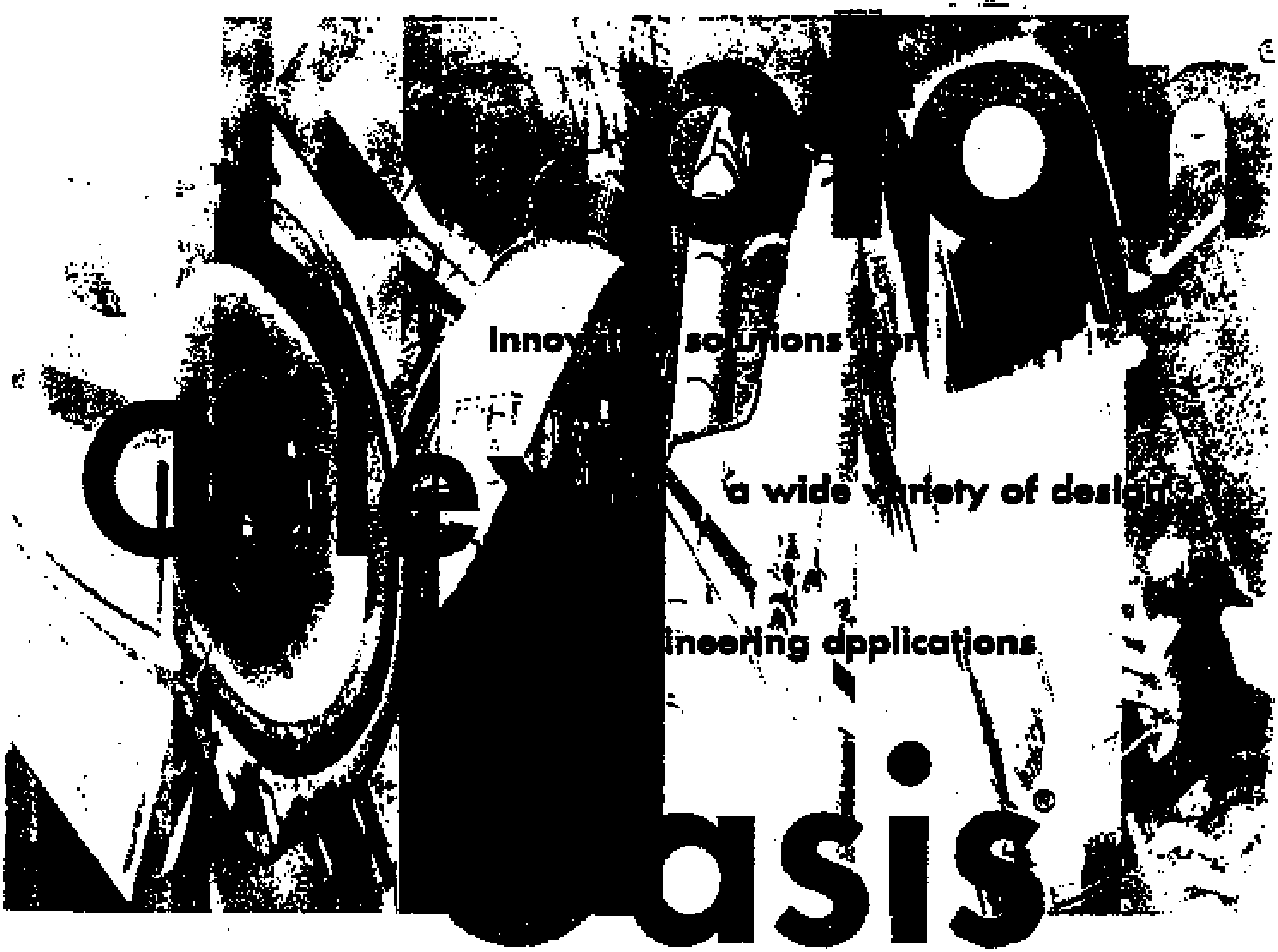
DuPont High Performance Films



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From the space shuttle's solar array to miniaturized electronic components, from high-speed locomotive motors to microprocessor chip carriers, *Kapton*® polyimide films, only by DuPont, have made innovative design solutions possible. That's because *Kapton*® offers a unique combination of electrical, chemical and mechanical properties and retains these properties over a wide range of temperatures, where other engineering materials may fail.

Kapton® has more than 30 years of proven performance as the material of choice in applications involving very high or very low operating temperatures. Designers continue to discover that the application potential for this unique industrial material has barely been tapped. Additionally, the DuPont family of high-performance materials has been expanded to include *Cirlex*® adhesiveless manufactured all-polyimide construction material and *Oasis*® composite film, giving design engineers even more performance options to meet their needs.

Although we continuously explore new application possibilities for these films, many uses for *Kapton*® are well established. In the electrical and electronics industries, for example, *Kapton*® excels in applications for field coil insulation, substrates for flexible printed circuits, motor and generator armature slot liners, magnet wire insulation, transformer and capacitor insulation, magnetic [illegible] and pressure-sensitive tapes and tubing, wire and cable insulation, speaker voice coils, automotive switches and bar code labels for printed circuit boards.

Versatile DuPont *Kapton*® and *Oasis*® Films

Kapton® HN is an all-purpose polyimide film that has been used successfully in applications at temperatures as low as -269°C (-452°F) and as high as 400°C (752°F). *Kapton*® HN film can be laminated, diecut, slit, formed or adhesive-coated. It is available in 0.3 mil (7.5 µm), 0.5 mil (12.5 µm), 1 mil (25 µm), 2 mil (50 µm), 3 mil (75 µm) and 5 mil (125 µm) thickness.

Kapton® HA polyimide film has good flex life and is well-suited for general-purpose applications. It features an amorphous structure that is pliable, yet tough.

Kapton® HPP-ST offers the same excellent balance of physical, chemical and electrical properties over a wide temperature range as *Kapton*® HN film, plus superior dimensional stability and adhesion. It is available in 1 mil (25 µm), 2 mil (50 µm), 3 mil (75 µm), 5 mil (125 µm), 6 mil (150 µm) and 7 mil (175 µm) thickness. In applications where low shrinkage and/or superior adhesion are important, *Kapton*® HPP-ST is the polyimide film of choice.

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Kapton® FN is *Kapton*® HN film coated or laminated on one or both sides with DuPont *Teflon*® FEP to impart heat sealability and to provide a moisture barrier and enhanced chemical resistance. It is available in a variety of constructions.

Kapton® BCL-Y eliminates the need for thick opaque coatings. It offers the thermal and electrical durability, as well as the chemical resistance of *Kapton*® HN, along with excellent surface reflectivity and bar code label contrast.

Kapton® KJ is a heat-sealable polyimide film used for high-temperature and high-performance material constructions. It maintains excellent adhesion well above its glass transition temperature.

Cirlex® adhesiveless manufactured all-polyimide laminate construction material complements DuPont *Kapton*® polyimide films. Available in sheets from 9 mil (225 µm) to 60 mil (1,500 µm), *Cirlex*® provides an expanded range of thickness options, while offering the excellent chemical, physical, thermal and electrical properties of *Kapton*®. It is readily modified by laser cutting, drilling, machining and chemical etching.

Oasis® composite film is heat sealable and is made using DuPont polyimide film and DuPont *Teflon*® fluoropolymer.

Oasis® composite film has excellent electrical, thermal, mechanical and chemical resistance properties.

DuPont *Kapton*® polyimide film can be laminated, coated and otherwise converted to meet a broad range of high-performance operating requirements. This outstanding versatility allows *Kapton*® to be custom-tailored to fit an almost endless variety of applications.

These high-quality performance films are supported by 30 years' experience, and we are committed to remaining the world leader in the manufacture and diversification of polyimide product offerings. Our significant investments in research, development and equipment in response to your needs continue to help us design products that can insulate or conduct electricity, as well as pigmented and heat conductive films, and new adhesive systems.

DuPont also offers custom-tailored products and programs to meet your special design requirements, where appropriate. For more information, please call 1-800-237-4357.

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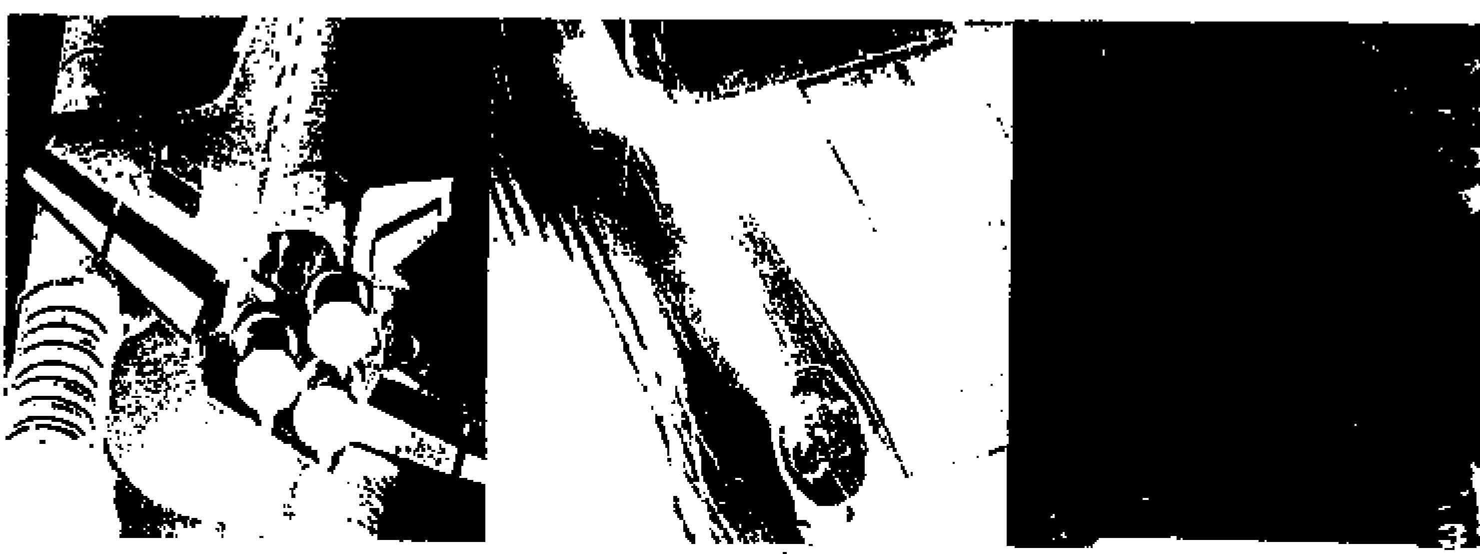


High-performance DuPont *Kapton*® stands [illegible]

For all of its outstanding properties, *Kapton*® polyimide film, only by DuPont, is probably best known for its ability to withstand heat. With a UL®-94 V-O rating, *Kapton*® will not sustain or propagate flame. Nor will it produce any significant smoke when exposed to flame.

UL rated at 220°C to 240°C (428°F to 464°F) for continuous service, *Kapton*® can function for brief periods after exposure to temperatures up to 400°C (752°F). Best of all, it retains its high dielectric strength even at elevated temperatures — 2,500 V/mil at 300°C (572°F).

The outstanding thermal properties of these high-performance films provide significant advantages to the designer. When used on the windings of large coils for motors, insulation thickness can be significantly reduced; flexible circuits can be wave-soldered without distortion; and, when used in combination with inorganic insulating tapes, these films allow high-performance cables to continue to operate in direct exposure to flame.

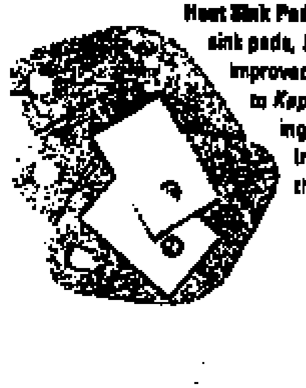
Kapton® polyimide film [illegible] nating varnishes, including [illegible] amides-imides and orga[illegible] electrical equipment. Magnet wire made [illegible] combinations of polyimide film and varnishes has a IEEE 57 [illegible]

Flame and heat resist[illegible] polyimide film, it also [illegible] while retaining its [illegible] becoming brittle.

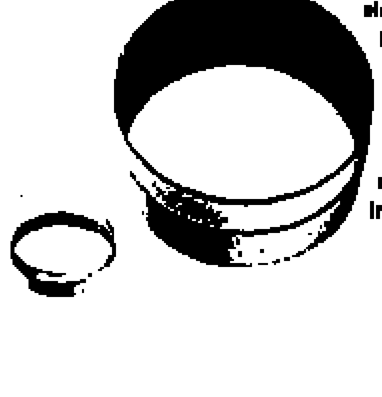
Kapton® MT and *Kapton*® MTB films are available for applications where improved thermal conductivity is an important design feature.

Kapton® MT provides thermal conductivity that is three times that of standard *Kapton*®. It has excellent physical properties and dielectric strength suitable for applications in heat-sink insulation for power transistors and power supplies.

Kapton® MTB is a black polyimide film with increased thermal conductivity [illegible]



Heat Sink Pads. When used in heat sink pads, *Kapton*® MT film provides improved heat transfer compared to *Kapton*® HN, while maintaining dielectric strength for interface and cut-through protection.



Speaker Coils. *Kapton*® HPP-FST and HPP-ST films provide outstanding electrical and thermal insulation for speaker coils. *Kapton*® resists distortion at high operating temperatures, offers superior dimensional stability and maintains excellent adhesion with other materials used in speaker manufacture.

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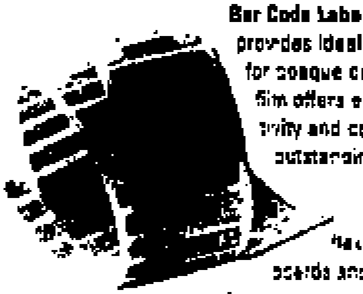
o both low and high temperature extremes.

For speaker coils, *Kapton*® Type MTB, a black polyimide film, dissipates high levels of heat and provides outstanding electrical and thermal insulation. It has three times the thermal conductivity of standard *Kapton*® and resists distortion at high operating temperatures.

Lightweight and resistant to radiation, *Kapton*® HN film is the ideal insulation material for use in space applications. In spacecraft blankets, *Kapton*® [illegible] provides outstanding [illegible] extremely high and low temperatures while maintaining superior dielectric strength, durability and flexibility.



Bar Code Labels. *Kapton*® BCL-ST film provides ideal surface characteristics for opaque coatings. *Kapton*® BCL-Y film offers excellent surface reflectivity and contrast. Both films have outstanding temperature and chemical resistance for bar code labels for flexible printed circuit boards and other high-temperature harsh environment applications.

Fiber Optics Cable. Using *Kapton*® HN film, fiber optics cable can be made smaller and lighter, allowing a much higher count computer. The thermal resistance and [illegible] flame propagation of *Kapton*® [illegible] held cables stand up to the [illegible] burn test. *Kapton*® [illegible] porous, making it ideal for indoor/outdoor cable applications.

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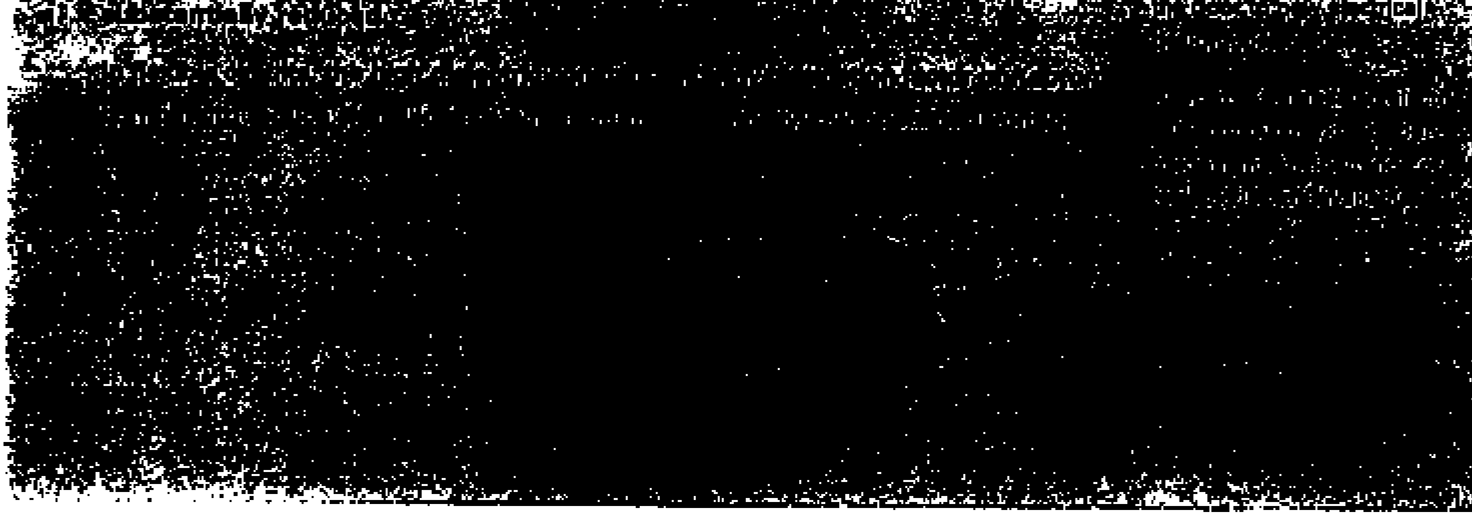
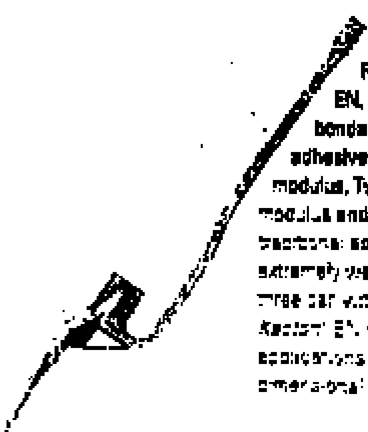
DuPont *Kapton* polyimide film opens up your desi

Next to its thermal properties, *Kapton*® polyimide film, only by DuPont, is selected by designers most frequently because of its excellent dielectric strength, dielectric constant and dissipation factor. The dielectric strength of 1 mil (25 µm) *Kapton*® — 7,000 volts at room temperature (23°C / 73.4°F) — is typically 2,500 volts even at an elevated temperature of 300°C (572°F). In fact, short-term exposure to temperatures as high as 400°C (752°F) will not significantly affect the electrical properties of *Kapton*®.

