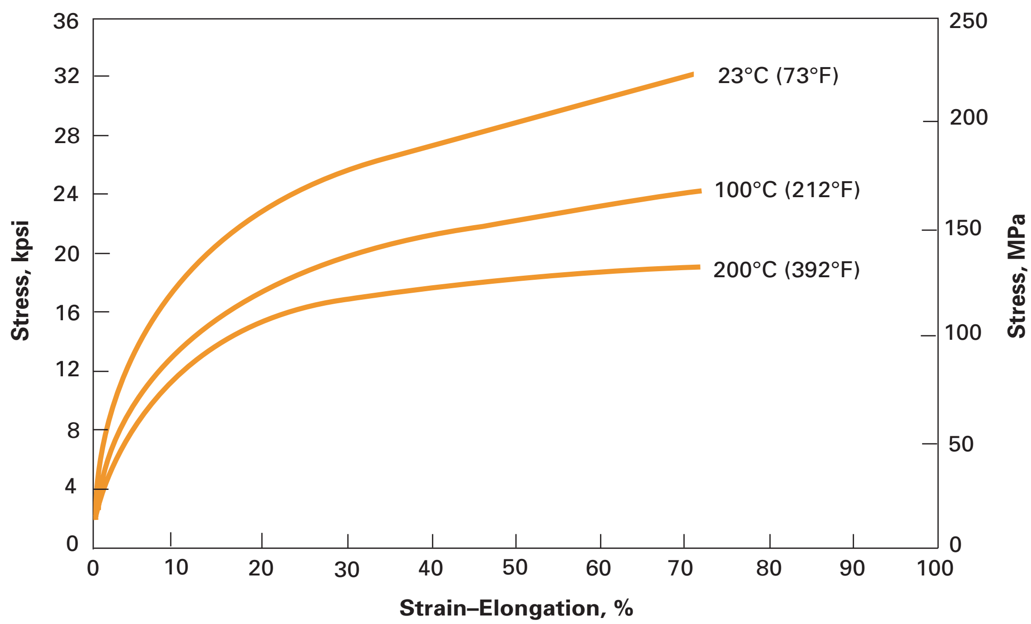
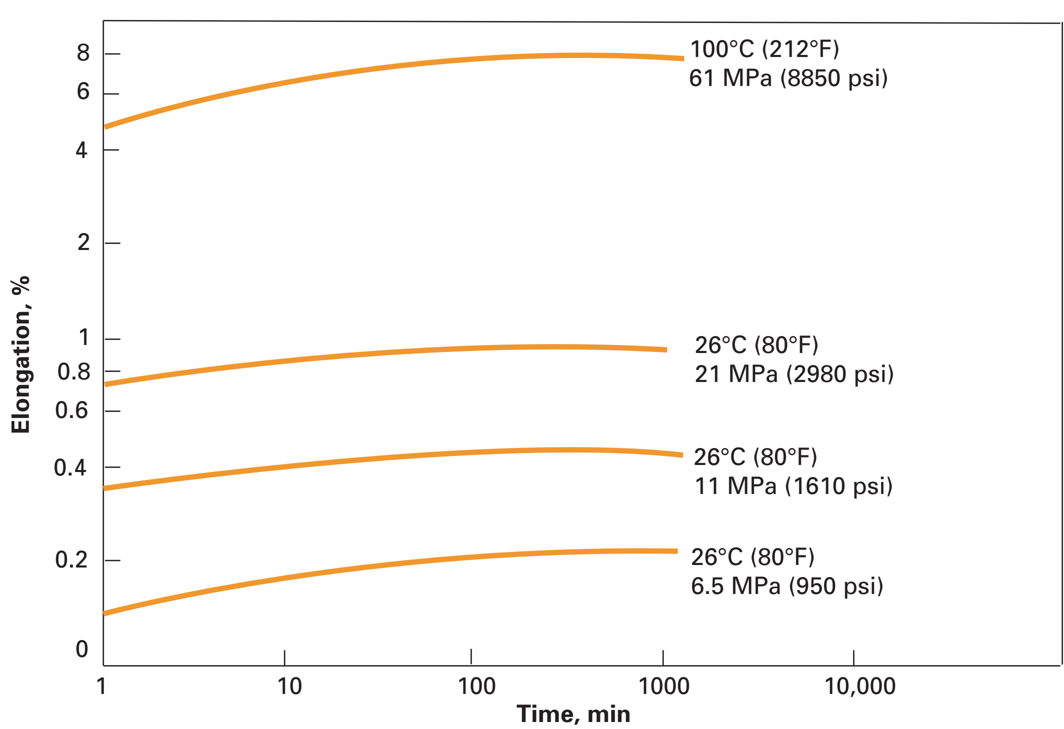


Figure 2. Tensile Creep Properties, Type HN Film, 25 µm (1 mil)



DUPONT™ KAPTON® SUMMARY OF PROPERTIES

HYDROLYTIC STABILITY

Kapton® polyimide film is made by a condensation reaction; therefore, its properties are affected by water. Although long-term exposure to boiling water, as shown in the curves in **Figures 3** and **4**, will reduce the level of film properties, sufficient tensile and elongation remain to ensure good mechanical performance. A decrease in the temperature and the water content will reduce the rate of Kapton® property reduction, whereas higher temperature and pressure will increase it.

Figure 3. Tensile Strength After Exposure to 100°C (212°F) Water, Type HN Film, 25 µm (1 mil)

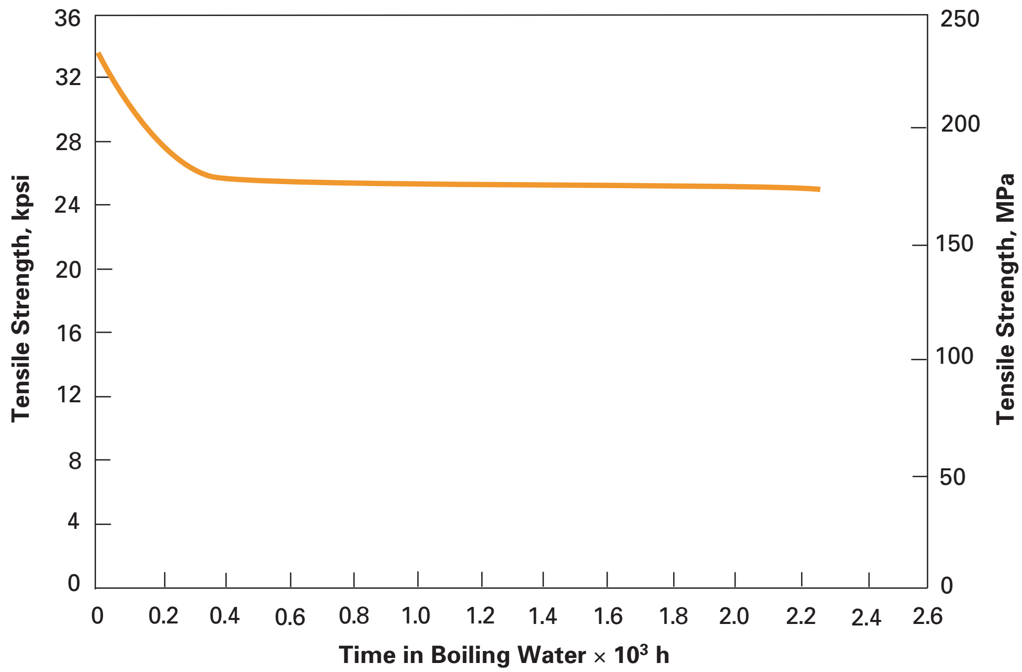
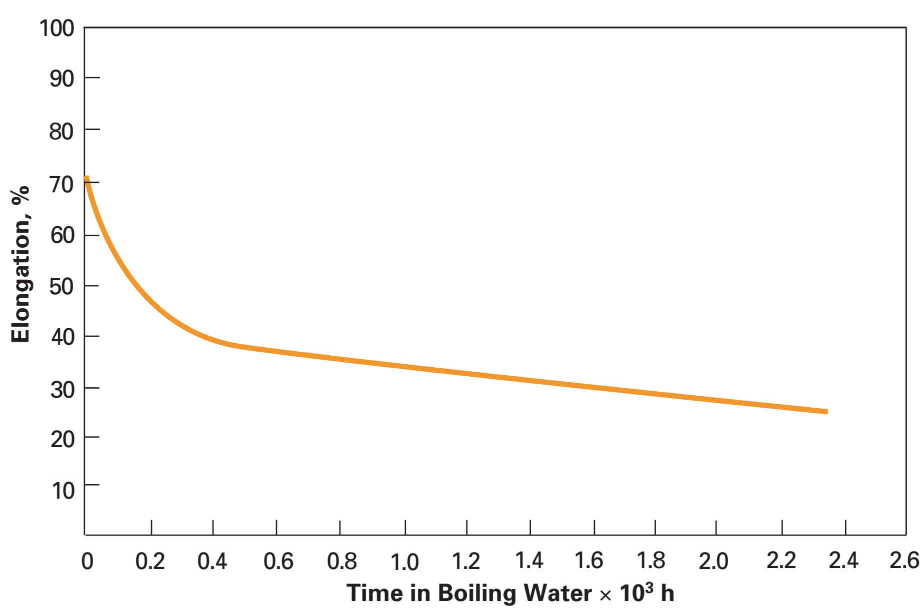