The combination of high dielectric strength, thermal stability, uniform thickness and excellent mechanical properties allows designers of electrical equipment to specify thinner insulation on coils for transformer, generator or motor windings. More conductors can [illegible] located within a given space, yielding greater power [illegible]. If the power requirement is constant, the weight and dimensions of a given coil, stator or rotor can be substantially [illegible]

Kapton® CR polyimide film was developed specifically to withstand the damaging effects of "corona," which can cause ionization and eventual breakdown of an insulation material or system when the voltage stress reaches a critical level. _Kapton_® CR shows corona resistance of greater than 100,000 hr at 500 V/mil (20 kV/mm) at 50 Hz, and provides twice the thermal conductivity of standard _Kapton_®. These substantial property improvements open [illegible]





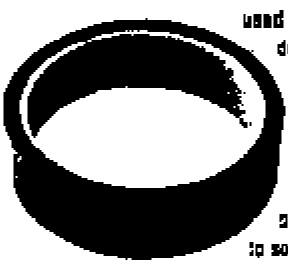
Flexible Circuits. *Kapton*® FPC, EN, and KN films offer excellent bondability to copper with various adhesives. Type EN has the highest modulus, Type KN has a mid-range modulus and Type FPC is well-suited for traditional applications. Adhesives work extremely well with these films and all three can withstand solder temperatures. *Kapton*® EN is well-suited for use in applications requiring exceptional dimensional stability.

Pin Grids. As a pin grid array, *Kapton*® HN film allows insertion of all pins into a circuit board in a single, high-speed operation. *Kapton*® HN withstands the high temperatures of wave soldering and allows visual inspection of completed connections. After soldering, *Kapton*® HN can either be peeled away or left in place as additional support for pins during further processing and handling.

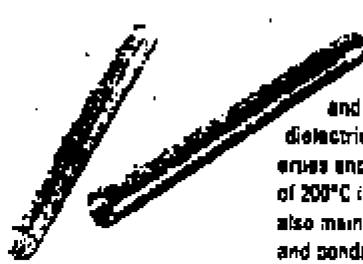
...ssibilities with its outstanding electrical properties.

Most of the world's trains are powered by AC or DC traction motors [illegible] Kapton® polyimide film. While Kapton® [illegible] and HN films have been railway staples for more than 30 years, Kapton® CR and FCR have [illegible] improved resistance to partial discharge, or corona.

...veloped specifically for the electronics industry, Kapton® EN and KN films allow [illegible] to printed circuit boards in a reel format. Kapton® EN ...as a higher modulus than standard Kapton®, and a coefficient of [illegible] expansion without inducing stress.



Pressure-Sensitive Tape. Whether it's used as protection for printed circuits during the manufacturing process, or as a repair/utility tape for high-performance electrical insulation applications, *Kapton®* PST film provides high-temperature capability, dimensional stability, resistance to solvents and compatibility with many types of adhesives.



Insulation Tubing. In tubing used for electrical insulation protection, *Kapton®* HN, MT and HPP-ST films have excellent dielectric and thermal insulation properties and can withstand temperatures of 200°C (392°F) or higher. These films also maintain good [illegible] and bondability for manufacturing [illegible] spiral wound, high-temperature [illegible]

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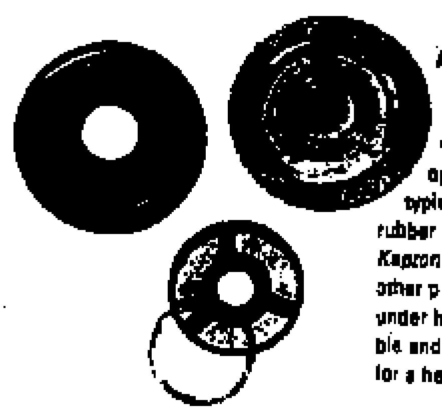
DuPont *Kapton* poly[illegible] film resists m[illegible]

Kapton® polyimide film, only by DuPont, is an ideal material for use in demanding environments where hostile elements such as chemicals, gases and radiation are present. Whether it's used as motor windings insulation in an oil well pump operating in a pit of gas and brine 20,000 feet (6,095 m) below the surface of the earth, a protective layer for a liquid level sensor submerged in an organic solvent or in demanding automotive applications, *Kapton*® can take the punishment and still deliver reliable performance.

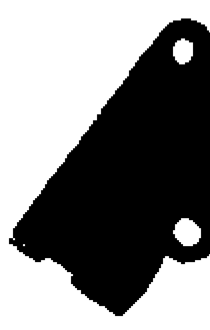
In flexible circuitry, conductors bonded between layers of *Kapton*® polyimide film are protected against chemicals, moisture, gases and foreign materials so they can operate reliably in demanding environments. In military and industrial applications, *Kapton*® remains tough and flexible. Although it is unaffected by most organic chemicals, solvents, fuels and lubricants, *Kapton*® can be dissolved by certain strong bases — a fact that printed circuit manufacturers use to their advantage in the chemical milling of features in printed circuits.

Kapton® FN is a heat-sealable film that retains the unique balance of properties of *Kapton*® HN over a wide temperature range. This is achieved by combining *Kapton*® HN with DuPont *Teflon*® FEP fluoropolymer in a composite structure. *Kapton*® FN imparts heat sealability, provides a moisture barrier and enhances chemical resistance.

Kapton® WR polyimide film was developed specifically to combat the effect of water on insulation systems and for applications where hydrolytic stability is important. It is available as plain film or laminated with DuPont *Teflon*® FEP (*Kapton*® FWR) for use as a heat-sealable magnet wire insulation.



Automotive Diaphragms. Although thin and lightweight, *Kapton*® HN and FN films can withstand flexing without developing cracks or tears, which are typical problems encountered with rubber and other common materials. *Kapton*® enables diaphragms and other parts to work "in movement" under high pressure and remain flexible and functional, while performing for a half-million plus cycles.



Automotive Sensors. *Kapton*® HN and FN films are used in automotive sensor devices because they are flexible, highly processable and able to withstand the extreme temperature changes that occur under the hood. These films also have excellent durability and proven resistance to automotive solvents, oils and fuels.

Kapton® JP film was designed specifically for deep draw forming. For automotive applications, this film provides excellent formability, chemical resistance and a long flex life. The film's resistance to permeation makes it suitable for use with some gases and liquids.

Buried miles deep in the earth, *Kapton*® FN insulation in submersible oil pump lead cable withstands the high temperatures and harsh chemical environments at the bottom of an oil well longer than conventional insulation materials.

Etched Applications. *Kapton*® is etchable and can be well controlled within the etching process, resulting in a fine line capability and high quality of etching. Although *Kapton*® HN or HPP-FST films are most frequently used for chemical etching, several other types of *Kapton*® have also been successfully etched.

Etching Controllability. *Kapton*® HKJ film is made from layers of *Kapton*® HA and KJ film, which have been bonded together. In this application, the *Kapton*® HA film has been etched through, while leaving the *Kapton*® KJ polyimide adhesive intact.

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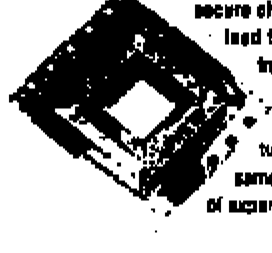
DuPont *Kapton* polyimide films and *Oasis* composit

Kapton® polyimide films and *Oasis*® composite films, only by DuPont, provide a host of performance options not available from conventional materials such as fibers, resins, metals, glass, ceramics, mica and others. The films' tensile strength and initial tear resistance provide the mechanical durability necessary for many critical manufacturing operations, such as printed circuit processing and installation. Exceptional toughness and resistance to cut-through and abrasion make *Kapton*® and *Oasis*® especially useful as insulation for aerospace and communications wire and cable, where it can be pulled through even the tightest routing.

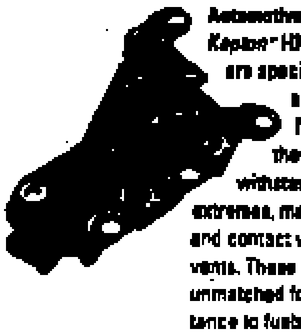
Since the outside diameter of a wire or cable insulated with *Kapton*® polyimide film or *Oasis*® composite film is smaller than conventional wiring using extruded insulations, more cable can be run through a given size conduit or plenum. Stripping and termination are also easier.

The strength, toughness, flexibility and wear resistance of *Kapton*® polyimide film have proven reliable for a number of non-electrical applications as well, such as drive belts, pressure [illegible] seals. Three-dimensional [illegible] of *Kapton*® are also [illegible]

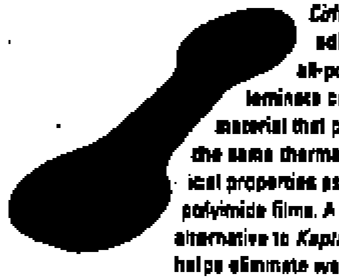
Kapton® JP polyimide film provides optimum forming characteristics. It offers higher elongation at elevated temperatures, while maintaining the combination of excellent physical, electrical and mechanical properties inherent in *Kapton*® HN and HA. The polymer properties of *Kapton*® JP enable drawing deeper parts at lower temperatures in shorter cycle times. After forming, parts exhibit excellent shape retention and minimum shrinkage.



Lead Frame Tape. Used to secure chips to circuit boards, lead frame tape made from *Kapton*® EN and KN films remains stable at high temperatures and provides the same thermal coefficient of expansion as copper.



Automotive Manifolds. *Kapton*® HN and FN films are specified for use in automotive manifolds because they are able to withstand temperature extremes, mechanical stress and contact with organic solvents. These films are unmatched for their resistance to fuels, fluids and other harsh chemicals.



Shims of *Cirlex*®. *Cirlex*® is an adhesiveless all-polyimide laminate construction material that possesses the same thermal and physical properties as *Kapton*® polyimide films. A thicker alternative to *Kapton*®, *Cirlex*® helps eliminate weak points in adhesive construction and can be used as shims.

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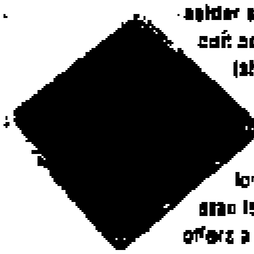
[illegible] strong, tough and [illegible] resistant.

[illegible] insulation for aircraft. *Oasis** composite film [illegible] highest [illegible] insulations. It's also lighter, tougher [illegible] by heat sealing, allowing wire to exceed [illegible] and hydrolysis requirements. *Oasis** generates little smoke, resists abrasion and has higher dielectric [illegible] than most other materials used in aircraft wiring applications.

[illegible] diameter [illegible] or cable insulated with *Kapton** polyimide film or *Oasis** composite film is smaller than conventional wire [illegible] more cable can be fit [illegible] a given size [illegible] planes. Stripping and termination are also easier.

Aircraft Shims. *Kapton* HN is lighter than metal, and more compatible with the advanced composite materials now used [illegible] aircraft [illegible]. The [illegible]

Speaker Cones. *Kapton* JP film provides improved acoustics and longer life for precision-formed loudspeaker cones. *Kapton* JP film maintains a higher stiffness to weight ratio than [illegible] speaker [illegible] superior electrical [illegible] and withstands high wattages.



Solder Mask Frames. Used in solder stencils for printed circuit boards, *Kapton** HPP-ST (shown) and *Cirlex* maintain through-hole definition, dent resistance and longevity better than [illegible] less steel. *Cirlex* [illegible] offers a smoother surface for more efficient [illegible] of solder paste.

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Caution: Do not use in medical applications involving permanent implantation in the human body. For other medical applications, see "DuPont Medical Caution Statement," H-50102.

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DuPont High Performance Films

Information Bulletin

Teflon

High Performance Films

DuPont FEP

fluorocarbon film

Teflon® as Film

DuPont FEP fluorocarbon film offers the outstanding properties of Teflon® resin in a convenient, easy-to-use form. It can be heat-sealed, thermoformed, welded, metallized, and laminated to many other materials or serve as a hot melt adhesive.

This combination of unique properties and easy-to-use form offers design and fabrication opportunities for a wide variety of end uses.

FEP Is Unique Among Plastics

- Most chemically inert of all plastics
- Withstands both high- and low-temperature extremes
- Superior antistick/low friction properties
- Outstanding weather resistance
- Excellent optical characteristics
- Superior electrical properties
- Free of plasticizers or additives
- Excellent processibility with conventional thermoplastic methods

DuPont FEP Film Is Offered

- In thicknesses from 12.5–4750 µm (0.5–190 mil)
- In custom slit widths up to 1.2–1.6 m (46–63 in) depending on thickness
- In various size rolls wound on 7.6 cm or 15.2 cm (3 in or 6 in) cores

DuPont FEP film affords the engineer/designer a wide range of opportunities to take advantage of these properties with minimal and convenient fabrication techniques.

The ability of DuPont FEP film to be easily cut, thermoformed, heat sealed, and welded permits ready application as diaphragms, gaskets, protective linings, or thermoformed pouches or containers, wherever high temperature and/or chemical resistance is required.

The excellent optical properties and resistance to weathering and ultraviolet degradation have led to the use of DuPont FEP film in such varied applications as environmental growth chambers, solar energy collectors, and radome windows.

Its superior dielectric properties have been used in flexible, flat cable insulation, printed circuits, and electronic components for computers and aircraft.

The nonstick properties of DuPont FEP film have found use in conveyor belts, process roll covers, and as mold release films.

Special grades of DuPont FEP film offer specific properties such as cementability or high stress crack resistance under extreme environmental conditions.

A complete listing of FEP film grades and their availability in different thicknesses is given in Table 1.

In addition to FEP, DuPont offers films of PFA, for use at temperatures up to 260°C (500°F), and Tefzel® fluoropolymer for increased toughness and resistance to tear propagation.

DuPont FEP film offers unique properties in a convenient form requiring minimal fabrication. Consider it for your next project.

For additional information, call (800) 237-4357.

Teflon® is a registered trademark of DuPont.

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Types and Gauges

Table 1
Types and Gauges of DuPont FEP Fluorocarbon Film

Gauge	50	100	200	300	500	750	1000	1500	2000	3000	6000	9000	12500	19000
Thickness, mil	0.5	1	2	3	5	7.5	10	15	20	30	60	90	125	190
Thickness, µm	12.5	25	50	75	125	190	250	375	500	750	1500	2300	3125	4750
Approximate area factor, ft²/lb	180	90	45	30	18	12	9	6.0	4.5	3	1.5	1	0.72	0.47
Approximate area factor, m²/kg	36	18	9	6	4	2.5	2	1.2	1	0.6	0.3	0.2	0.14	0.09
Availability														
Type A—FEP, general-purpose	X	X	X	X	X	X	X	—	X	—	—	—	—	—
Type C—FEP, one side cementable	X	X	X	X	X	—	—	—	—	—	—	—	—	—
Type C-20—FEP, both sides cementable	X	X	X	—	X	—	—	—	—	—	—	—	—	—
Type L—FEP, high stress crack resistance in extreme environments	—	—	—	—	X	—	X	X	X	X	X	X	X	X

Note: Each roll of DuPont film is clearly identified as to resin type, film thickness, and film type.

FEP 500 C
- Resin type
- Film thickness, 500 gauge, 5 mil
- Film type cementable one side

Mechanical and Thermal Properties

DuPont FEP films perform well over a wide range of temperatures. DuPont FEP film has a continuous service temperature range from –240 to 205°C (–400 to 400°F), and it can be used in intermittent service at temperatures as high as 260°C (500°F). See Tables 2 and 3.

Tensile Properties

Figures 1–3 show how tensile properties of DuPont FEP film vary with temperature. FEP films retain useful mechanical properties over a wide range from cryogenic to high temperatures.

Dimensional Stability

There are three components to the property of dimensional stability—hygroscopic expansion, residual shrinkage, and thermal expansion.

Hygroscopic Expansion

Because the moisture absorption of DuPont FEP fluorocarbon film is less than 0.01% when totally immersed in water, changes in relative humidity have little effect on the film.

Figure 1. Tensile Stress vs. Elongation of DuPont FEP Film

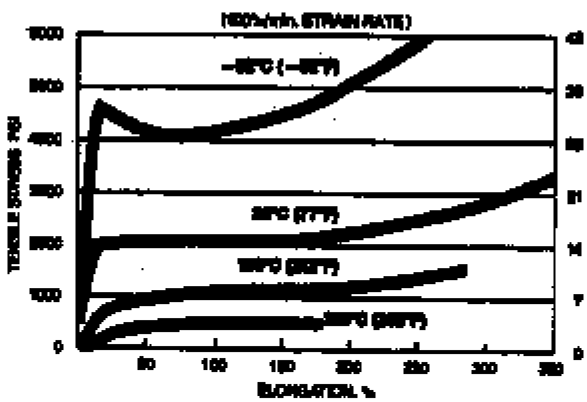

Figure 2. Tensile Properties of DuPont FEP Film vs. Temperature

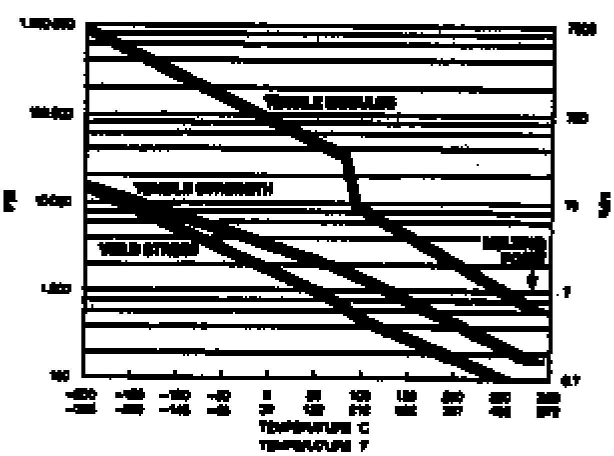

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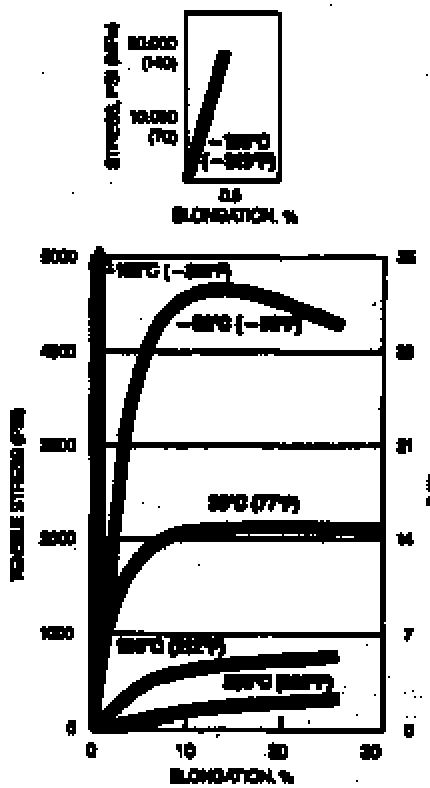
Figure 3. Tensile Stress vs. Elongation of DuPont FEP Film



Residual Shrinkage

Stresses set up in the film during manufacturing or converting can cause shrinkage in unrestrained film when exposed to high temperatures.

Exposure of film to an elevated temperature, and the attendant shrinkage, will relieve this stress, and no further shrinkage will occur at lower temperatures.