Figure 4. Ultimate Elongation After Exposure to 100°C (212°F) Water, Type HN Film, 25 µm (1 mil)



DUPONT™ KAPTON® SUMMARY OF PROPERTIES

DIMENSIONAL STABILITY

The dimensional stability of Kapton® polyimide film depends on two factors—the normal coefficient of thermal expansion and the residual stresses placed in the film during manufacture. The latter causes Kapton® to shrink on its first exposure to elevated temperatures as indicated in the bar graph in **Figure 5**. Once the film has been exposed, the normal values for the thermal coefficient of linear expansion as shown in **Table 5** can be expected.

Figure 5. Residual Shrinkage vs. Exposure Temperature and Thickness, Type HN and HPP-ST Films

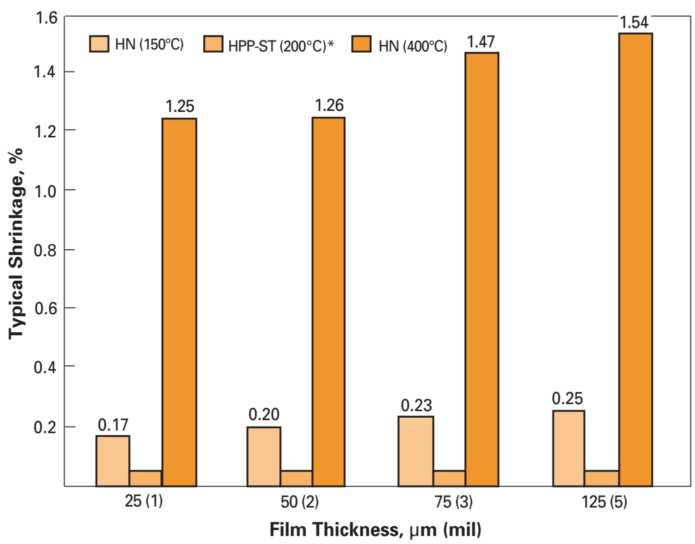


Table 5. Thermal Coefficient of Expansion, Type HN Film, 25 µm (1 mil), Thermally Exposed

Temperature Range, °C (°F)	ppm/°C
30–100 (86–212)	17
100–200 (212–392)	32
200–300 (392–572)	40
300–400 (572–752)	44
30–400 (86–752)	34

THERMAL AGING

The useful life of Kapton® polyimide film is a function of both temperature and oxygen concentration. In accordance with UL-746B test procedures, the thermal life of Kapton® was determined at various temperatures. At time zero and 325°C (617°F), the tensile strength is 234 MPa (34,000 psi) and the elongation is 67%. The results are shown in **Figures 6–8**.

Figure 6. Tensile Strength vs. Aging in Air at 325°C (617°F), Type HN Film, 25 µm (1 mil)

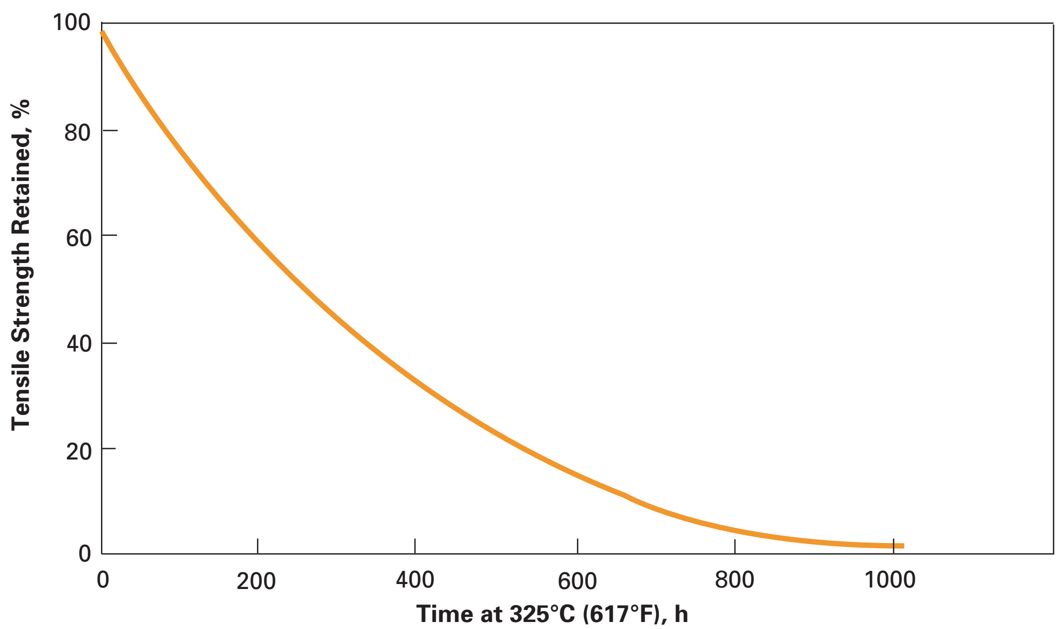


Figure 7. Ultimate Elongation vs. Aging in Air at 325°C (617°F), Type HN Film, 25 µm (1 mil)

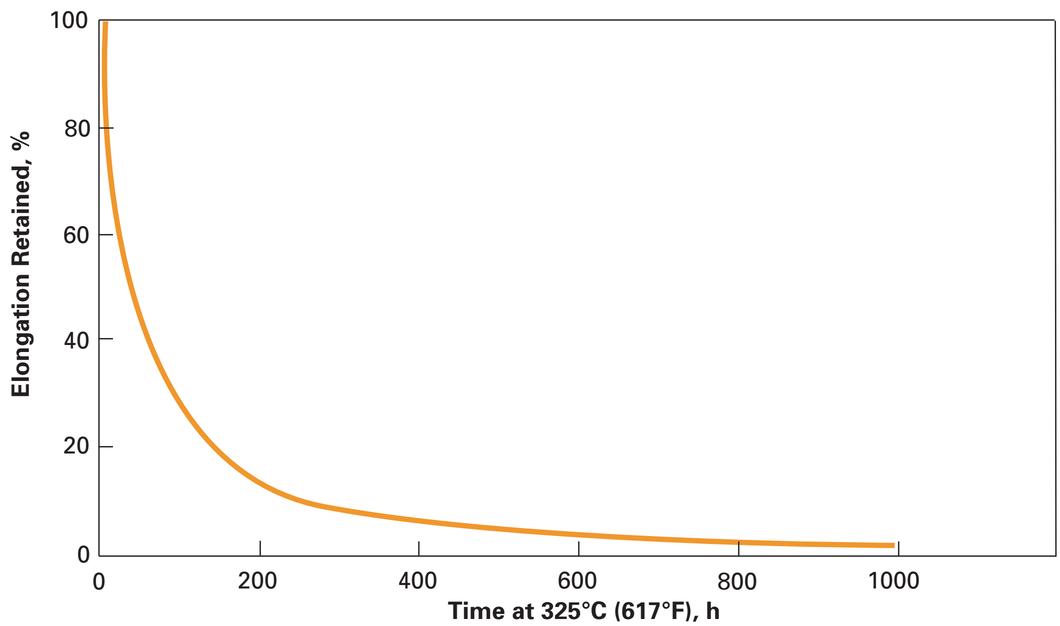
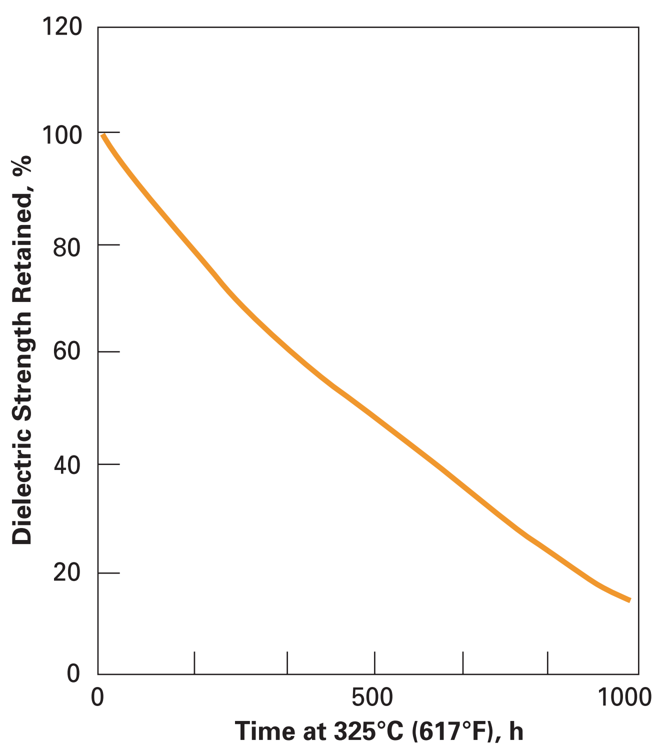


Figure 8. Retained Dielectric Strength at 325°C (617°F) for 25 µm (1 mil) Film, Test Method UL-746B



The life of Kapton® polyimide film at high temperature is significantly extended in a low oxygen environment. Kapton® is subject to oxidative degradation. Hence, when it was tested in a helium environment, its useful life was at least an order of magnitude greater than in air. Using a DuPont™ 1090 thermal analyzer system, the weight loss characteristics of Kapton® in air and helium at elevated temperatures are shown in **Figures 9** and **10**.

Table 6. Time Required for Reduction in Ultimate Elongation from 70% to 1%, Type HN Film, 25 µm (1 mil)

Temperature	Air Environment
450°C (840°F)	2 hours
425°C (800°F)	5 hours
400°C (750°F)	12 hours
375°C (710°F)	2 days
350°C (660°F)	6 days
325°C (620°F)	1 month
300°C (570°F)	3 months
275°C (530°F)	1 year
250°C (480°F)	8 years

Figure 9. Weight Loss, Type HN Film, 25 µm (1 mil)*

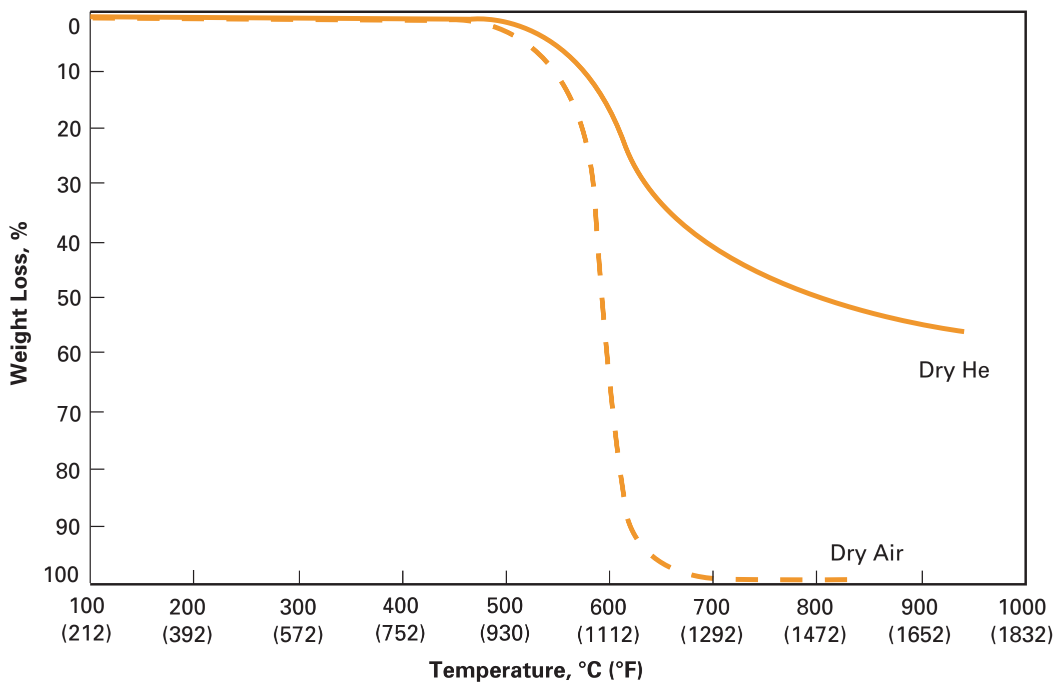
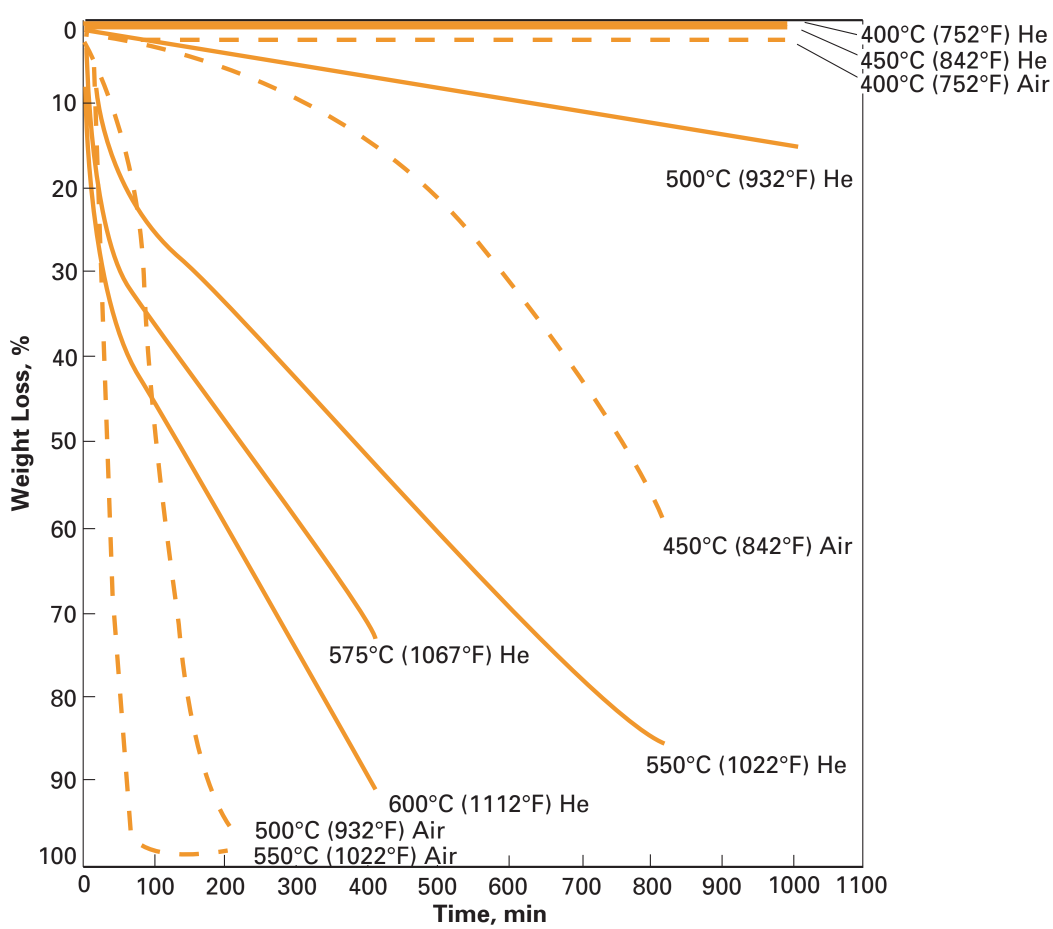