Thermal Expansion

After residual shrinkage has been removed, DuPont FEP film will expand and contract according to its normal coefficient of thermal expansion (see Figures 4 and 5). Note that this coefficient increases with temperature.

Figure 4. Shrinkage of DuPont FEP 100A Film vs. Temperature

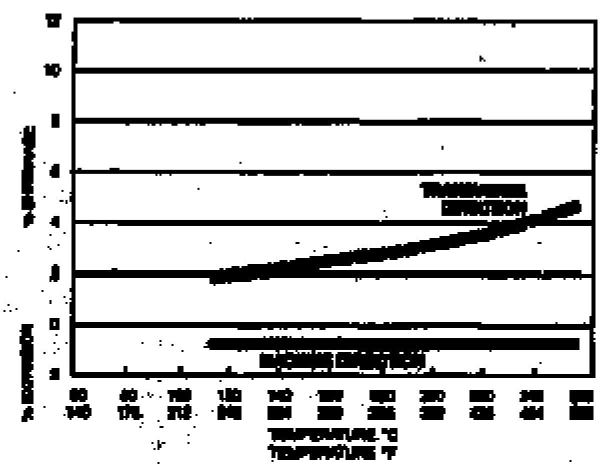


Table 2
Typical Mechanical Properties of DuPont FEP Film*

Property	ASTM Method	SI Units	English Units
Tensile strength (at break)	D-882-81	21 MPa	3000 psi
Elongation at break	D-882-81	300%	300%
Elastic modulus	D-882-81	480 MPa	70 000 psi
Yield point	D-882-81	12 MPa	1700 psi
Stress to produce 5% strain	D-882-81	12 MPa	1700 psi
Folding endurance (MIT)	D-2176-69	10,000 cycles	10,000 cycles
Initial tear strength (Graves)	D-1004-66	5.3 N	1.2 lbf
Propagating tear strength (Elmendorf)	D-1922-67	2.5 N	250 g
Bursting strength**	D-774-67 (Mullen)	76 kPa	11 psi
Density	D-1505-68	2150 kg/m³	134 lb/ft³
Coefficient of friction Kinetic (film to steel)	D-1894-63	0.3	0.3

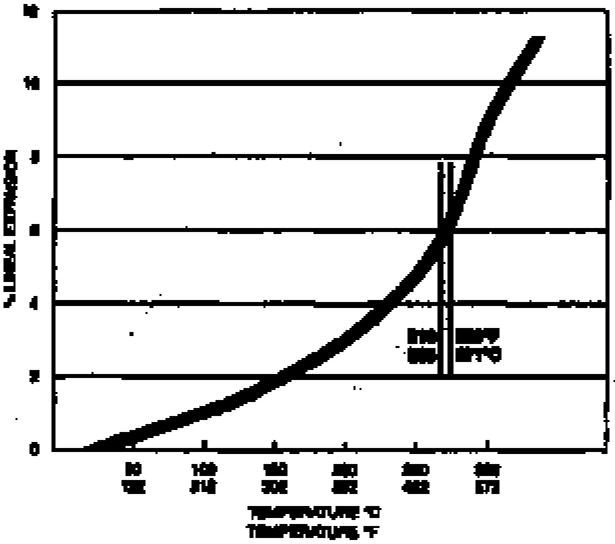
*200 gauge unless otherwise noted
**100 gauge film

Table 3
Typical Thermal Properties of DuPont FEP Film*

Property	ASTM Method	SI Units	English Units
Melt point	D-3418 (DTA)	260–280°C	500–536°F
Maximum continuous service temperature		204°C	400°F
Zero strength** temperature	***	255°C	490°F
Specific heat		1172 J/kg·K	0.28 Btu/lb·°F
Coefficient of thermal conductivity		0.195 W/m·K	1.35 $\frac{Btu \cdot in}{h \cdot ft^2 \cdot °F}$
Coefficient of linear thermal expansion	D-696-79	$8.4 \times 10^{-5} \frac{mm}{mm \cdot °C}$	$5.4 \times 10^{-5} \frac{in}{in \cdot °F}$
Flammability classification	ANSI/UL-94	VTM-0	VTM-0
Oxygen index	D-2863-77	95%	95%
Dimensional stability MD	30 min at 150°C (302°F)	0.7% expansion	0.7% expansion
Dimensional stability TD	30 min at 150°C (302°F)	2.5% shrinkage	2.2% shrinkage

*200 gauge unless otherwise noted
**100 gauge film
***Temperature at which film supports a load of 0.14 MPa (20 psi) for 5 sec

Figure 5. Thermal Expansion of DuPont FEP Film



Electrical Properties

FEP fluorocarbon films exhibit excellent electrical properties over a wide range of frequencies and temperatures. Table 4 shows how initial properties are retained even after long-term exposure to extreme environmental conditions.

Table 4
Typical Electrical Properties of DuPont FEP Fluorocarbon Film 25 µm (1 mil) Thickness

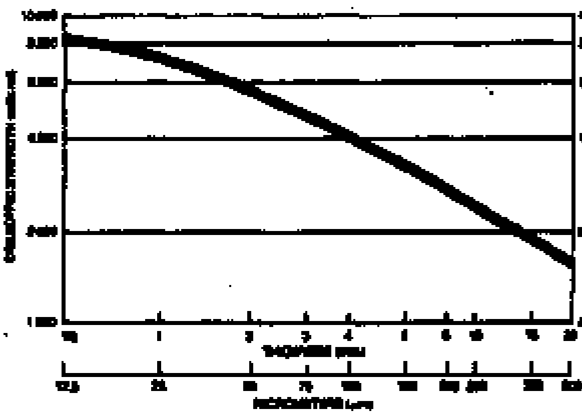
Property	ASTM Method	SI Units	English Units
Dielectric strength	D-149A-81 (6.4 mm [0.25 in] electrode in air, 60 Hz)	260 kV/mm	6500 V/mil
Dielectric constant	D-150-81 (1 kHz)	2.0	2.0
Dissipation factor	D-150-81 (1 kHz)	0.0002	0.0002
Volume resistivity	D-257-78	1×10^{16} ohm-m	1×10^{18} ohm-cm
Surface resistivity	D-257-78	1×10^{16} ohm (per square)	1×10^{16} ohm (per square)
Surface arc resistance	D-495-73	>165 s*	>165 s*

*Samples melted in arc did not track.

Dielectric Strength

Figure 6 shows how the dielectric strength of DuPont FEP film is a function of film thickness; thinner films exhibit greater dielectric strength.

Figure 6. Dielectric Strength vs. Film Thickness of DuPont FEP Film



Dielectric Constant

For DuPont FEP film, dielectric constant is independent of film thickness. There is no difference between Type A and Type C films.

At a constant frequency, the dielectric constant of DuPont FEP film decreases with rise in temperature due to thermal expansion (see Figure 7).

At a constant temperature, the dielectric constant falls slightly with an increase in frequency above 10^7 Hz (see Figure 8).

Figure 7. Dielectric Constant vs. Temperature of DuPont FEP Film at 1 kHz and 100 kHz

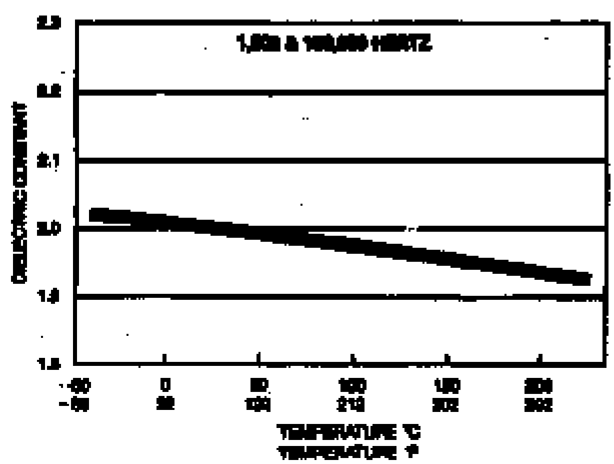
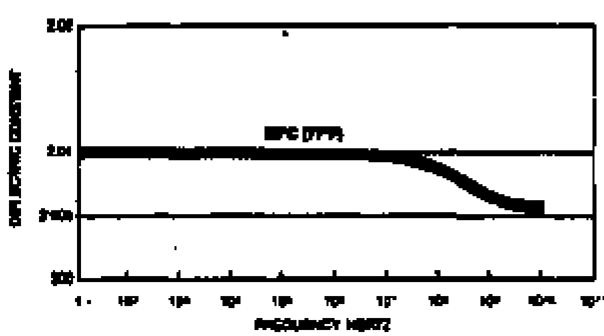


Figure 8. Dielectric Constant vs. Frequency



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Dissipation Factor

The consistently low value of the dissipation factor over a broad range of temperature and frequency makes FEP fluorocarbon film ideal in applications where electrical losses must be minimized (see Figure 9).

At a constant temperature, this dissipation factor of FEP films varies as noted in **Figure 10**. Absolute values remain low in comparison with many other dielectric materials.

Figure 9. Dissipation Factor vs. Temperature of DuPont FEP Film

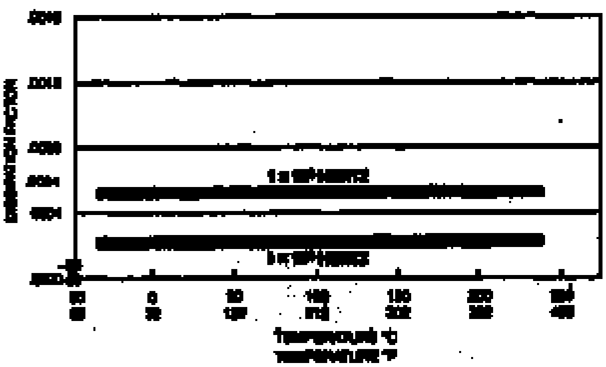
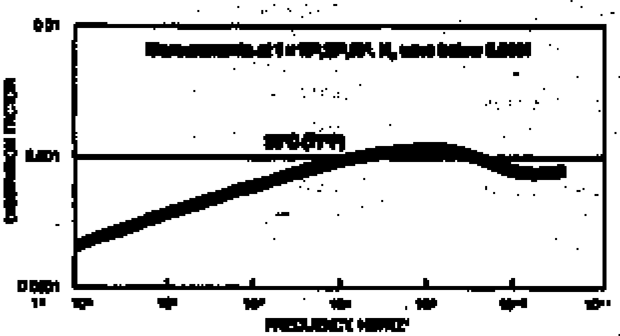


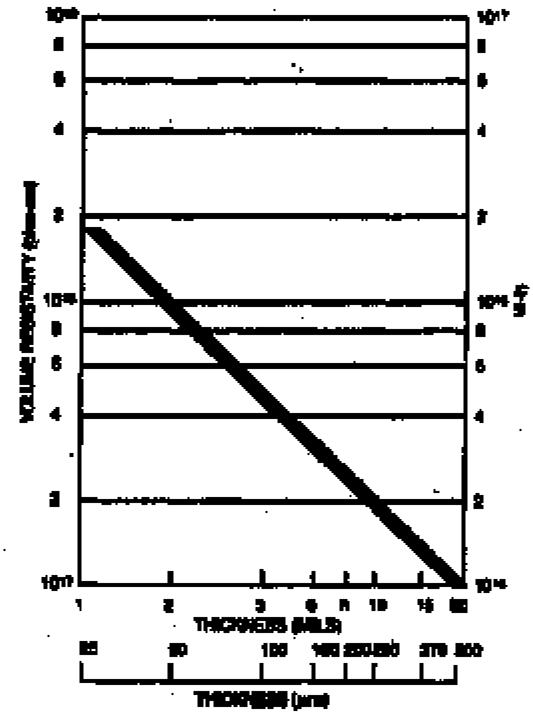
Figure 10. Dissipation Factor vs. Frequency of DuPont FEP Film



Volume Resistivity

Volume resistivity of DuPont FEP film decreases slightly as the film thickness increases (see Figure 11).

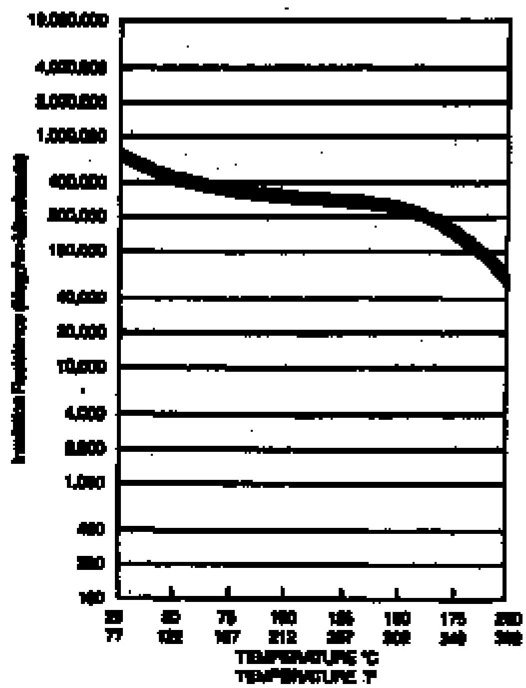
Figure 11. Volume Resistivity vs. Thickness (at 175°C [347°F])



Insulation Resistance

Even at 200°C (392°F), the insulation resistance of DuPont FEP film (65,000 megohm-microfarad) is higher than most conventional dielectric materials at room temperature (see **Figure 12**).

Figure 12. Insulation Resistance vs. Temperature (125 μm/0.5 mil DuPont FEP film)



Chemical Properties

DuPont FEP fluorocarbon film is chemically inert and solvent resistant to virtually all chemicals except molten alkali metals, fluorine at elevated temperatures, and certain complex halogenated compounds such as chlorine trifluoride at elevated temperatures and pressures.

In circumstances where end-use temperatures are close to the upper service limit 205°C (400°F), 80% sodium hydroxide, metal hydrides, aluminum chloride, ammonia, and certain amines ($R\text{-}NH_2$) may attack the film in a manner similar to molten alkali metals. Special testing is required when such extreme reducing or oxidizing conditions are evident.

With these exceptions noted, DuPont FEP fluorocarbon films exhibit a very broad range of chemical and thermal serviceability.

Due to the many complex aspects of performance in severe environments, final selection should be based on functional evaluations or experience under actual end-use conditions.

The chemical substances listed in Table 5 are representative of those with which DuPont FEP film has been found to be nonreactive.

Table 5
Typical Chemicals with Which DuPont FEP Film Is Nonreactive*

Abietic acid	Cyclohexanone	Hydrofluoric acid	Phthalic acid
Acetic acid	Dibutyl phthalate	Hydrogen peroxide	Pinene
Acetic anhydride	Dibutyl sebacate	Lead	Piperidine
Acetone	Diethyl carbonate	Magnesium chloride	Polyacrylonitrile
Acetophenone	Diethyl ether	Mercury	Potassium acetate
Acrylic anhydride	Dimethyl formamide	Methyl ethyl ketone	Potassium hydroxide
Allyl acetate	Di-isobutyl adipate	Methacrylic acid	Potassium permanganate
Allyl methacrylate	Dimethylformamide	Methanol	Pyridine
Aluminum chloride	Dimethylhydrazine, unsymmetrical	Methyl methacrylate	Soap and detergents
Ammonia, liquid	Dioxane	Naphthalene	Sodium hydroxide
Ammonium chloride	Ethyl acetate	Naphthols	Sodium hypochlorite
Aniline	Ethyl alcohol	Nitric acid	Sodium peroxide
Benzonitrile	Ethyl ether	Nitrobenzene	Solvents, aliphatic and aromatic**
Benzoyl chloride	Ethyl hexoate	2-Nitro-butanol	Stannous chloride
Benzyl alcohol	Ethylene bromide	Nitromethane	Sulfur
Borax	Ethylene glycol	Nitrogen tetroxide	Sulfuric acid
Boric acid	Ferric chloride	2-Nitro-2-methyl propanol	Tetrabromoethane
Bromine	Ferric phosphate	n-Octadecyl alcohol	Tetrachlorethylene
n-Butyl amine	Fluoronaphthalene	Oils, animal and vegetable	Trichloracetic acid
Butyl acetate	Fluoronitrobenzene	Ozone	Trichlorethylene
Butyl methacrylate	Formaldehyde	Perchlorethylene	Tricresyl phosphate
Calcium chloride	Formic acid	Pentachloro-benzamide	Triethanolamine
Carbon disulfide	Furane	Perfluoroxylene	Vinyl methacrylate
Cetane	Gasoline	Phenol	Water
Chlorine	Hexachlorethane	Phosphoric acid	Xylene
Chloroform	Hexane	Phosphorus pentachloride	Zinc chloride
Chlorosulfonic acid	Hydrazine		
Chromic acid	Hydrochloric acid		
Cyclohexane			

*Based on experiments conducted up to the boiling points of the liquids listed. FEP resins have normal service temperatures up to 205°C (400°F). Absence of a specific chemical does not mean that it is reactive with FEP film.

**Some halogenated solvents may cause moderate swelling.

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Physical Properties

Absorption

Almost all plastics absorb small quantities of certain materials with which they come in contact. Submicroscopic voids between polymer molecules provide space for the material absorbed without chemical reaction. This phenomenon is usually marked by a slight weight increase and sometimes by discoloration.

DuPont FEP fluorocarbon films have unusually low absorption compared with other thermoplastics. They absorb practically no common acids or bases at temperatures as high as 200°C (392°F) and exposures of up to one year. Even the absorption of solvents is extremely small. Weight increases are generally less than 1% when exposed at elevated temperatures for long periods. In general, aqueous solutions are absorbed very little by DuPont FEP film. ***Moisture absorption is typically less than 0.01% at ambient temperature and pressure.***

Permeability

Many gases and vapors permeate FEP films at a much lower rate than for other thermoplastics (see Figure 13). In general, permeation increases with temperature, pressure, and surface contact area and decreases with increased film thickness. Table 6 lists rates at which various gases are transmitted through DuPont FEP fluorocarbon film, while Table 7 lists rates of vapor permeability for some representative substances. Note that the pressure for each material is its vapor pressure at the indicated temperature.

Table 6
Typical Gas Permeability Rates of DuPont FEP Fluorocarbon Film, 25 µm (1 mil) Thickness
(Test Method: ASTM D-1434 at 25°C [77°F])

Gas	Permeability Rate* cm³/(m²·24 h·atm)
Carbon Dioxide	25.9×10^3
Hydrogen	34.1×10^3
Nitrogen	5.0×10^3
Oxygen	11.6×10^3

*To convert to cm³/(100 in²·24 h·atm), multiply by 0.0645.

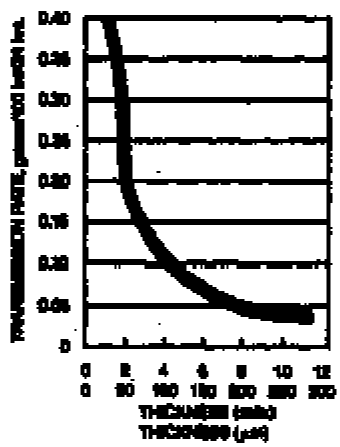


Figure 13. Water Vapor Transmission Rate of DuPont FEP Film at 40°C (104°F) per ASTM E-96 (Modified)

Notes: Values are averages only and not for specification purposes. To convert the permeation values for 100 in² to those for 1 m², multiply by 15.5.