Figure 10. Isothermal Weight Loss, Type HN Film, 25 µm (1 mil)



DUPONT™ KAPTON® SUMMARY OF PROPERTIES

ELECTRICAL PROPERTIES

The most common electrical properties of Kapton® polyimide film of various gauges are shown in **Tables 7** and **8**. These values were measured at 23°C (73°F) and 50% relative humidity. The effect of such factors as humidity, temperature, and frequency on these basic values can be found in **Table 9** and **Figures 11–13**.

Table 7. Typical Electrical Properties of Kapton® Type HN and HPP-ST Films

Property Film Gauge	Typical Value		Test Condition	Test Method
Dielectric Strength	**V/µm (kV/mm)**	**(V/mil)**		
25 µm (1 mil)	303	(7700)	60 Hz	ASTM D-149
50 µm (2 mil)	240	(6100)	1/4 in electrodes	
75 µm (3 mil)	201	(5,100)	500 V/sec rise	
125 µm (5 mil)	154	(3900)		
Dielectric Constant			1 kHz	ASTM D-150
25 µm (1 mil)	3.4			
50 µm (2 mil)	3.4			
75 µm (3 mil)	3.5			
125 µm (5 mil)	3.5			
Dissipation Factor			1 kHz	ASTM D-150
25 µm (1 mil)	0.0018			
50 µm (2 mil)	0.0020			
75 µm (3 mil)	0.0020			
125 µm (5 mil)	0.0026			
Volume Resistivity	Ω•cm			ASTM D-257
25 µm (1 mil)	1.5×10^{17}			
50 µm (2 mil)	1.5×10^{17}			
75 µm (3 mil)	1.4×10^{17}			
125 µm (5 mil)	1.0×10^{17}			

Table 8. Typical Electrical Properties of Kapton® Type FN Film

Property	120FN616	150FN019	250FN029
Dielectric Strength, V/µm (V/mil)	272 (6900)	197 (5000)	197 (5000)
Dielectric Constant	3.1	2.7	3.0
Dissipation Factor	0.0015	0.0013	0.0013
Volume Resistivity, Ω•cm			
at 23°C (7°F)	1.4×10^{17}	2.3×10^{17}	1.9×10^{17}
at 200°C (392°F)	4.4×10^{14}	3.6×10^{14}	3.7×10^{14}

EFFECT OF HUMIDITY

Because the water content of Kapton® polyimide film can affect its electrical properties, electrical measurements were made on 25 µm (1 mil) film after exposure to environments of varying relative humidities at 23°C (73°F). The results of these measurements are shown in **Table 9** and **Figures 11–13**.

Table 9. Relative Humidity vs. Electrical Properties of Kapton®* Type HN Film, 25µm (1 mil)

Relative Humidity, %	Dielectric Strength, AC V/µm (kV/mm)	Dielectric Strength, AC V/mil	Dielectric Constant	Dissipation Factor
0	339	8600	3.0	0.0015
30	315	8000	3.3	0.0017
50	303	7700	3.5	0.0020
80	280	7100	3.7	0.0027
100	268	6800	3.8	0.0035

*For calculations involving absolute water content, 50% RH in our study is equal to 1.8% water in the film and 100% RH is equal to 2.8% water, the maximum adsorption possible regardless of the driving force.

Figure 11. AC Dielectric Strength vs. Relative Humidity, Type HN Film, 25 µm (1 mil)

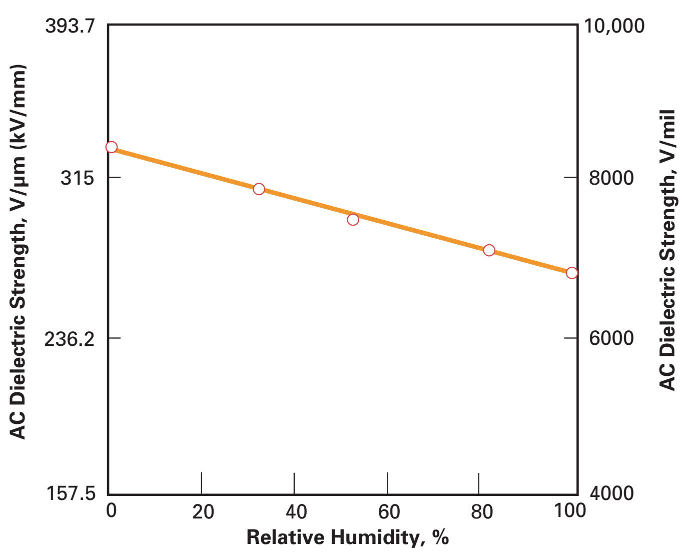


Figure 12. Dissipation Factor vs. Relative Humidity, Type HN Film, 25 µm (1 mil)

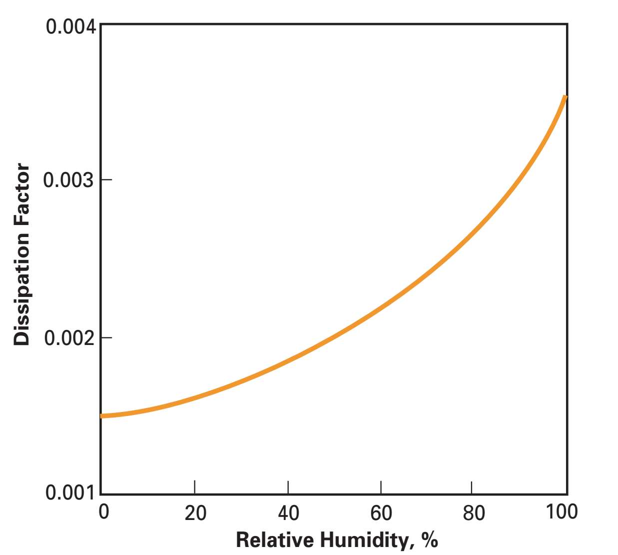


Figure 13. Dielectric Constant vs. Relative Humidity, Type HN Film, 25 µm (1 mil)

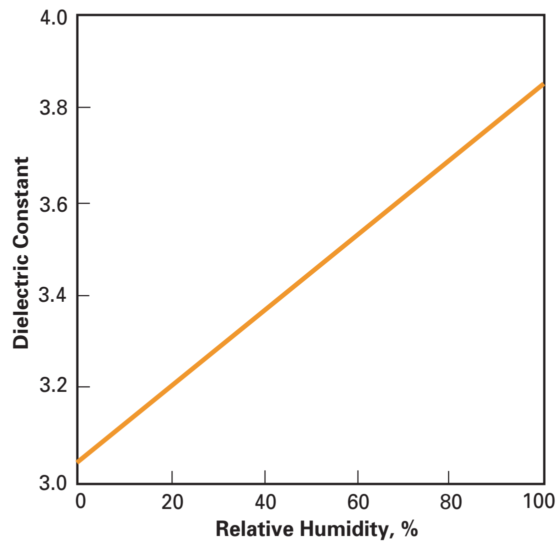
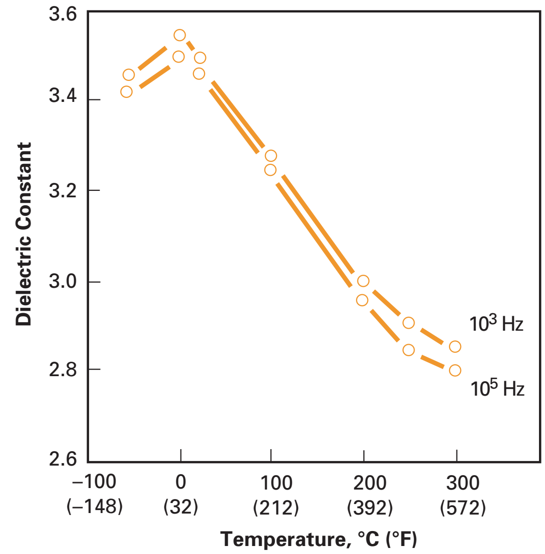


Figure 15. Dielectric Constant vs. Temperature, Type HN Film, 25 µm (1 mil)



EFFECT OF TEMPERATURE

As **Figures 14–17** indicate, extreme changes in temperature have relatively little effect on the excellent room temperature electrical properties of Kapton® polyimide film.

Figure 14. AC Dielectric Strength vs. Temperature, Type HN Film, 25 µm (1 mil)

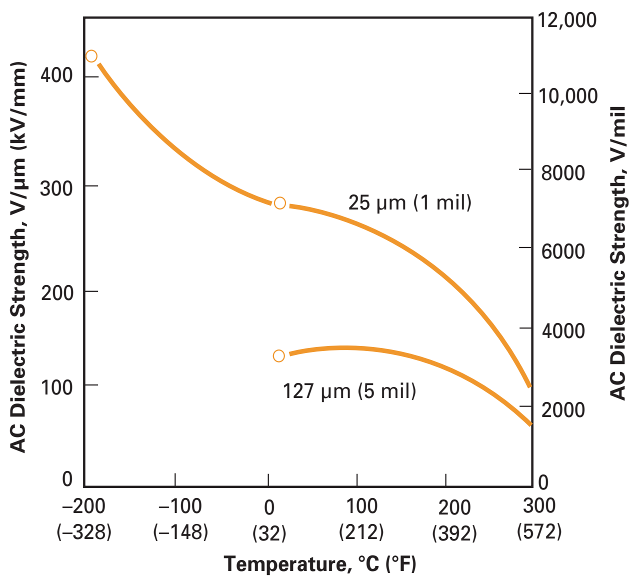


Figure 16. Dissipation Factor vs. Temperature, Type HN Film, 25 µm (1 mil)

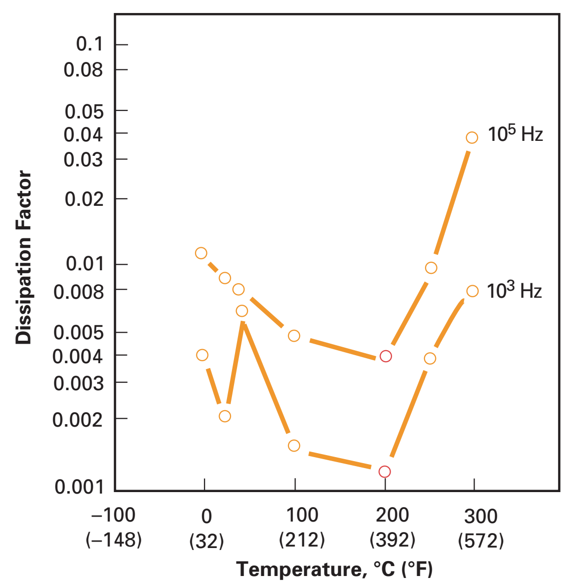
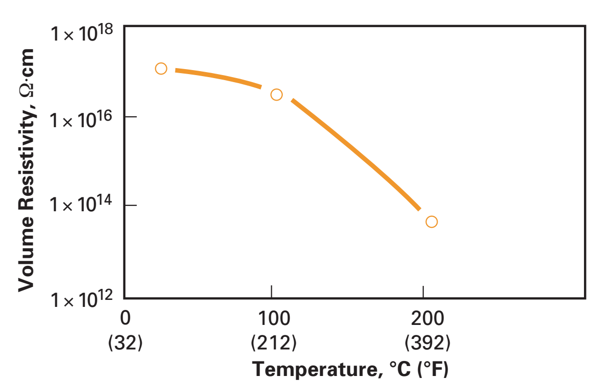


Figure 17. Volume Resistivity vs. Temperature, Type HN Film, 25 µm (1 mil)



DUPONT™ KAPTON® SUMMARY OF PROPERTIES

EFFECT OF FREQUENCY

The effect of frequency on the values of the dielectric constant and dissipation factor at various isotherms are shown in **Figures 18** and **19** for Type HN film, 25 µm (1 mil), and in **Figures 20** and **21** for HN, 125 µm (5 mil).

Figure 18. Dielectric Constant vs. Frequency, Type HN Film, 25 µm (1 mil)

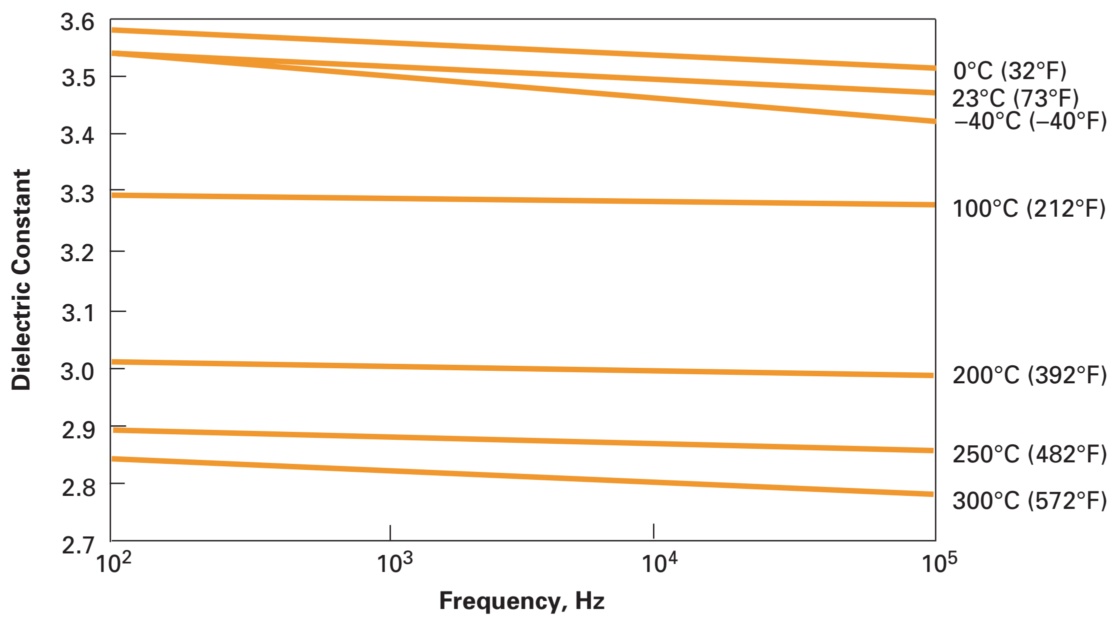


Figure 19. Dissipation Factor vs. Frequency, Type HN Film, 25 µm (1 mil)