Table 7
Typical Vapors Transmission Rates of DuPont FEP Fluorocarbon Film, 25 µm (1 mil) Thickness
(Test Method: Modified ASTM E-96)

Vapor	Temperature		Vapor Transmission Rate	
	°C	°F	SI Units (g/m²·d)	English Units (g/100 in²·d)
Acetic Acid	35	95	6.3	0.41
Acetone	35	95	14.7	0.95
Benzene	35	95	9.9	0.64
Carbon Tetrachloride	35	95	4.8	0.31
Ethyl Acetate	35	95	11.7	0.76
Ethyl Alcohol	35	95	10.7	0.69
Freon® F-12	23	73	372.0	24.0
Hexane	35	95	8.7	0.56
Hydrochloric Acid	25	77	<0.2	<0.01
Nitric Acid (Red Fuming)	25	77	160.0	10.5
Sodium Hydroxide, 50%	25	77	<0.2	<0.01
Sulfuric Acid, 98%	25	77	2×10^{-4}	1×10^{-4}
Water	39.5	103	7.0	0.40

Optical Properties

DuPont FEP films transmit a high percentage of ultraviolet and visible light and are much more transparent to the infrared spectrum than glass (see Figures 14–16).

Other optical properties of FEP films of interest are:

	FEP
Solar Transmission (ASTM E-424)	96%
Refractive Index (ASTM D-542)	1.341–1.347

Figure 14. Transmission Spectrum for DuPont FEP Film

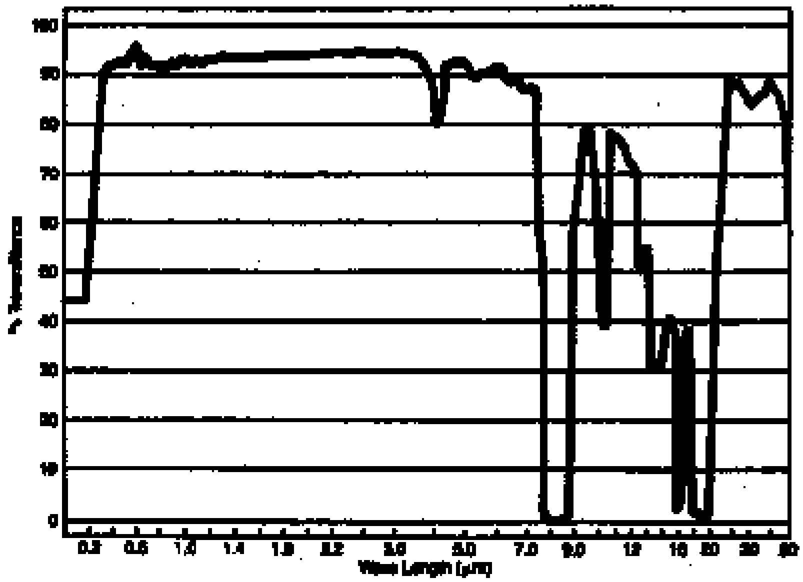


Figure 15. Transmittance at Normal Incidence of Solar Radiation through DuPont FEP Films for Various Thicknesses

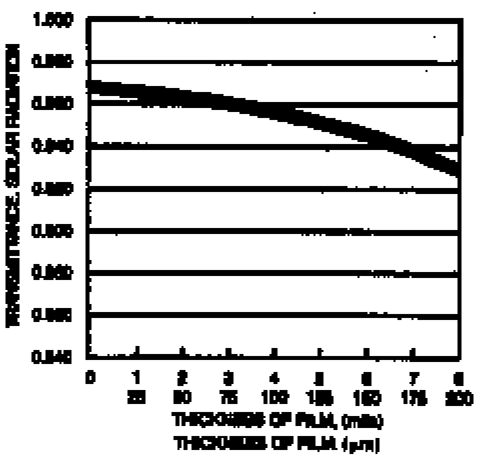
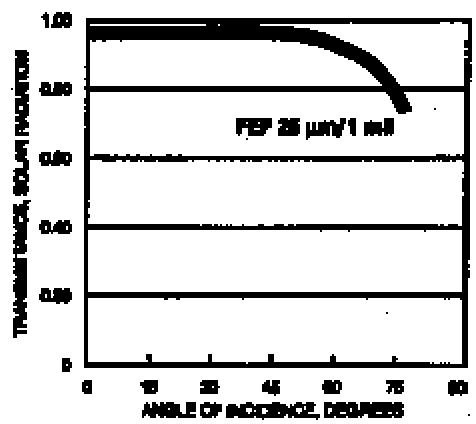


Figure 16. Transmittance of Solar Radiation through 25 μm (1 mil) DuPont FEP Film for Various Angles of Incidence



Miscellaneous Properties

Cryogenic Service

FEP has performed satisfactorily in cryogenic service at temperatures below that of liquid nitrogen. DuPont FEP fluorocarbon film is normally inert to liquid oxygen (LOX) when the film is free of contamination, pigmentation, or fillers for reinforcement.

FDA Compliance

Clear DuPont FEP fluorocarbon film complies with Part 177 of Title 21 of the Food & Drug Administration regulations for safe use as articles or components of articles for producing, manufacturing, processing, preparing, treating, packaging, transporting, or holding food in accordance with Regulation 177.1550.

USDA Acceptance

Clear DuPont FEP fluorocarbon film is acceptable as a component of materials for use in slaughtering, processing, transporting, or storage areas in direct contact with meat or poultry food product prepared under federal inspection.

Mildew (Fungus) Resistance

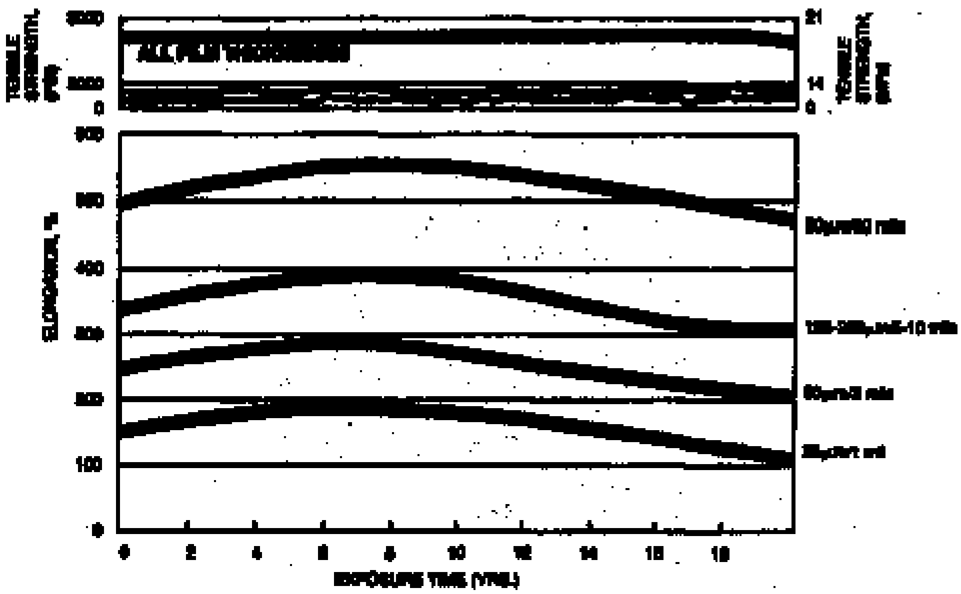
FEP has been shown to be completely resistant to mildew growth by testing both in humidity chamber exposure inoculated with a mixed spore suspension and a soil burial test for three months.

Weatherability

In contrast to most other clear thermoplastic films, DuPont FEP film remains essentially unchanged after 20 years of outdoor exposure (see Figure 17). There is no evidence of discoloration, ultraviolet degradation, or strength loss. This outstanding performance is due to the structure of the polymer molecule and is not the result of chemical additives.

Types C and C-20 DuPont FEP film are not recommended for outdoor applications because ultraviolet radiation may adversely affect the treated surface.

Figure 17. The Effects of Florida Weathering on DuPont FEP Film



Safety and Handling

Unheated FEP fluorocarbon is essentially inert. Animal tests indicate that FEP is nonirritating and nonsensitizing to the skin. Dust generated by cutting, grinding, or machining the unheated film should be avoided, as with any other nuisance dusts that are regulated by OSHA at 15 mg/m³ in air (29 CFR 1910:1000).

Care should be taken to avoid contamination of smoking tobacco or cigarettes with fluorocarbon resins.

DuPont FEP film can be processed and used at elevated temperatures without hazard if proper ventilation is used. Ventilation should be provided at processing temperatures of 275°C (525°F) or above.

Additional details on safety in handling and use are available in bulletin H-48633, "Guide to the Safe Handling of Fluoropolymer Resins, 2nd Edition," available from DuPont.

Other related literature available from DuPont:

Bulletin	Title
E-80413-2	DuPont PFA Film—Specification Bulletin (T62-3)
H-55003-2	DuPont FEP Film—Specification Bulletin (T62-1)
H-55008-2	DuPont FEP Film—Properties Bulletin

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DuPont Films

DuPont Films

High Performance Films

Kapton®

polyimide film

General Specifications

Introduction

DuPont High Performance Films manufactures and sells a variety of high-quality plastic film products in conformance with ISO 9002 certification.

These specifications describe the values and tolerances for Kapton® film properties. Where necessary for thorough understanding, test methods and procedures have been included.

Any aspects of the specifications that require further interpretation or clarification should be discussed with representatives of DuPont High Performance Films.

Types of Kapton® Polyimide Film

DuPont makes several types of Kapton® film. Types HN, FN, and VN are used most commonly.

Types H, F, and V are alternative, special versions of these standard types. The specifications in this bulletin apply to them as well. 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 High Performance Films representative.

Type HN Film

Kapton® Type HN is a tough, aromatic polyimide film, exhibiting an excellent balance of physical, chemical, and electrical properties over a wide temperature range, particularly at unusually high temperatures. Chemically, its polyimide polymer makeup is the result of a polycondensation reaction between pyromellitic dianhydride and 4,4'diaminodiphenyl ether. Kapton® HN is available in the following gauges: 30 (7.5 µm), 50 (12.7 µm), 100 (25.4 µm), 200 (50.8 µm), 300 (76.2 µm), and 500 (127 µm). Other gauges, such as 75 (19.1 µm) and 400 (102 µm), are available by special request.

Type FN Film

Kapton® Type FN film is a heat sealable grade that retains the unique balance of properties of Kapton® Type HN over a wide temperature range. This is achieved by combining Type HN with DuPont Teflon® FEP fluorocarbon resin in a composite structure. Table 1 lists the common types of FN film available. Other combinations are available. Consult your DuPont High Performance Films marketing representative for further information.

Table 1
Kapton® FN Polyimide Film Types

Designation	Construction, mil (µm) FEP	HN	FEP
120FN616	0.10 (2.5)	1.00 (25.4)	0.10 (2.5)
120FN616B	0.15 (3.8)	1.00 (25.4)	0.15 (3.8)
150FN019		1.00 (25.4)	0.50 (12.7)
200FN919	0.50 (12.7)	1.00 (25.4)	0.50 (12.7)
200FN011		1.00 (25.4)	1.00 (25.4)
250FN029		2.00 (50.8)	0.50 (12.7)
300FN021		2.00 (50.8)	1.00 (25.4)
300FN929	0.50 (12.7)	2.00 (50.8)	0.50 (12.7)
400FN022		2.00 (50.8)	2.00 (50.8)
500FN131	1.00 (25.4)	3.00 (76.2)	1.00 (25.4)

Type VN Film

Kapton® Type VN is the same tough polyimide film as Type HN Film, exhibiting an excellent balance of physical, chemical, and electrical properties over a wide temperature range, with superior dimensional stability at elevated temperatures. This product is available in 50 (12.7 µm), 75 (19.1 µm), 100 (25.4 µm), 200 (50.8 µm), 300 (76.2 µm), and 500 (127 µm) gauges.

Certification

Kapton® is certified to meet the requirements of the military specification MIL-P-46112 B and ASTM D-5213-95 in addition to the items covered by this specifications bulletin. Written confirmation is available with each delivery upon request.

Thermal Durability

The thermal durability of Kapton® film depends on the environmental conditions under which it is aged and tested. Its lifetime depends on the criterion of failure. Kapton® is routinely tested at the manufacturing site in the following manner:

Sheets of film 8.5" × 11" (216 mm × 279 mm) are freely suspended in an oven at a temperature of 400°C ±2°C (752°F ±3.6°F), monitored with a thermocouple to ensure accuracy. Sheets are removed after 2 hr (1 hr for 30 [7.6 µm] and 50 [12.7 µm] gauge film) and tested on an Instron Tensile Tester as described in **Table 2**. The elongation of the film at 23.5°C (74.3°F) should not be less than 10% after this aging at 400°C (752°F). This conforms to MIL-P-46112B "Elongation After Aging at 400°C" test (paragraph 4.4.5) and "Elongation, Percent, After Two Hour 400°C" requirement (**Table 2**).

In addition, Kapton® conforms to ASTM D-5213-95, Standard Specification for Polymeric Resin Film for Electrical Insulation and Dielectric Applications.

Underwriters Laboratories, Inc. lists a thermal index of 200 to 220°C (392 to 428°F) (depending on gauge and type) for mechanical properties and 220 to 240°C (428 to 464°F) (depending on gauge and type) for electrical properties, under their file number E39505 for Kapton® polyimide film.

Properties of Type FN Film

Heat Seal Strength

Film-to-Film Seals

The peel strength of heat seals between the coated and uncoated sides of one-side coated Kapton® or between the coated sides of both one- and two-side coated Kapton® is determined as follows.

Seals are made in a jaw sealer at 350°C (662°F), 20 psi (1.4 bar), with a 20-sec dwell time. After cooling, the seals are cut into 1" (25.4-mm) wide strips using a Thwing-Albert JDC sample cutter or its equivalent. The seal strength is measured with an Instron-type tensile tester. Seal strength is defined as the peak instantaneous strength occurring in each seal. Five specimen values are averaged.

The minimum peel strength between the coated sides of one- or two-side coated Kapton® film will be 700 g/in (2.7 N/cm), except for 120FN616 and 120FN616B, which will be 450 g/in (1.7 N/cm). The minimum peel strength between the coated and uncoated side of one-side coated Kapton® will be 450 g/in (1.7 N/cm).

Film-to-Copper Seals

The ability of FEP film to adhere to copper is measured using the same heat seal peel strength technique as described in "Film-to-Film Seals."

The peel strength is measured with the FEP side sealed to the untreated side of 1 mil (25.4 µm), ¾ oz GT copper foil; it will be a minimum of 300 g/in (1.2 N/cm).

As-Received Strength (Cold Peel) of Bonds Between Kapton® Type HN and Teflon® Layers

The bond between the Kapton® Type HN and Teflon® fluorocarbon resin layers on all Type FN products except 120FN616 and 120FN616B will have a minimum peel strength of 225 g/in (0.87 N/cm), measured using an Instron-type tensile tester and a 180° peel.

Table 2
Mechanical Properties of Kapton* Type HN Polyimide Film

Property	Property Value—Film Thickness, mil (μm)						Method
	0.30 (7.6)	0.50 (12.7)*	1.00 (25.4)*	2.00 (50.8)*	3.00 (76.2)*	5.00 (127)*	
Tensile Strength, psi (MPa) at 23°C (73°F). Machine Direction (MD) and Transverse Direction (TD), min.	16,000 (110)	20,000 (138)	24,000 (165)	24,000 (165)	24,000 (165)	24,000 (165)	ASTM D-882-91, Method A, using an Instron Tensile Tester (specimen size: ½" × 6" (12.7 mm × 152 mm); jaw separation: 4" (102 mm); jaw speed: 2"/min (51 mm/min)). Calculate the average of five specimens based on original measured thickness.
Elongation, %, MD and TD, min.	25	35	40	45	50	50	Same as above.
Shrinkage, %, MD and TD at 400°C (752°F), max.	4.0	4.0	2.5	2.5	2.5	2.5	MIL-P-46112B. The percent shrinkage is obtained for either the MD or TD using the average of three measurements in either direction before and after conditioning. Prior to measurement, the 8½" × 11" (216 mm × 279 mm) specimen is conditioned by freely suspending it for 2 hr** in an oven controlled to 400°C (752°F).
Moisture Absorption, %, max.	4.0	4.0	4.0	4.0	4.0	4.0	ASTM D-570-82, using 24-hr immersion at 23°C (73°F). Average of three specimens.

*Also applies to Type VN, except shrinkage, which is shown in Table 5.
**1 hr for 30 and 50 gauge film

Table 3
Electrical Properties of HN Film

Property	Property Value—Film Thickness, mil (μm)						Method
	0.30 (7.6)	0.50 (12.7)*	1.00 (25.4)*	2.00 (50.8)*	3.00 (76.2)*	5.00 (127)*	
Dielectric Strength, AC V/mil (kV/mm), min.	3,000 (118)	3,000 (118)	6,000 (236)	5,000 (197)	4,500 (177)	3,000 (118)	ASTM D-149-94. (Average of ten specimens.) Flat sheets in air placed between ¼" (6 mm) diameter brass electrodes with 1/32" (0.8 mm) edge radius subjected to 60 cycles AC voltage at 500 V/sec rate of rise to the breakdown voltage.
Volume Resistivity, ohm-cm at 200°C (392°F), min.	10^{12}	10^{12}	10^{12}	10^{13}	10^{11}	10^{12}	ASTM D-257-93
Dielectric Constant at 1 kHz, max.	4.0	4.0	3.9	3.9	3.9	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.
Dissipation Factor at 1 kHz, max.	0.0070	0.0050	0.0036	0.0036	0.0036	0.0036	Same as above.

*Also applies to Type VN

Table 4
Dielectric Strength of Kapton® Type FN Polyimide Films

Gauge Construction	Minimum Breakdown V/mil (kV/mm)
120FN616	4,300 (165)
120FN6165	4,300 (165)
150FN019	3,700 (145)
200FN919	3,200 (126)
200FN011	3,200 (126)
250FN029	2,750 (108)
300FN021	2,700 (106)
300FN929	2,700 (106)
400FN022	2,200 (87)
500FN131	2,200 (87)

Test Method
Average of ten specimens tested per ASTM D-149-92. Flat sheets in air placed between ¼" (6 mm) diameter brass electrodes with 1/32" (0.8 mm) edge radius subjected to 60 cycles AC voltage. Rise is 500 V/sec to the breakdown voltage.

General

Materials

Kapton® Type HN and Type VN films are polyimide polymers in the form of a film.