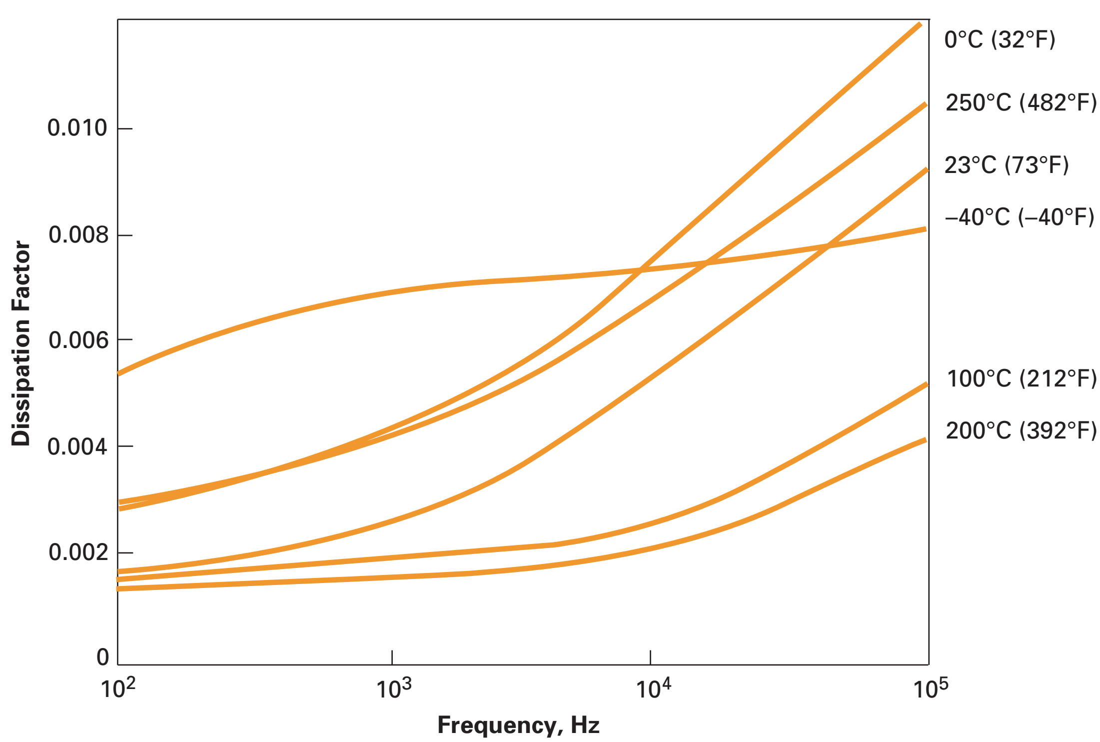


Figure 20. Dielectric Constant vs. Frequency, Type HN Film, 125 µm (5 mil)*

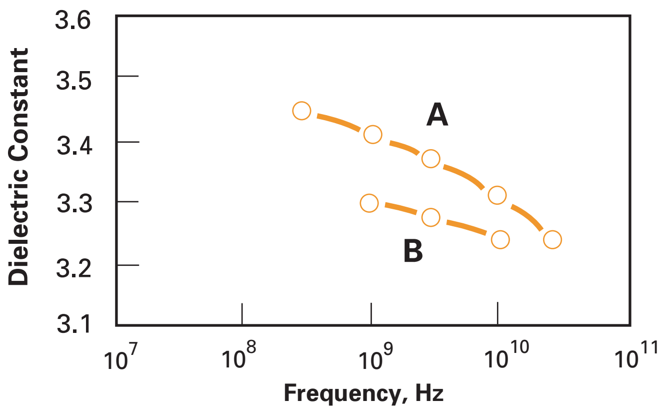
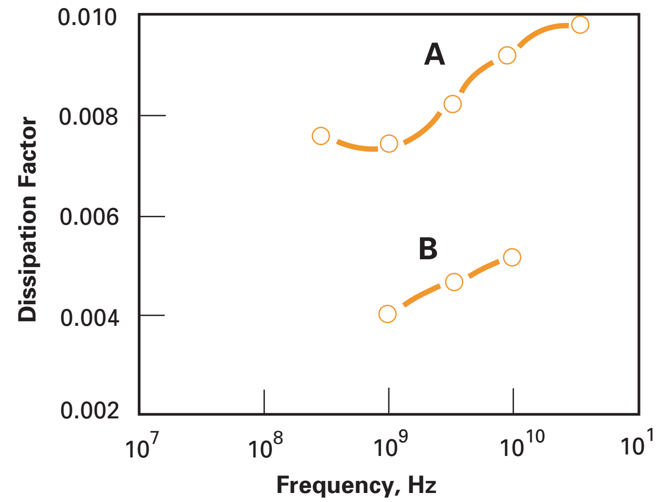


Figure 21. Dissipation Factor vs. Frequency, Type HN Film, 125 µm (5 mil)*



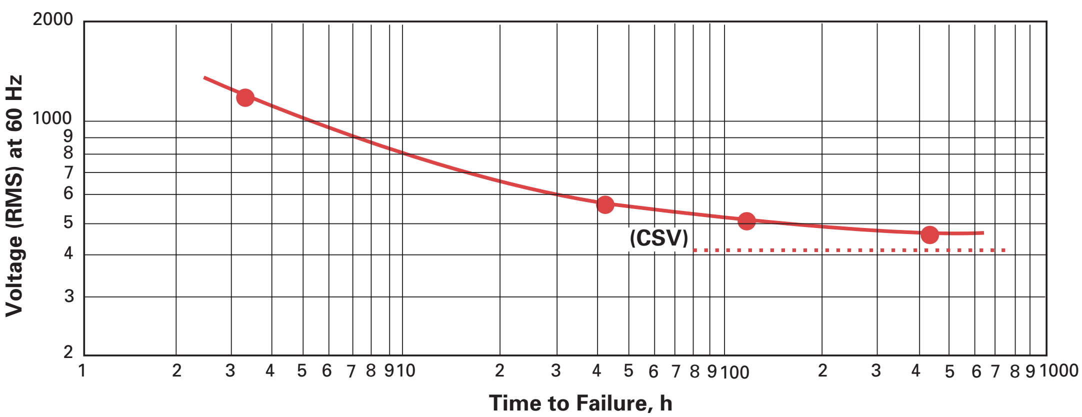
*Technical Report AFML-TR-72-39—Curve A is 500H Kapton® as received and measured at 25°C (77°F) and 45% RH with the electric field in the plane of the sheet. Curve B is the same measurement after conditioning the film at 100°C (212°F) for 48 h. Performance of 500HN is believed to be equivalent to 500H.

CORONA LIFE

Like all organic materials, Kapton® is attacked by a corona discharge and when exposed continuously to it will ultimately fail dielectrically. At moderate levels of corona exposure, devices insulated with Kapton® have survived up to 3000 h, giving reasonable assurance that brief exposure to a corona will not significantly affect the life of a properly designed insulation system based on Kapton®. Corona threshold voltage and intensity are functions of many parameters, including insulation thickness, air gap thickness, and device shape. Consult with a DuPont technical representative on the suitability of Kapton® for specific applications where corona may be present.

Figure 22 shows the life for 25 µm (1 mil) Kapton® HN polyimide film as a function of voltage (RMS) at 60 Hz. As the corona starting level is approached, the Kapton® life curve flattens, indicating a long life. It should be emphasized that the superior thermal and moisture-proof capabilities of Kapton® insulated magnet wire, wrappers, and slot insulation can be utilized without fear of corona in properly designed systems. Kapton® can be used alone or in combination with other insulation materials.

Figure 22. Voltage Endurance of 100HN Kapton® Polyimide Film*



*Corona Starting Voltage (CSV) = 425 V

DUPONT™ KAPTON® SUMMARY OF PROPERTIES

CHEMICAL PROPERTIES

Typical chemical properties of Kapton® Types HN and FN films are given in Tables 10 and 11. The chemical properties of Type HPP-ST film are similar to those of Type HN.