Kapton® Type FN film is a combination of Type HN film with Teflon® FEP fluorocarbon resin on one or both sides.

Uniformity

Material shall be uniform in composition and free from defects that impair serviceability and/or appearance in proven applications.

U.S. Cores

Cores shall be of sufficient strength to prevent collapsing from handling. Standard core internal diameters (I.D.) are nominally 3" and 6" (76 mm and 152 mm) with the following specifications:

Paper

3" (76 mm) I.D.	3.032" ± 0.008" (77.01 mm ± 0.2 mm)
6" (152 mm) I.D.	6.028" ± 0.010" (153.11 mm ± 0.25 mm)

Plastic

3" (76 mm) I.D.	3.024" ± 0.005" (76.81 mm ± 0.1 mm)
6" (152 mm) I.D.	6.041" ± 0.010" (153.44 mm ± 0.25 mm)

Core material will be plastic for 3" (76 mm) I.D. cores less than ⅝" (16 mm) wide.

Core material will be fiber for 3" (76 mm) I.D. cores wider than ⅝" (16 mm) and for 6" (152 mm) I.D. cores. A split 3" (76 mm) I.D. fiber core is standard for all universal and Step-Pac™ rolls.

If these cores are not suitable, further information on other options may be obtained from your DuPont High Performance Films representative.

Table 5
Shrinkage of Kapton® Type VN Polyimide Film

Property	Property Value Film Thickness, mil (µm)				
	0.50 (12.7)	1.00 (25.4)	2.00 (50.8)	3.00 (76.2)	5.00 (127)
Shrinkage, %, MD and TD at 200°C (392°F), max.	0.10	0.10	0.10	0.10	0.10

Test Method
The percent shrinkage obtained for either the MD or TD by using the average of three measurements in either direction before and after conditioning. Temperature exposure 200°C ±2°C (392°F ±3.6°F) for 1 hr. Measurements must be made at the same temperature and humidity conditions before and after conditioning. To ensure sample/ambient equilibrium before and after conditioning, specimens should be exposed for 3 hr.

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Width Tolerance
The maximum variation in film width from that specified on the order shall be as follows:

Slit Width Range	Tolerance
1" (25 mm) or less	±0.005" (0.13 mm)
1" to 4" (>25 mm to 102 mm)	±0.030" (0.76 mm)
>4" (>102 mm)	±0.060" (1.5 mm)

Luxembourg Supply

Cores shall be of sufficient strength to prevent collapsing from handling. Luxembourg supplies pad rolls in widths below 9½" (240 mm) and universal wound rolls.

Standard core internal diameter for Luxembourg is 3" (76 mm) (nominal 3" ±0.008" [76 mm ±0.2 mm]).

Standard cores for pad rolls are paper cores, except for widths below ½" (13 mm), where it will be plastic.

Standard universal: core length

2.8" ±0.08" (70 mm ±2 mm) (split core)

Wide universal: core length

4.3" ±0.08" (110 mm ±2 mm) (non-split core)

A different put-up called Step-Pac™ is available from the U.S. Contact your DuPont High Performance Films representative for more information.

Width Tolerance
The maximum variation in film width from that specified on the order shall be as follows:

Slit Width Range	Tolerance
0.9" (22 mm) or less Universal	0.008" (0.20 mm)
6" (152 mm) or less Pad rolls	0.016" (0.40 mm)
6" to 9½" (153 mm to 240 mm) Pad rolls	0.04" (1.00 mm)

Outside diameter tolerance: ±0.4" (10 mm)

Table 6
Kapton® Polyimide Film Specifications and Tolerances

Film Type	Thickness Nominal mil (µm)*	Thickness Tolerance Min. mil (µm)	Thickness Tolerance Max. mil (µm)	Width Range Min. in (mm)	Width Range Max. in (mm)	Unit Weight Min. g/m²	Unit Weight Max. g/m²	Area Factor ft²/lb	Area Factor (m²/kg)
30HN	0.30 (7.6)	0.24 (6.1)	0.36 (9.1)	3/16 (4.8)	52 (1320)	7.6	14.0	453	92.8
50HN	0.50 (12.7)	0.35 (8.9)	0.65 (16.5)	3/16 (4.8)	52 (1320)	14.0	28.0	272	55.7
100HN	1.00 (25.4)	0.85 (21.6)	1.15 (29.2)	3/16 (4.8)	52 (1320)	32.7	38.7	136	27.9
200HN	2.00 (50.8)	1.75 (44.5)	2.25 (57.2)	3/16 (4.8)	52 (1320)	65.9	77.9	68	13.9
300HN	3.00 (76.2)	2.72 (69.1)	3.28 (83.3)	3/16 (4.8)	52 (1320)	101.9	115.4	45	9.2
500HN	5.00 (127)	4.65 (118)	5.35 (136)	3/16 (4.8)	52 (1320)	169.5	192.5	27	5.5
50VN	0.50 (12.7)	0.35 (8.9)	0.65 (16.5)	3/16 (4.8)	52 (1320)	14.0	28.0	272	55.7
100VN	1.00 (25.4)	0.85 (21.6)	1.15 (29.2)	3/16 (4.8)	52 (1320)	32.7	38.7	136	27.9
200VN	2.00 (50.8)	1.75 (44.5)	2.25 (57.2)	3/16 (4.8)	52 (1320)	65.9	77.9	68	13.9
300VN	3.00 (76.2)	2.72 (69.1)	3.28 (83.3)	3/16 (4.8)	50 (1270)	101.9	115.4	45	9.2
500VN	5.00 (127)	4.65 (118)	5.35 (136)	3/16 (4.8)	50 (1270)	169.5	192.5	27	5.5
120FN616	1.20 (30.5)	1.10 (27.9)	1.40 (35.6)	3/16 (4.8)	44 (1118)	41.0	58.0	104	21.3
120FN616B	1.30 (33.0)	1.20 (30.5)	1.50 (38.1)	3/16 (4.8)	44 (1118)	47.0	54.0	92	18.8
150FN019	1.50 (38.1)	1.25 (31.8)	1.75 (44.5)	3/16 (4.8)	44 (1118)	53.0	74.0	77	15.8
200FN011	2.00 (50.8)	1.70 (43.2)	2.30 (58.4)	3/16 (4.8)	44 (1118)	77.0	104.0	54	11.1
200FN919	2.00 (50.8)	1.70 (43.2)	2.30 (58.4)	3/16 (4.8)	44 (1118)	77.0	104.0	54	11.1
250FN029	2.50 (63.5)	2.25 (57.2)	2.75 (69.9)	3/16 (4.8)	44 (1118)	87.0	113.0	48	10.0
300FN021	3.00 (76.2)	2.60 (66.0)	3.40 (86.4)	3/16 (4.8)	44 (1118)	111.0	142.0	39	8.0
300FN929	3.00 (76.2)	2.60 (66.0)	3.40 (86.4)	3/16 (4.8)	44 (1118)	111.0	142.0	39	8.0
400FN022	4.00 (102)	3.50 (88.9)	4.50 (114)	3/16 (4.8)	44 (1118)	163.0	200.0	27	5.5
500FN131	5.00 (127)	4.50 (114)	5.50 (140)	3/16 (4.8)	44 (1118)	195.0	238.0	23	4.7

*Reference: ASTM D-374-94, Method A, C, or D.

The usual dimensions of pad rolls are 3" (76 mm) I.D. × 6" (152 mm) or 9" (230 mm) outside diameter (O.D.) for widths up to 4" (102 mm). In Luxembourg, 152 mm, 180 mm, 203 mm, and 240 mm O.D. rolls are available. For wider rolls, the usual dimensions are 6" (152 mm) I.D. × 9½" (240 mm) or 11" (280 mm) O.D. For Universal and Step-Pac™ rolls, the dimensions are 3" (76 mm) I.D. × 6" (152 mm), 8" (203 mm), or 12" (305 mm) O.D. If these dimensions are not suitable, information on other options is available from your DuPont High Performance Films technical or customer service representative.

Roll Types

Kapton® polyimide film is supplied in three types of rolls: pad, universal, and Step-Pac™ wind.

Pad Roll Specifications

- Core width will be the film width +¼" (+3.2 mm), –0.
- Core edges shall not project more than 1/16" (1.6 mm) beyond the 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 a manner to prevent unwinding.
- "Dishing" or "cupping" may not exceed 1/16" (1.6 mm), measured with a straightedge across the diameter of the roll.

Universal and Step-Pac™ Roll Specifications

- The difference between the lengths of the projecting core on each side shall not exceed 3/16" (4.8 mm).
- Film shall not project from the main body of the roll more than ⅛" (3.2 mm).
- The outside and starting ends of the film shall be fastened in a manner to prevent unwinding.
- Roll face depression, the difference between the highest and lowest points of the roll, unstressed, shall not exceed 3/16" (4.8 mm).

Table 7
Reference Guide: Standard Length versus Roll O.D. (U.S. Supply)

Type	Standard Length Roll	Roll O.D. 3" Core I.D.	Roll O.D. 6" Core I.D.
100HN	5,000 ft (1,525 m)	8½" (241 mm)	11" (279 mm)
	10,000 ft (3,050 m)	11" (279 mm)	14" (356 mm)
200HN	2,500 ft (763 m)	9½" (241 mm)	11" (279 mm)
300HN	1,670 ft (509 m)	9½" (241 mm)	11" (279 mm)
500HN	1,000 ft (305 m)	9½" (241 mm)	11" (279 mm)

Splices

Description

Three types of splice are available:

- Mylar® polyester film-based yellow tape (standard).
- Kapton® polyimide film-based tape (special requirements only).
- Heat seal splice, 12" (305 mm) or less in width (Type FN).

Splices will be centered on the joint to ±¼" (±6 mm). They will be smooth and wrinkle-free to avoid distortion of the adjacent film layers in the roll.

Tape Splices

Tape splices are standard on all gauges of HN and VN film and on all gauges of FN film more than 12" (305 mm) wide.

Tape splices are made with the butt edges of the film covered on both sides with pressure-sensitive adhesive tape. Two-inch (50 mm) wide splicing tape is used.

Heat Seal Splices

Overlap heat seal splices are made on all FN films, except 250FN029, with an overlap that is a minimum of ⅜" (9.5 mm) wide.

On 250FN029, a butt splice is made using 120FN616 as the joining tape applied on the FEP surface. The butt splice is oriented with the 120FN616 tape on the top of the film as it unwinds from a universal put-up and on the bottom as it unwinds from a pad.

Overlap heat seal splices for one-side and two-side FEP composites are oriented with the leading edge of the new film on the bottom for universal and Step-Pac™ put-ups. Pad put-ups of one- or two-side FEP composites have the leading edge of the new film on the top.

Packaging and Marking

Packaging

Kapton® polyimide film shall be adequately packed to prevent loss of contents or damage during shipment.

All film will be wrapped with a non-fibrous material.

Marking

Kapton® is identified, as shown in Table 8, to allow complete traceability back to the raw materials and processing conditions.

Arrangements for special markings can be made (such as part or specification number). Consult with your DuPont High Performance Films technical or customer service representative for details.

All package marking information is available with bar code labels.

Table 8
Package Marking

	Shipping Container	Package	Core Label*
Scheduled Date	X	X	X
Customer Order Number	X	X	
DuPont Order Number	X	X	X
Gauge	X	X	X
Type	X	X	X
Width	X	X	X
Number of Rolls per Container	X	X	
Net Weight	X	X	
Actual Footage			X
Mill Roll Number	X	X	X
I.D. and O.D.**	X	X	

* Affixed to the core on all cores 2.25" (57 mm) wide and over. Included with the package on all cores less than 2.25" (57 mm) wide

** Inside diameter of core and nominal outside diameter of roll

DUP 000029

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DuPont Films

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

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® does not melt or burn 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).

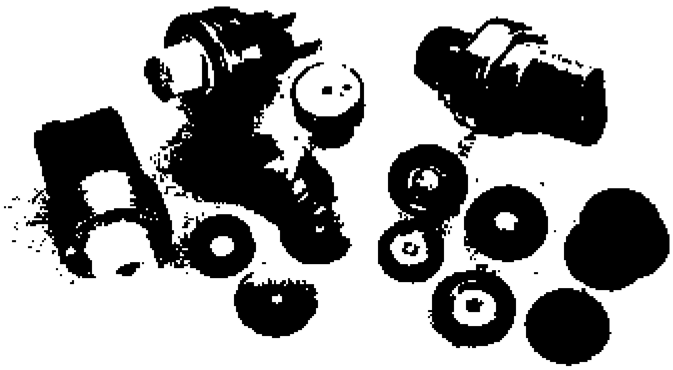
  Type HN film can be laminated, metallized, punched, formed, or adhesive coated. It is available as 7.5 µm (0.3 mil), 12.5 µm (0.5 mil), 19 µm (0.75 mil), 25 µm (1 mil), 50 µm (2 mil), 75 µm (3 mil), and 125 µm (5 mil) films.
- Kapton® Type VN, all-polyimide film with all of the properties of Type HN, plus superior dimensional stability. Type VN is available as 12.5 µm (0.5 mil), 19 µm (0.75 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 on one or both sides with Teflon® 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 Teflon® 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.

The Chemical Abstracts Service Registry Number for Kapton® polyimide film is [25036-53-7].



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

Kapton® is used in numerous electronic applications, including hard disk drives.

Physical and Thermal Properties

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 (–452°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.

Table 1
Physical Properties of Kapton® Type 100 HN Film, 25 μm (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)	139 (20,000)	ASTM D-882-91, Method A*
Yield Point at 3%, MPa (psi)	69 (10,000)	41 (6000)	ASTM D-882-91
Stress to Produce 5% Elongation, MPa (psi)	90 (13,000)	61 (9000)	ASTM D-882-91
Ultimate Elongation, %	72	83	ASTM D-882-91
Tensile Modulus, GPa (psi)	2.5 (370,000)	2.0 (290,000)	ASTM D-882-91
Impact Strength, N·cm (ft·lb)	78 (0.58)		DuPont Pneumatic Impact Test
Folding Endurance (MIT), cycles	285,000		ASTM D-2176-89
Tear Strength—Propagating (Elmendorf), N (lbf)	0.07 (0.02)		ASTM D-1922-89
Tear Strength—Initial (Graves), N (lbf)	7.2 (1.6)		ASTM D-1004-90
Density, g/cc or g/mL	1.42		ASTM D-1505-90
Coefficient of Friction—Kinetic (Film-to-Film)	0.48		ASTM D-1894-90
Coefficient of Friction—Static (Film-to-Film)	0.63		ASTM D-1894-90
Refractive Index (Sodium D Line)	1.70		ASTM D-542-90
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: 25 × 150 mm (1 × 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-794-85 (1989)
Thermal Coefficient of Linear Expansion	20 ppm/°C (11 ppm/°F)	–14 to 38°C (7 to 100°F)	ASTM D-696-91
Coefficient of Thermal Conductivity, W/m·K	0.12	296 K	ASTM F-433-77 (1987)ε1
$\frac{cal}{cm \cdot sec \cdot °C}$	2.87×10^{-4}	23°C	
Specific Heat, J/g·K (cal/g·°C)	1.09 (0.261)		Differential Calorimetry
Flammability	94V-0		UL-94 (2-8-89)
Shrinkage, %	0.17 1.25	30 min at 150°C 120 min at 400°C	IPC TM 650, Method 2.2.4A ASTM D-5214-91
Heat Sealability	Not Heat Sealable		
Limiting Oxygen Index, %	37		ASTM D-2863-87
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.		

Table 3
Physical and Thermal Properties of Kapton* Type VN Film

Property	Typical Value for Film Thickness 25 µm (1 mil)	50 µm (2 mil)	75 µm (3 mil)	125 µm (5 mil)	Test Method
Ultimate Tensile Strength, MPa (psi)	231 (33,500)	234 (34,000)	231 (33,500)	231 (33,500)	ASTM D-882-91
Ultimate Elongation, %	72	82	82	82	ASTM D-882-91
Tear Strength—Propagating (Elmendorf), N	0.07	0.21	0.38	0.58	ASTM D-1922-89
Tear Strength—Initial (Graves), N	7.2	16.3	26.3	46.9	ASTM D-1004-90
Folding Endurance (MIT), × 10³ cycles	285	55	6	5	ASTM D-2176-89
Density, g/cc or g/mL	1.42	1.42	1.42	1.42	ASTM D-1505-90
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-2863-87

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)	207 (30,000)	162 (23,500)	200 (29,000)
200°C (392°F)	121 (17,500)	89 (13,000)	115 (17,000)
Yield Point at 3%, MPa (psi)			
23°C (73°F)	61 (9000)	49 (7000)	58 (8500)
200°C (392°F)	42 (6000)	43 (6000)	36 (5000)
Stress at 5% Elongation, MPa (psi)			
23°C (73°F)	79 (11,500)	65 (9,500)	76 (11,000)
200°C (392°F)	53 (8000)	41 (6000)	48 (7000)
Ultimate Elongation, %			
23°C (73°F)	75	70	85
200°C (392°F)	80	75	110
Tensile Modulus, GPa (psi)			
23°C (73°F)	2.48 (360,000)	2.28 (330,000)	2.62 (380,000)
200°C (392°F)	1.62 (235,000)	1.14 (165,000)	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)	11.5 (2.6)	11.5 (2.6)	17.8 (4.0)
Polyimide, wt%	80	57	73
FEP, wt%	20	43	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 Teflon* 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 of Teflon* on each side.

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)

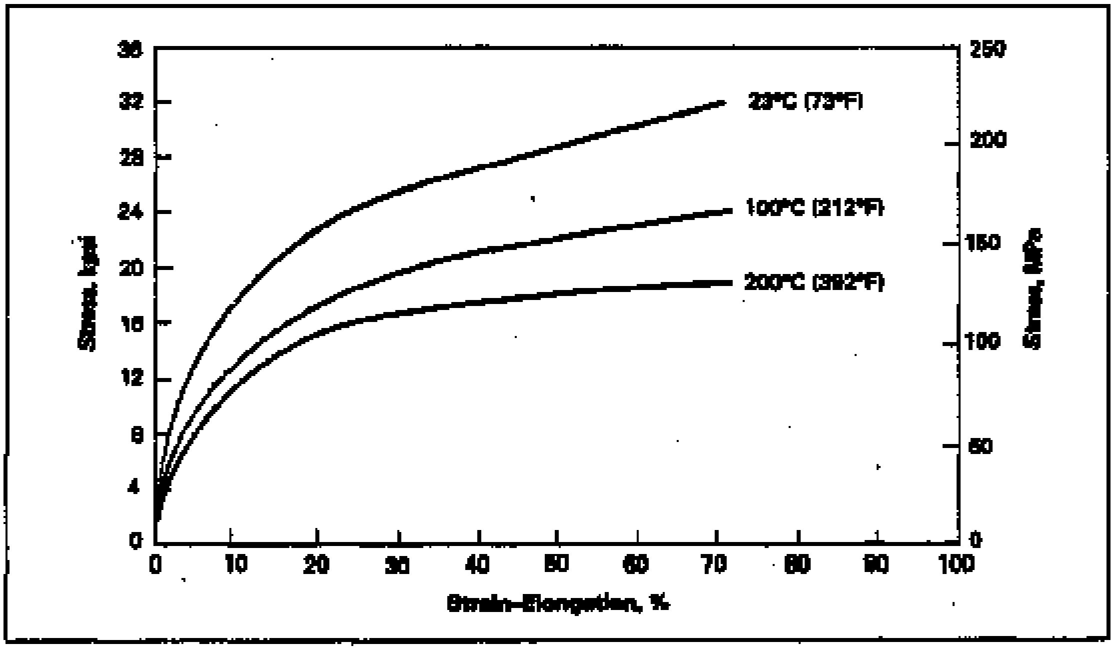
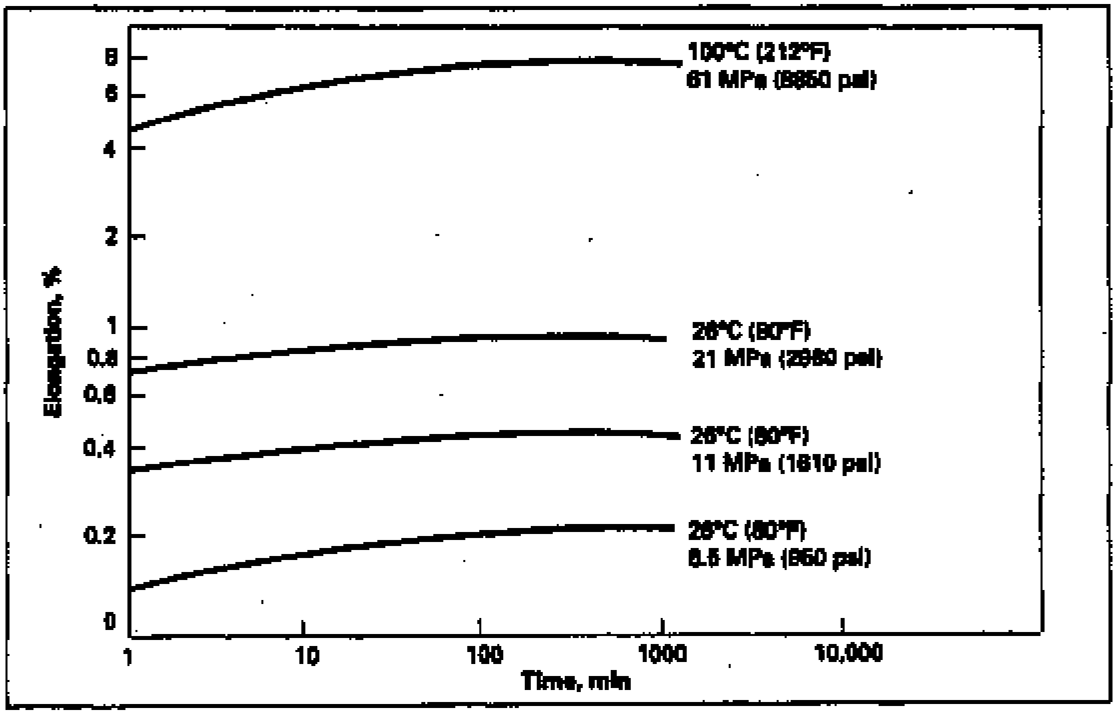


Figure 2. Tensile Creep Properties, Type HN Film, 25 μm (1 mil)



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)

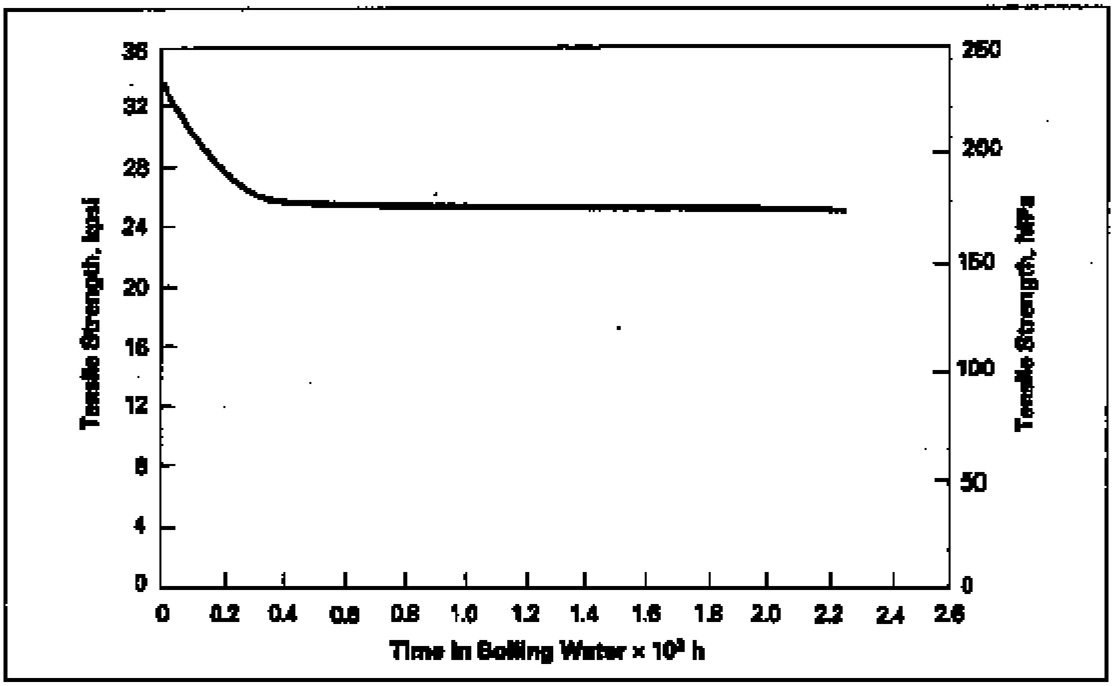
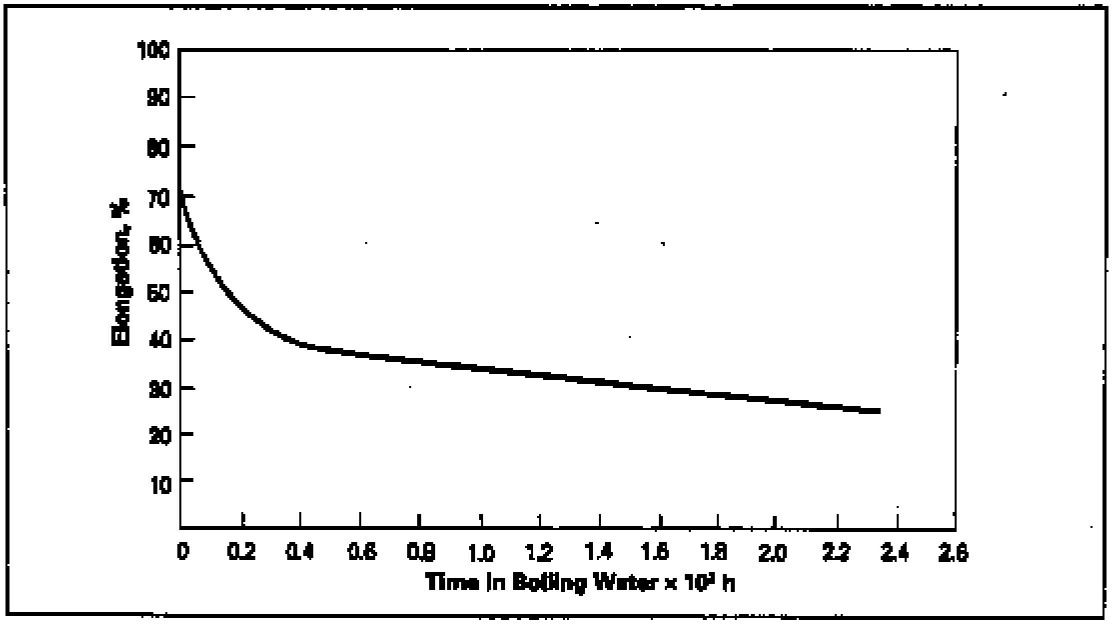


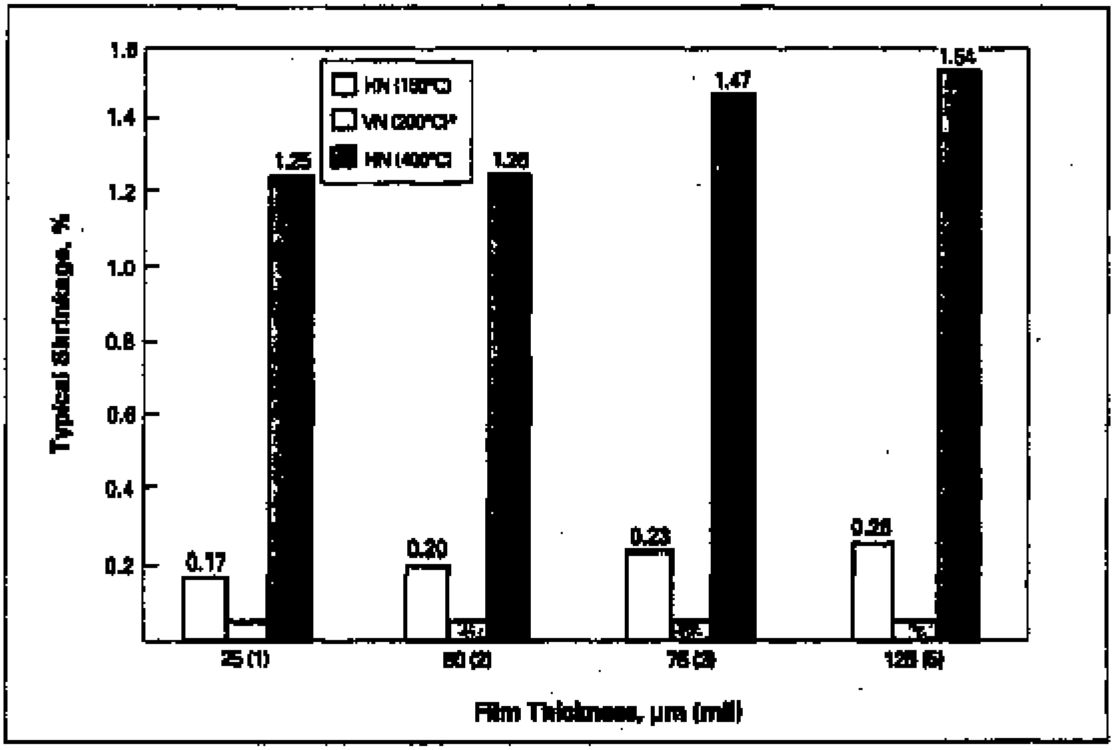
Figure 4. Ultimate Elongation After Exposure to 100°C (212°F) Water, Type HN Film, 25 μm (1 mil)



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 VN Films



*Type VN shrinkage is 0.03% for all thicknesses.

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)

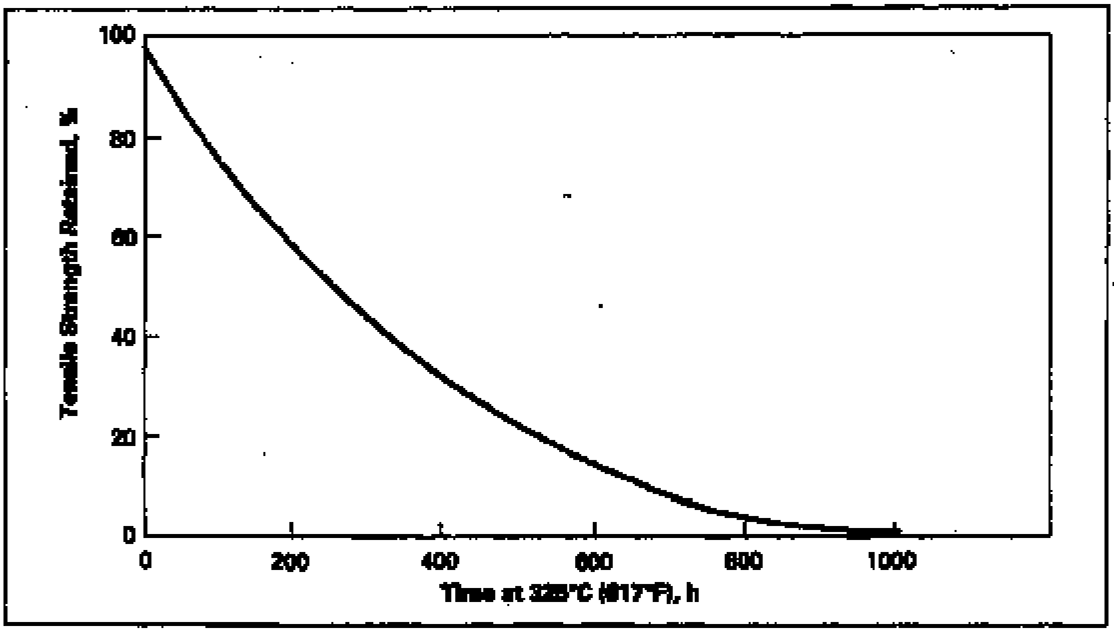


Figure 7. Ultimate Elongation vs. Aging in Air at 325°C (617°F), Type HN Film, 25 µm (1 mil)

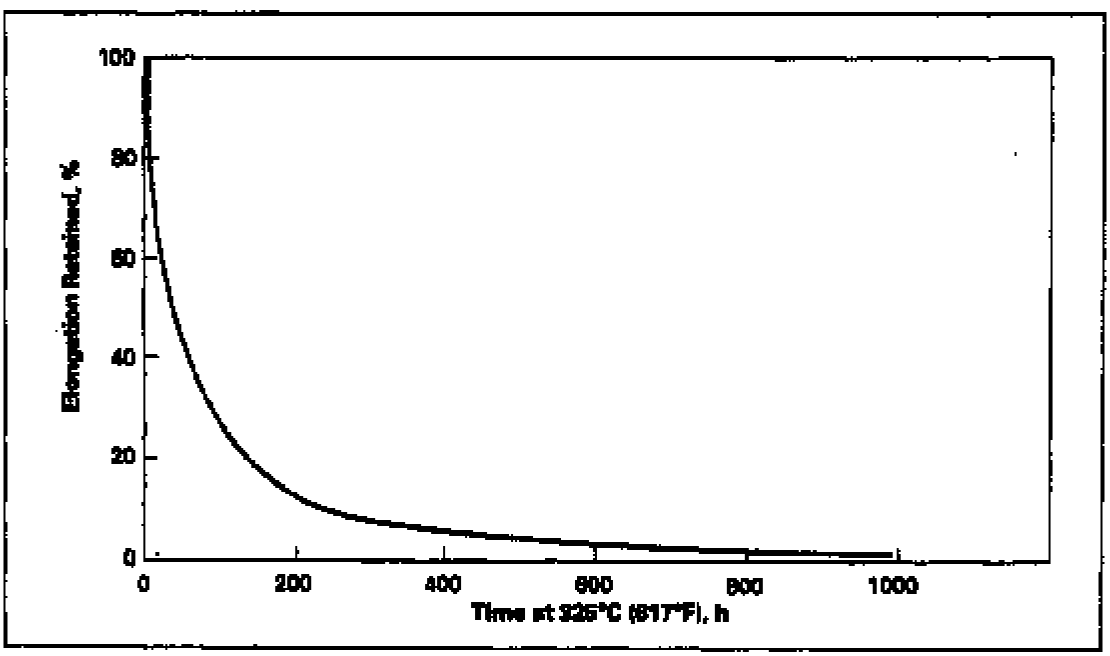
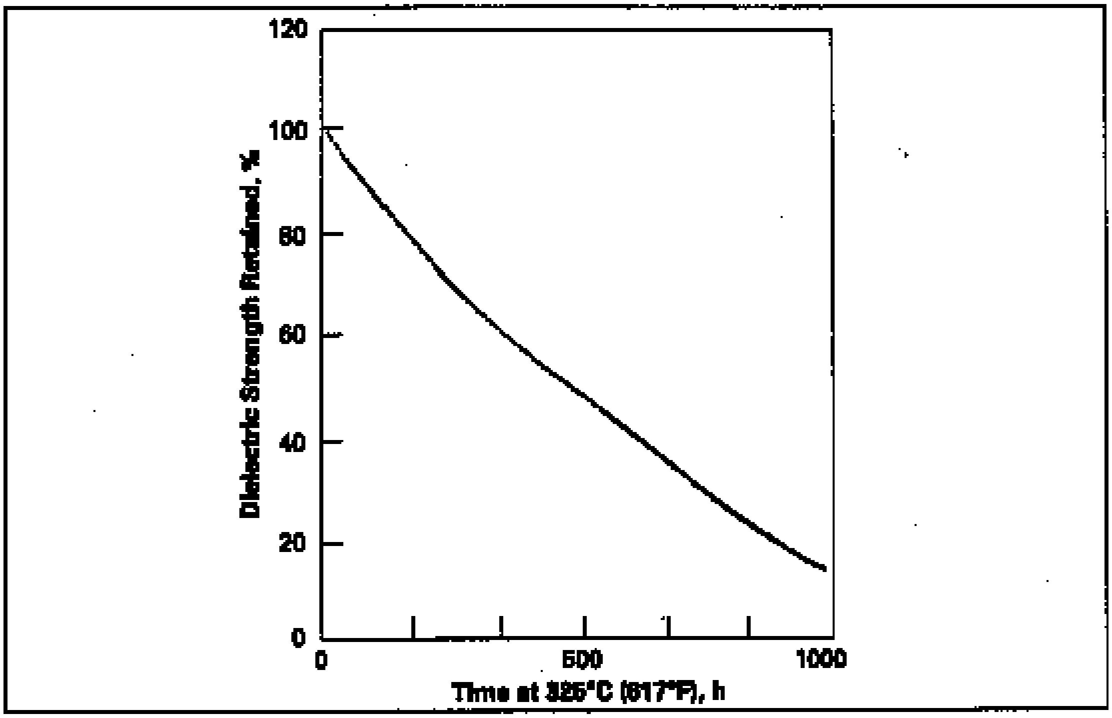
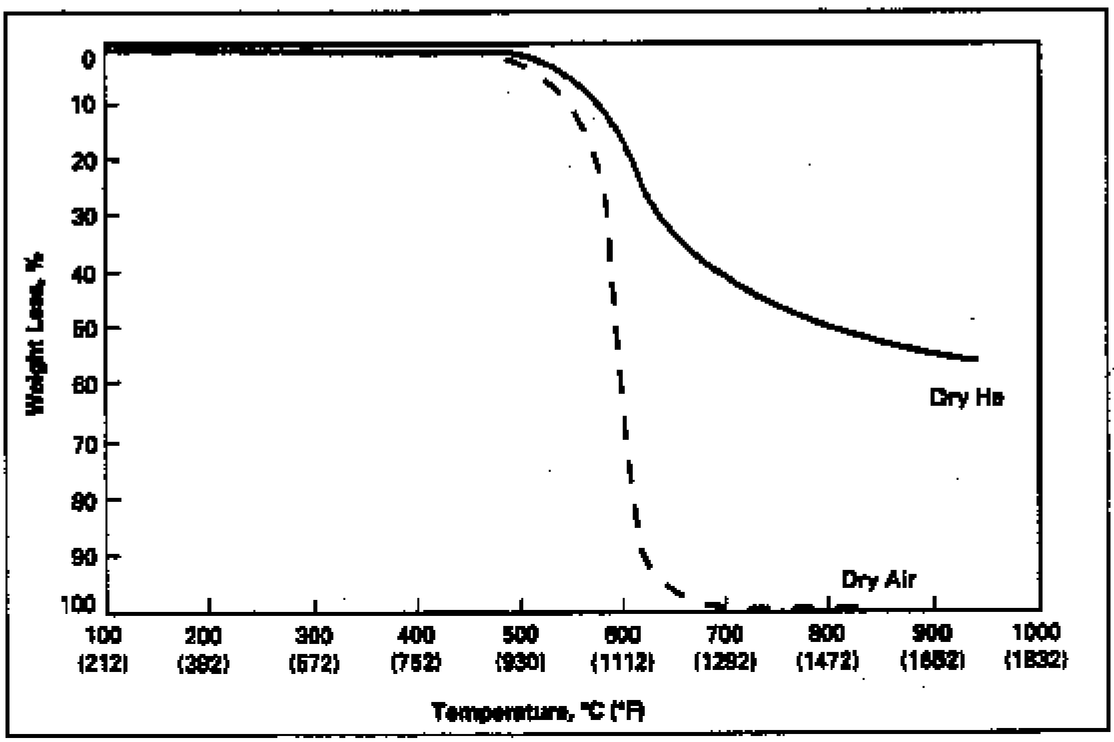


Figure 8. Retained Dielectric Strength at 325°C (617°F) for 25 μm (1 mil) Film, Test Method UL-746B



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.**

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



*Rate of temperature rise in °C (°F) was 3°C/min (5.4°F/min).