Table 10. Chemical Properties of Kapton® Type HN Film, 25 µm (1 mil)

Property	Typical Value		Test Condition	Test Method
	Tensile Retained, %	Elongation Retained, %		
Chemical Resistance				
Isopropyl Alcohol	96	94	10 min at 23°C	IPC TM-650 Method 2.2.3B
Toluene	99	91		
Methyl Ethyl Ketone	99	90		
Methylene Chloride/Trichloroethylene (1:1)	98	85		
2 N Hydrochloric Acid	98	89		
2 N Sodium Hydroxide	82	54		
Fungus Resistance	Non-nutrient			IPC TM-650 Method 2.6.1
Moisture Absorption	1.8% Types HN and HPP-ST 2.8% Types HN and HPP-ST		50% RH at 23°C Immersion for 24 h at 23°C (73°F)	ASTM D-570 (1988)
Hygroscopic Coefficient of Expansion	22 ppm/% RH		23°C (73°F), 20–80% RH	
Permeability				
Gas	mL/m²•24 h•MPa	cc/(100 in²•24 h•atm)	23°C (73°F), 50% RH	ASTM D-1434 (1988)
Carbon Dioxide	6840	45		
Oxygen	3800	25		
Hydrogen	38,000	250		
Nitrogen	910	6		
Helium	63,080	415		
Vapor	g/(m²•24 h)	g/(100 in²•24 h)		ASTM E-96
Water	54	3.5		

Table 11. Chemical Properties of Kapton® Type FN Film

Property	120FN616	150FN019	400FN022
Moisture Absorption, % at 23°C (73°F),			
50% RH	1.3	0.8	0.4
98% RH	2.5	1.7	1.2
Water Vapor Permeability,			
g/(m²•24 h)	17.5	9.6	2.4
g/(100 in²•24 h)	1.13	0.62	0.16

DUPONT™ KAPTON® SUMMARY OF PROPERTIES

RADIATION RESISTANCE

Because of its excellent radiation resistance, Kapton® is frequently used in high radiation environments where a flexible insulating material is required. In outer space, Kapton® is used both alone and in combination with other materials for applications that require radiation resistance at minimum weight. U.S. Government laboratory test data on gamma and neutron radiation exposure of Kapton® are summarized in **Tables 12** and **13**. Testing the suitability of Kapton® for nuclear reactors and linear accelerators involves exposure to an adverse chemical environment in addition to radiation. For example, loss of coolant accident (LOCA) tests for qualification in containment areas in nuclear power plants expose the system to steam and sodium hydroxide, both of which tend to degrade Kapton®. Accordingly, when Kapton® is used in nuclear power systems that require certification to IEEE-323 and -383, engineered designs that protect Kapton® from direct exposure to LOCA sprays are required. The excellent ultraviolet resistance of Kapton® in the high vacuum of outer space is demonstrated by the data in **Table 14**. In the earth's atmosphere, however, there is a synergistic effect upon Kapton® if it is directly exposed to some combinations of ultraviolet radiation, oxygen, and water. **Figure 23** shows this effect as a loss of elongation when Kapton® was exposed in Florida test panels. **Figure 24** shows the loss of elongation as a function of exposure time in an Atlas Weatherometer. Design considerations should recognize this phenomenon.

Table 12. Effect of Gamma Radiation Exposure on Kapton® Polyimide Film (Cobalt 60 Source, Oak Ridge)

Property	Control 1 mil Film	10^4 Gy 1 h	10^5 Gy 10 h	10^6 Gy 4 d	10^7 Gy 42 d
Tensile Strength, MPa (psi $\times 10^3$)	207 (30)	207 (30)	214 (31)	214 (31)	152 (22)
Elongation, %	80	78	78	79	42
Tensile Modulus, MPa (psi $\times 10^3$)	3172 (460)	3275 (475)	3378 (490)	3275 (475)	2903 (421)
Volume Resistivity Ω•cm $\times 10^{13}$ at 2°C (392°F)	4.8	6.6	5.2	1.7	1.6
Dielectric Constant 1 kHz at 2°C (73°F)	3.46	3.54	3.63	3.71	3.50
Dissipation Factor 1 kHz at 23°C (73°F)	0.0020	0.0023	0.0024	0.0037	0.0029
Dielectric Strength V/μm (kV/mm)	256	223	218	221	254

Table 13. Effect of Electron Exposure on Kapton® Polyimide Film Mixed Neutron and Gamma

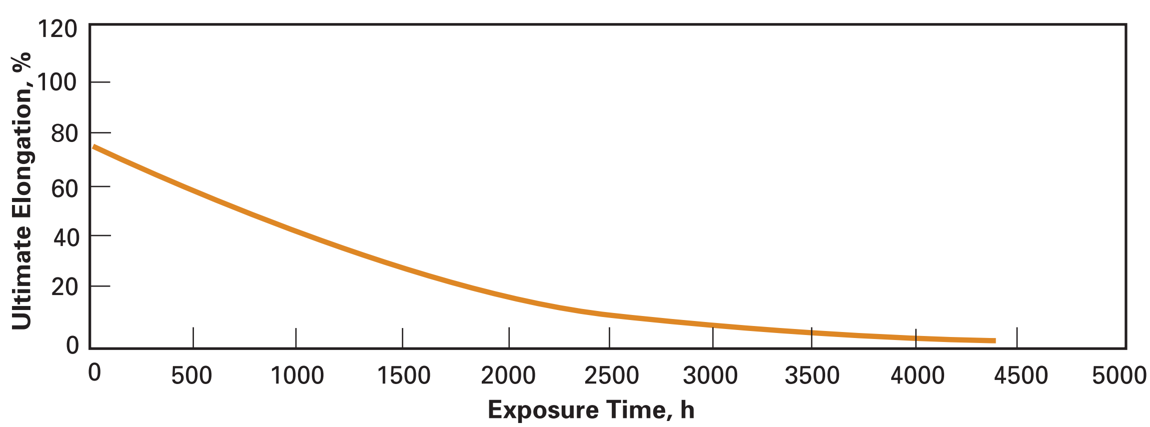
	5×10^7 Gy	10^8 Gy
5×10^{12} neutrons/cm/s Flux at 175°C (347°F)	Film Darkened	Film Darkened and Tough

Table 14. Effect of Ultraviolet Exposure on Kapton® Polyimide Film*

	1000 h Exposure
Tensile Strength, % of Initial Value Retained	100
Elongation, % of Initial Value Retained	74

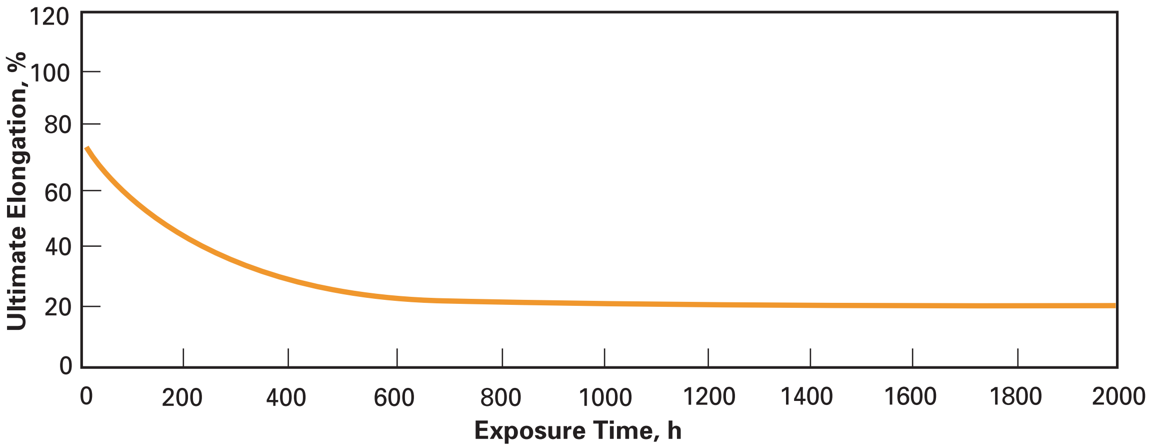
*Vacuum environment, 2×10^{-6} mmHg at 50°C (122°F). UV intensity equal to space sunlight to 2500A.