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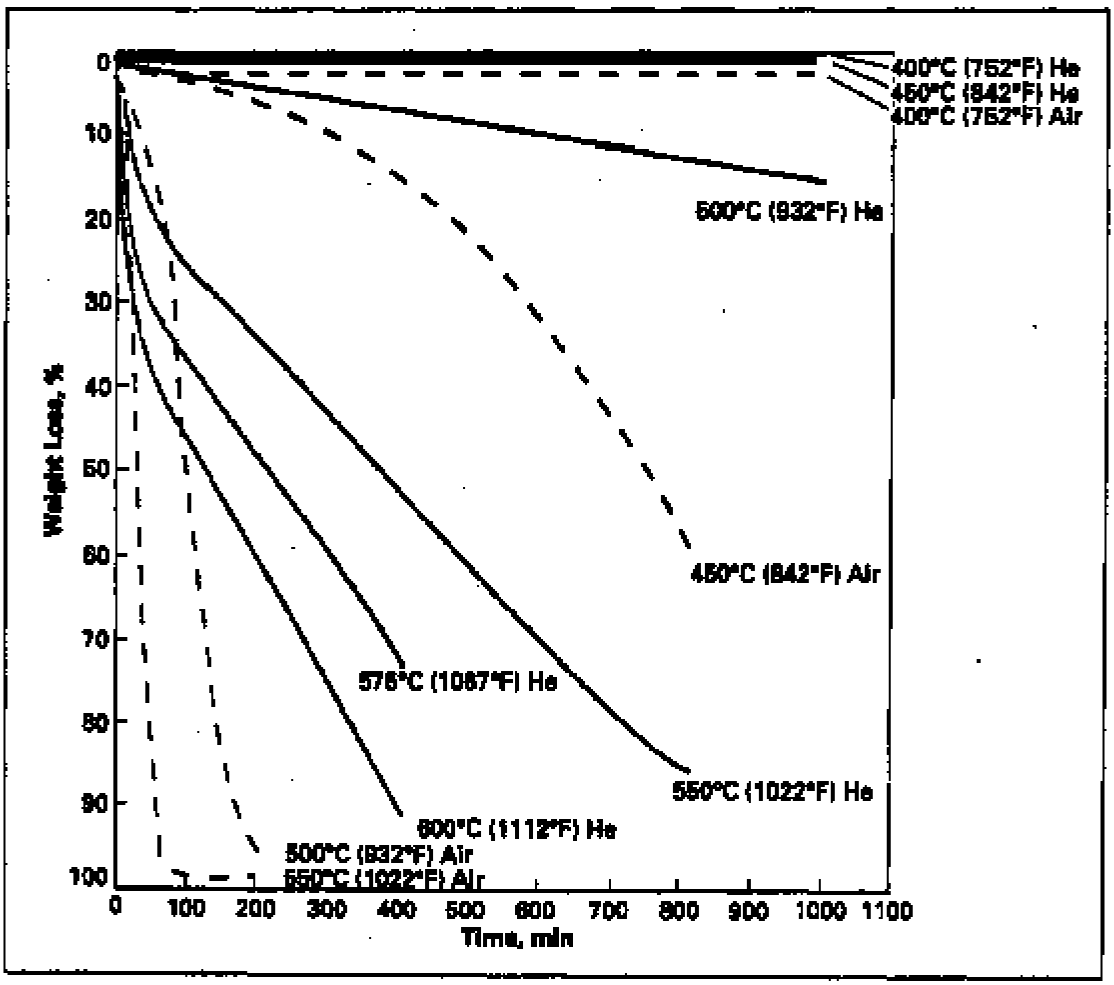
Table 6
Time Required for Reduction in Ultimate Elongation from 70% to 1%, Type HN Film, 25 µm (1 mil)

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



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Electrical Properties

The most common electrical properties of Kapton® polyimide film of various gauges are shown in **Tables 6 and 7**. 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 VN Films

Property Film Gauge	Typical Value		Test Condition	Test Method
Dielectric Strength	V/μm (kV/mm)	(V/mil)	60 Hz	ASTM D-149-91*1
25 μm (1 mil)	303	(7700)	1/4 in electrodes	
50 μm (2 mil)	240	(6100)	500 V/sec rise	
75 μm (3 mil)	205	(5200)		
125 μm (5 mil)	154	(3900)		
Dielectric Constant			1 kHz	ASTM D-150-92
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-150-92
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-257-91
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 (73°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}

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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, 25 µm (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)

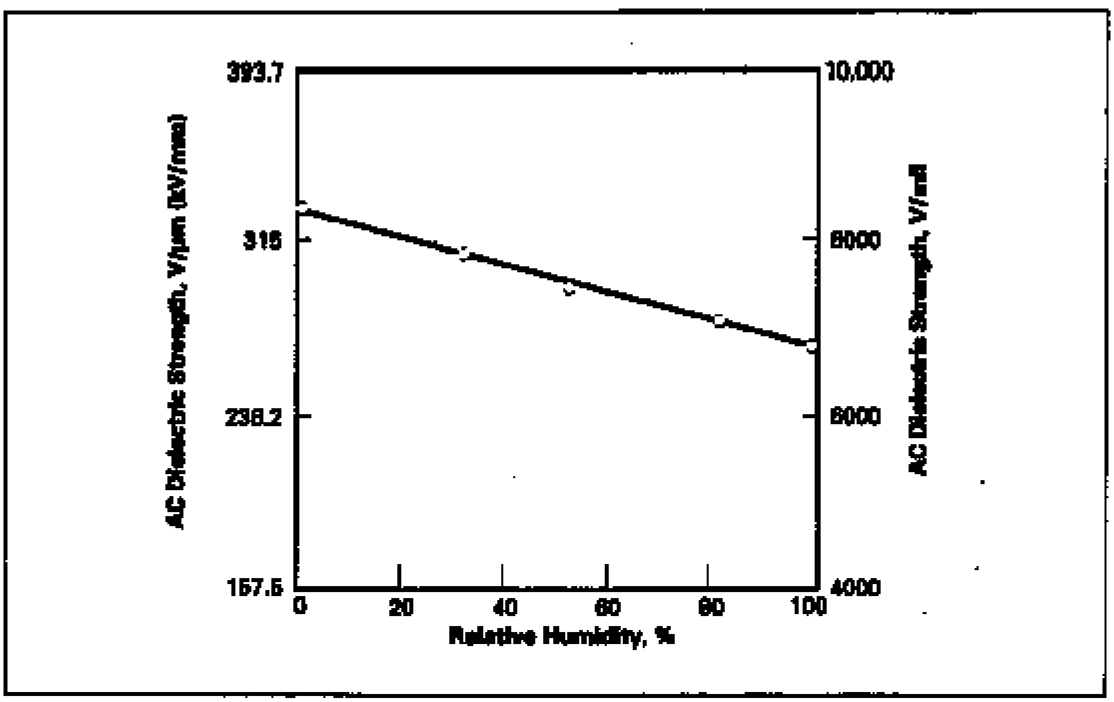

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Figure 12. Dissipation Factor vs. Relative Humidity, Type HN Film, 25 µm (1 mil)

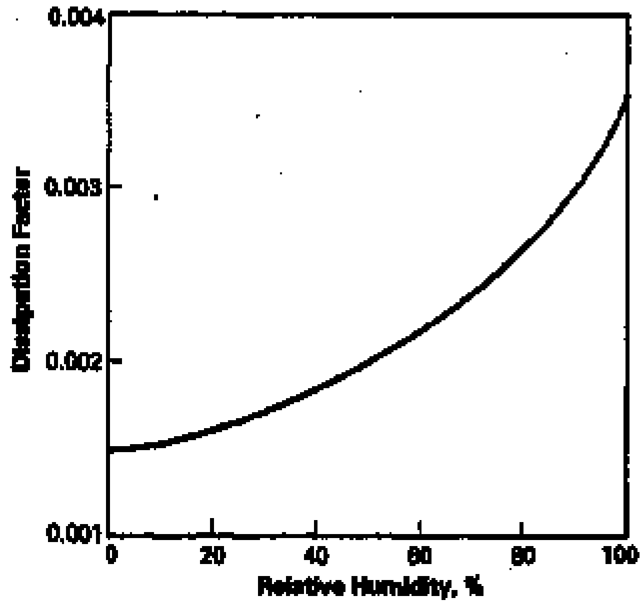
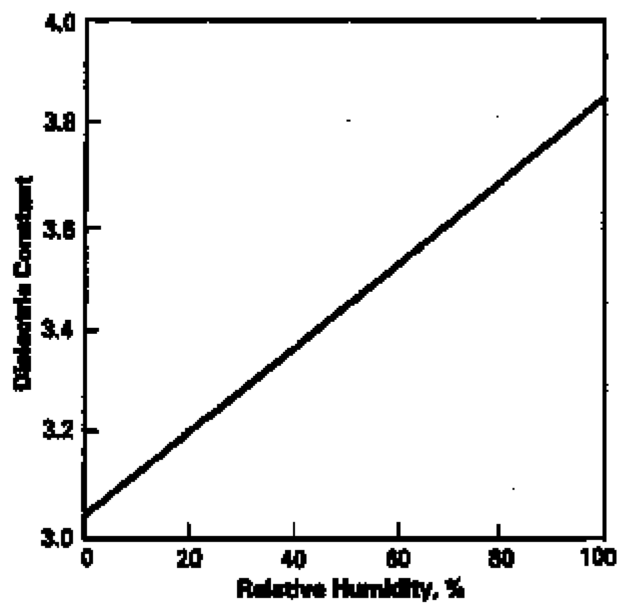


Figure 13. Dielectric Constant vs. Relative Humidity, Type HN Film, 25 µm (1 mil)



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)

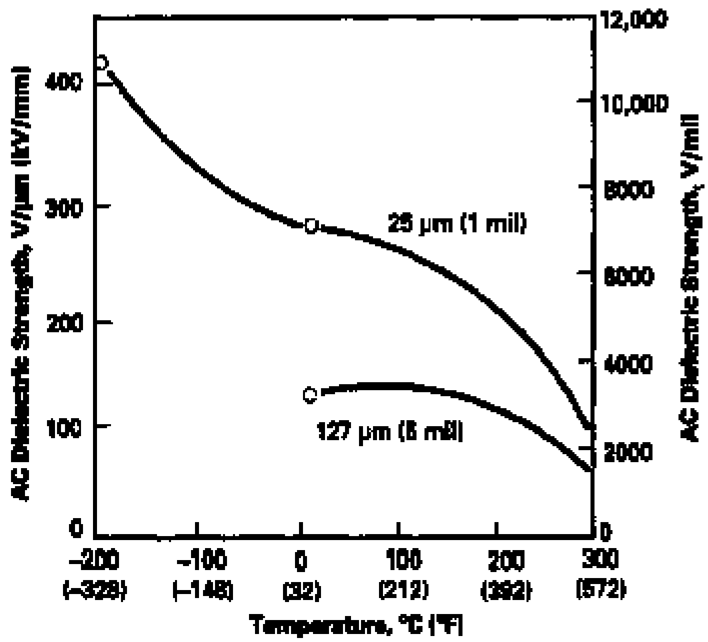


Figure 15. Dielectric Constant vs. Temperature, Type HN Film, 25 μm (1 mil)

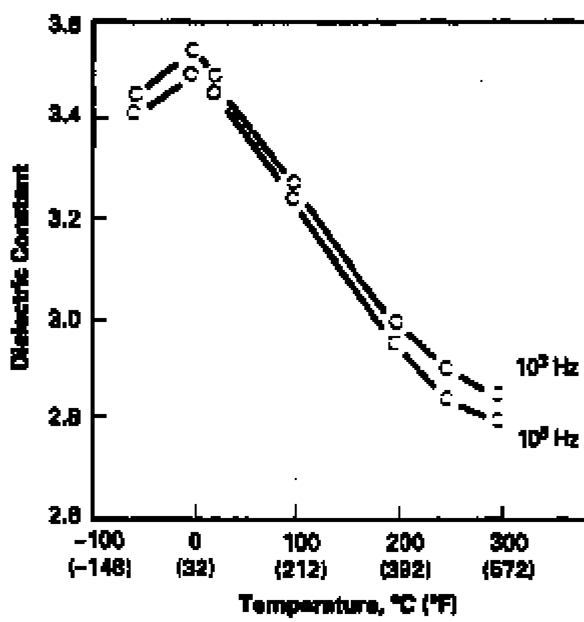


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Figure 16. Dissipation Factor vs. Temperature, Type HN Film, 25 μm (1 mil)

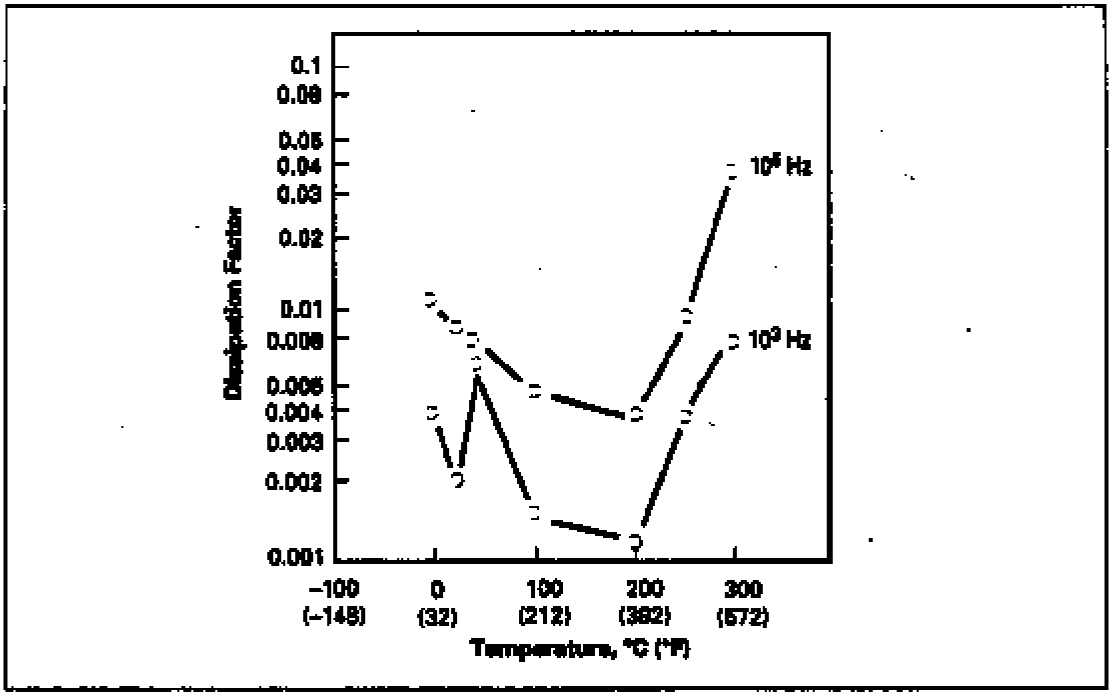
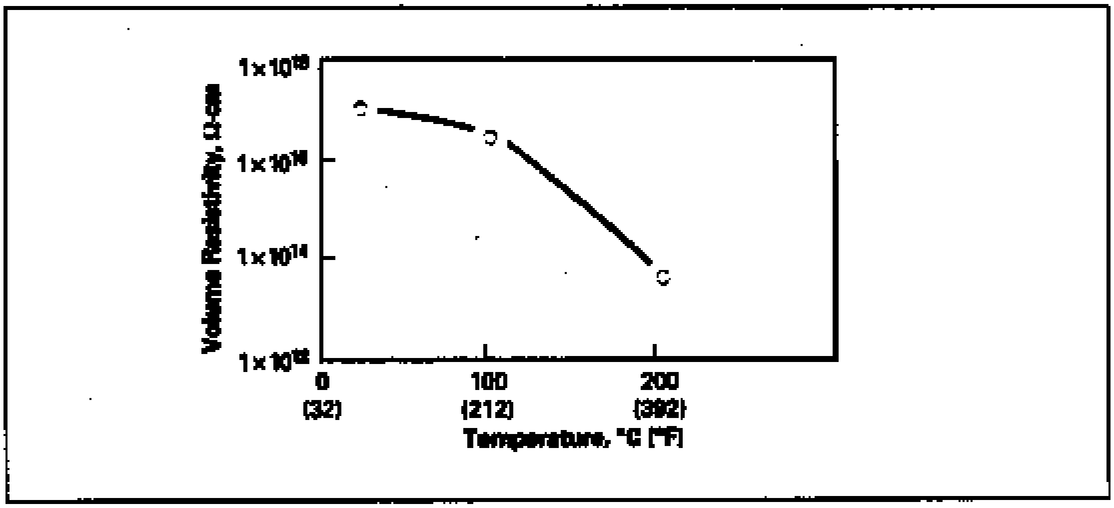