Figure 23. Effect of Florida Aging on Kapton® Polyimide Film

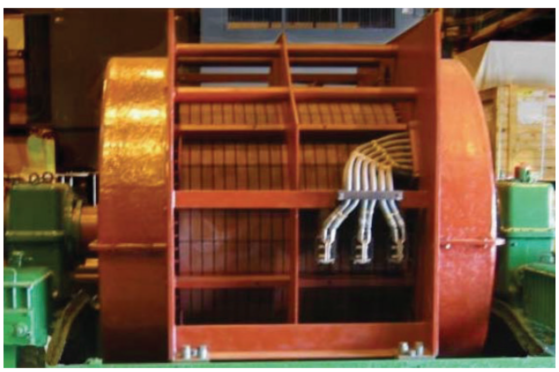


DUPONT™ KAPTON® SUMMARY OF PROPERTIES

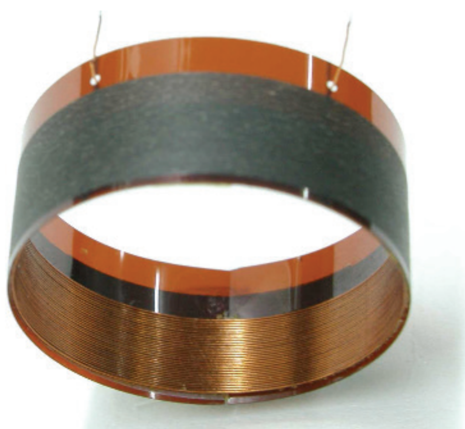
Figure 24. Effect of Weathering on Kapton® Polyimide Film (Atlas Weatherometer)



Kapton® is used as primary insulation for traction motors because of its outstanding combination of thermal, mechanical, and electrical properties.



Voice coils made with Kapton® possess superior high-frequency sound performance at operating temperatures.



KAPTON® FILM TYPE INFORMATION

Table 15. Type and Thickness

Type	Nominal Thickness		Area Factor	
	µm	mil	m²/kg	ft²/lb
30HN	7.6	0.3	93	455
50HN	12.7	0.5	56	272
100HN	25.4	1.0	28	136
200HN	50.8	2.0	14	68
300HN	76.2	3.0	9.2	45
500HN	127	5.0	5.5	27
50HPP-ST	12.7	0.5	56	272
100HPP-ST	25.4	1.0	28	136
200HPP-ST	50.8	2.0	14	68
300HPP-ST	76.2	3.0	9.2	45
500HPP-ST	127	5.0	5.5	27
100FN099	25.4	1.0	23	110
120FN616	30.5	1.2	21	104
150FN019	38.1	1.5	16	77
200FN011	50.8	2.0	11	54
200FN919	50.8	2.0	11	54
250FN029	63.5	2.5	10	49
300FN021	76.2	3.0	8.0	39
300FN929	76.2	3.0	8.0	39
400FN022	101.6	4.0	5.5	27
500FN131	127	5.0	4.7	23

DUPONT™ KAPTON® SUMMARY OF PROPERTIES

NOMINAL CONSTRUCTION, TYPE FN

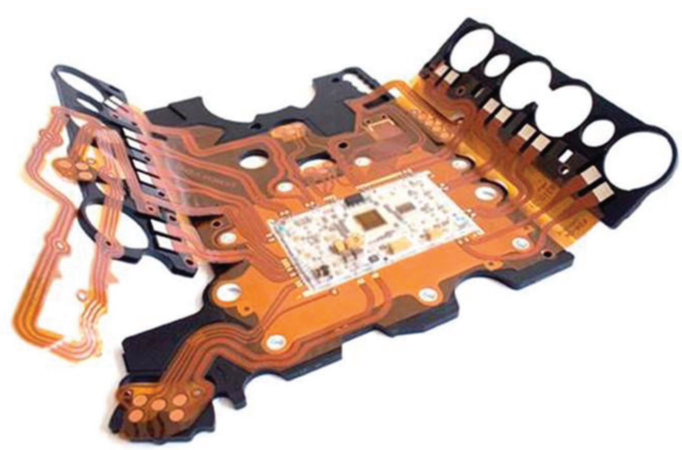
In the Kapton® Type FN order code of three digits, the middle digit represents the nominal thickness of the base Kapton® in mils. The first and third digits represent the nominal thickness of the coating of FEP fluoropolymer resin in mils. The symbol 9 is used to represent 12.7 µm (0.5 mil) and 6 to represent 2.54 µm (0.1 mil). Example: 120FN616 is a 120-gauge structure consisting of a 25.4 µm (1 mil) base film with a 2.54 µm (0.1 mil) coating of fluoropolymer on each side. Illustrated in **Table 16** are several examples of the many film types available.

Table 16. Type FN Film Constructions

	Construction					
	FEP		HN		FEP	
Type	µm	mil	µm	mil	µm	mil
100FN099			12.7	0.50	12.7	0.50
120FN616	2.54	0.10	25.4	1.00	2.54	0.10
150FN019			25.4	1.00	12.7	0.50
200FN011			25.4	1.00	25.4	1.00
200FN919	12.7	0.50	25.4	1.00	12.7	0.50
250FN029			50.8	2.00	12.7	0.50
300FN021			50.8	2.00	25.4	1.00
300FN929	12.7	0.50	50.8	2.00	12.7	0.50
400FN022			50.8	2.00	50.8	2.00
500FN131	25.4	1.00	76.2	3.00	25.4	1.00

Kapton® bar code labels are used in the harsh environments PC boards are exposed to during soldering.

Kapton® is an excellent dielectric substrate that meets the stringent requirements of flexible circuitry.



DUPONT™ KAPTON® SUMMARY OF PROPERTIES

SAFETY AND HANDLING

Safe handling of Type HN and HPP-ST Kapton® polyimide films at high temperatures requires adequate ventilation. Meeting the requirements of OSHA (29 CFR 1910.1000) will provide adequate ventilation. If small quantities of Kapton® are involved, as is often the case, normal air circulation will be all that is needed in case of overheating. Whether or not existing ventilation is adequate will depend on the combined factors of film quantity, temperature, and exposure time.

Soldering and Hot Wire Stripping

Major uses for all types of Kapton® include electrical insulation for wire and cable and other electronic equipment. In virtually all of these applications, soldering is a routine fabricating procedure, as is the use of a heated element, to remove insulation. Soldering operations rarely produce off-gases to be of toxicological significance.

Welding and Flame Cutting

Direct application of welding arcs and torches can quickly destroy most plastics, including all types of Kapton® film. For practical reasons, therefore, it is best to remove all such parts from equipment to be welded. Where removal is not possible, such as in welding or cutting coated parts, mechanical ventilation should be provided. Because Kapton® can be used at very high temperatures, parts made from it may survive at locations close to the point of direct flame contact. Thus, some in-place welding operations can be done. Because the quantity of film heated is usually relatively small (less than 1 lb), ventilation requirements seldom exceed those for normal welding work. Because of the possibility of inadvertent overheating, the use of a small fan or elephant-trunk exhaust is advisable.

Scrap Disposal

Disposal of scrap Kapton® polyimide films presents no special problem to the user. Small amounts of scrap may be incinerated along with general plant refuse. The incinerator should have sufficient draft to exhaust all combustion products to the stack. Care should be taken to avoid breathing smoke and fumes from any fire. Because Kapton® is so difficult to burn, it is often best to dispose of scrap film in a landfill.

Fire Hazards

Whether in storage or use, Kapton® is unlikely to add appreciably to the hazards of fire. Bulk quantities of Kapton® (over 100 lb) should be stored away from flammable materials. In the event of fire, personnel entering the area should use a fresh air supply or a respirator. All types of chemical extinguishers may be used to fight fires involving Kapton®. Large quantities of water also may be used to cool and extinguish a fire.

Static Electricity

The processing of Kapton® can generate a strong static charge. Unless this charge is bled off as it forms by using ionizing radiation or tinsel, it can build to many thousands of volts and discharge to people or metal equipment. In dust- or solvent-laden air, a flash fire or explosion could result. Precautions for static charges should also be taken when removing plastic films used as protective packaging for Kapton®. For additional information, users should refer to the bulletin “Kapton® Polyimide Film— Products of Decomposition” (H-16512).

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

kapton.com

EI-10142 (1/22)