Figure 17. Volume Resistivity vs. Temperature, Type HN Film, 25 μm (1 mil)



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)

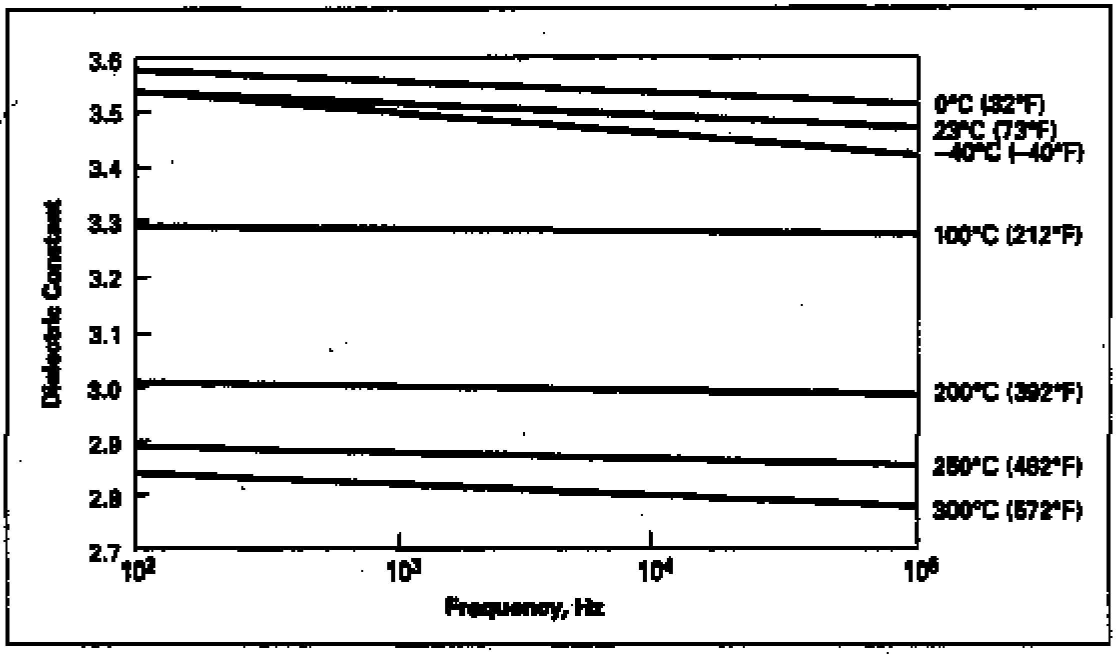


Figure 19. Dissipation Factor vs. Frequency, Type HN Film, 25 µm (1 mil)

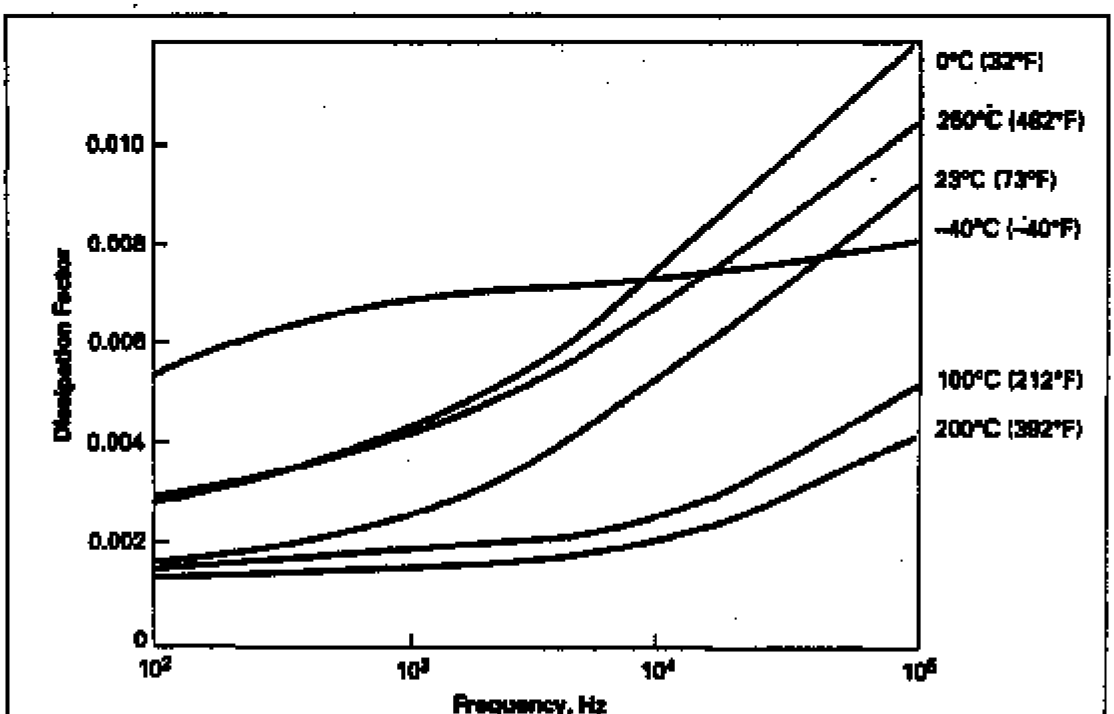


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Figure 20. Dielectric Constant vs. Frequency, Type HN Film, 125 µm (5 mil)*

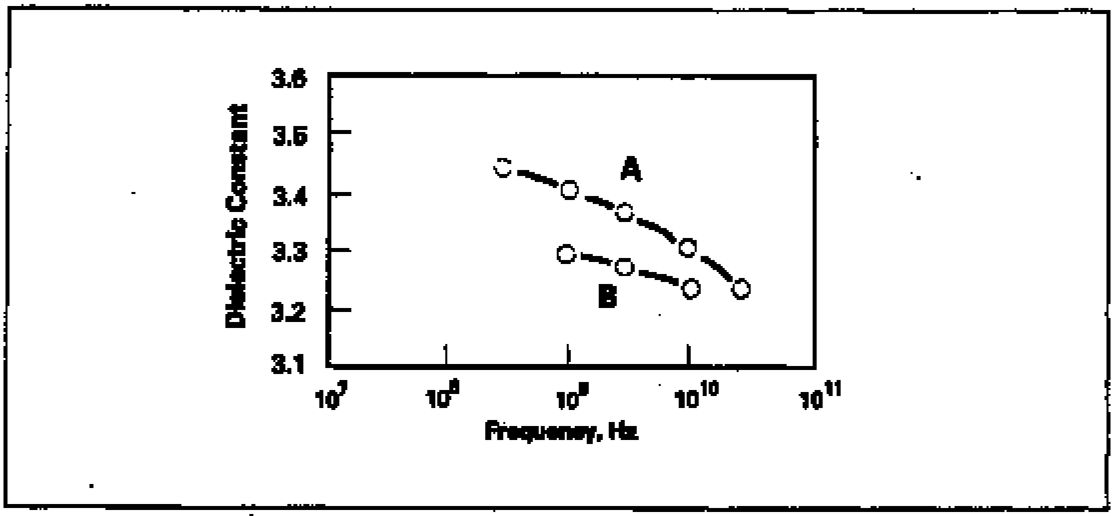
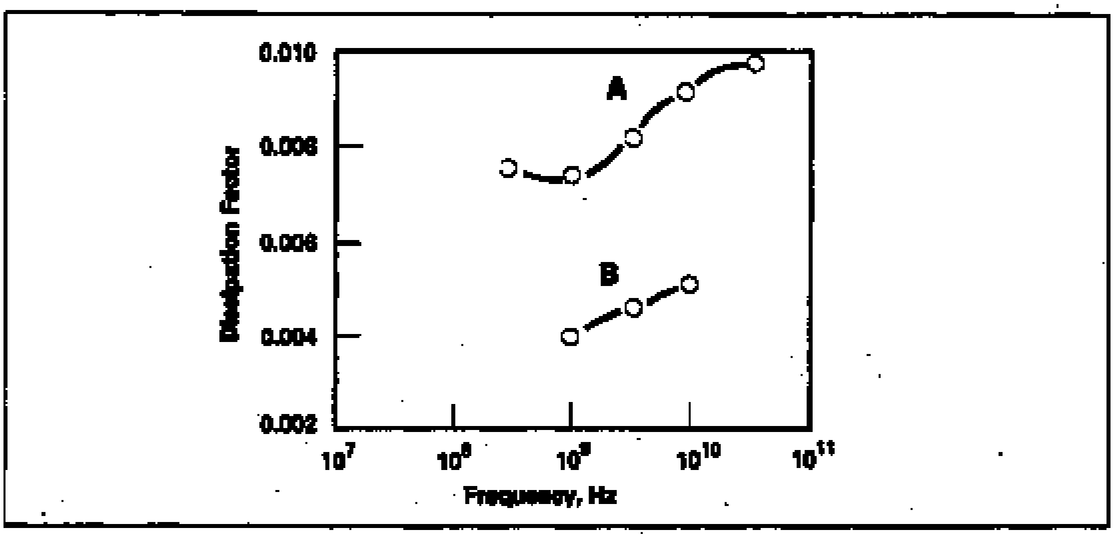


Figure 21. Dissipation Factor vs. Frequency, Type HN Film, 125 µm (5 mil)*



* 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.

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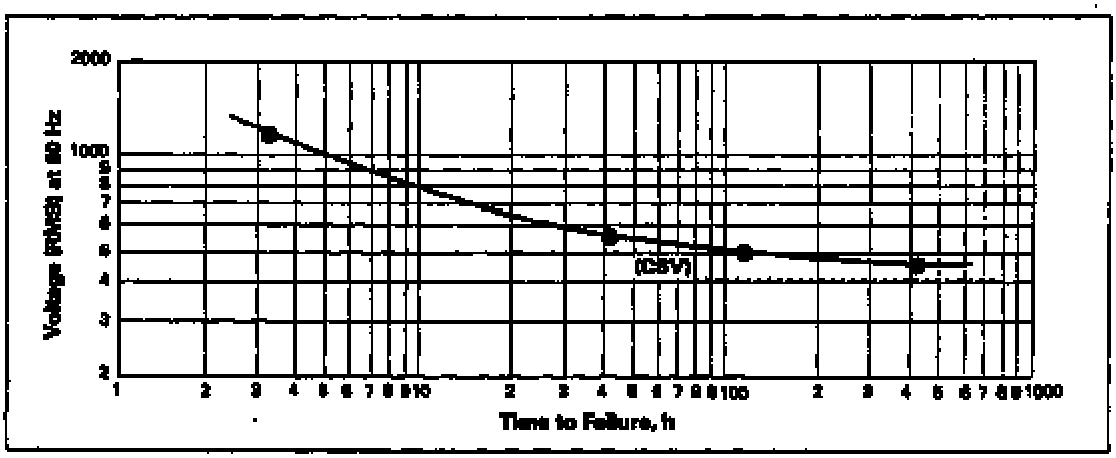
Corona Life

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 a 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

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Chemical Properties

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

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

Property	Typical Value: Tensile Retained, %	Typical Value: Elongation Retained, %	Test Condition	Test Method
Chemical Resistance				
Isopropyl Alcohol	95	94	10 min at 23°C	IPC TM-650
Toluene	99	91		Method 2.3.38
Methyl Ethyl Ketone	98	90		
Methylene Chloride/				
Trichloroethylene (1:1)	98	85		
2 N Hydrochloric Acid	98	89		
2 N Sodium Hydroxide	82	54		
Fungus Resistance	Nonnutrient			IPC TM-650 Method 2.6.1
Moisture Absorption	1.8% Types HN and VN		50% RH at 23°C	ASTM D-570-81 (1988)[e1]
	2.8% Types HN and VN		Immersion for	24 h at 23°C (73°F)
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-1434-82 (1988)[e1]
Carbon Dioxide	6840	45		
Oxygen	3800	25		
Hydrogen	38,000	250		
Nitrogen	910	6		
Helium	63,000	415		
Vapor	*g/(m²·24 h)*	*g/(100 in²·24 h)*		ASTM E-96-92
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
95% 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

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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 × 10^3)	207 (30)	207 (30)	214 (31)	214 (31)	152 (22)
Elongation, %	80	78	78	79	42
Tensile Modulus, MPa (psi × 10^3)	3172 (460)	3275 (475)	3378 (490)	3275 (475)	2903 (421)
Volume Resistivity Ω-cm × 10^{12} at 200°C (392°F)	4.8	6.5	5.2	1.7	1.6
Dielectric Constant 1 kHz at 23°C (73°F)	3.46	3.54	3.62	3.71	3.58
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^{10} neutrons/cm/s Flux at 175°C (347°F)	Film Darkened	Film Darkened and Tough

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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 2500Å.

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

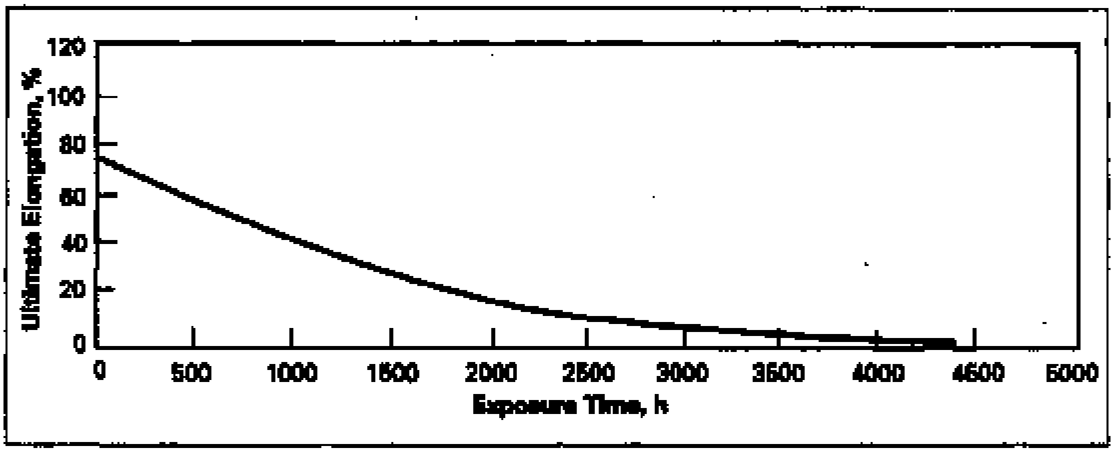
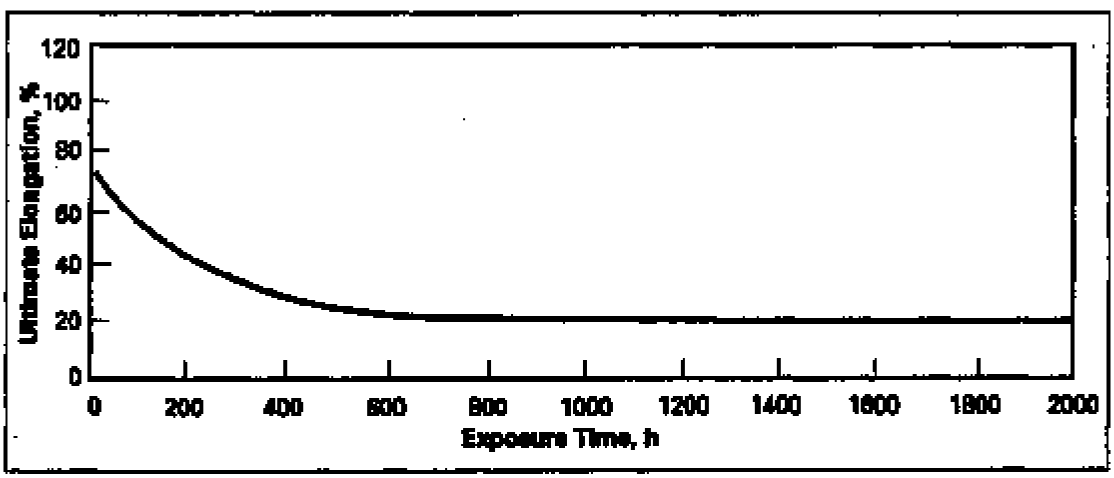


Figure 24. Effect of Weathering on Kapton® Polyimide Film (Atlas Weatherometer)



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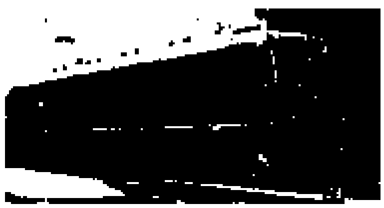

Kapton[1] is used as primary insulation for traction motors because of its outstanding combination of thermal, mechanical, and electrical properties.

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

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Kapton® Film Type Information

Table 15
Type and Thickness

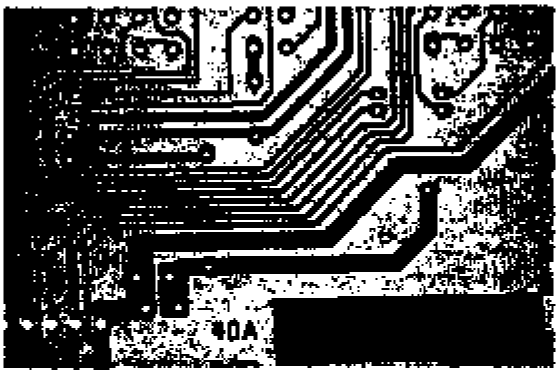
Type	Nominal Thickness		Area Factor	
	µm	mil	m²/kg	ft²/lb
30HN	7.6	0.3	93	455
50HN	12.7	0.5	56	272
75HN	19.1	0.75	37	181
100HN	25.4	1.0	28	136
200HN	50.8	2.0	14	68
300HN	76.2	3.0	9.2	45
500HN	127	5.0	5.5	27
50VN	12.7	0.5	56	272
75VN	19.1	0.75	37	181
100VN	25.4	1.0	28	136
200VN	50.8	2.0	14	68
300VN	76.2	3.0	9.2	45
500VN	127	5.0	5.5	27
100FN099	25.4	1.0	23	110
120FN616	30.5	1.2	21	104
150FN999	38.1	1.5	14	68
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
400FN031	101.6	4.0	6.1	30
500FN131	127	5.0	4.7	23
600FN051	152.4	6.0	4.3	21

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 Teflon® 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 Teflon® on each side. Illustrated in Table 16 are several examples of the many film types available.

Table 16
Type FN Film Constructions

Type	*Construction*					
	FEP		*HN*		*FEP*	
	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
150FN999	12.7	0.50	12.7	0.50	12.7	0.50
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
400FN031			76.2	3.00	25.4	1.00
500FN131	25.4	1.00	76.2	3.00	25.4	1.00
600FN051			127	5.00	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.

DUP 000055

Safety and Handling

Safe handling of Type HN and VN 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. For additional information on the Teflon® FEP coating used on Type FN Kapton®, refer to the booklet "Guide to the Safe Handling of Fluoropolymer Resins" (H-48633).

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

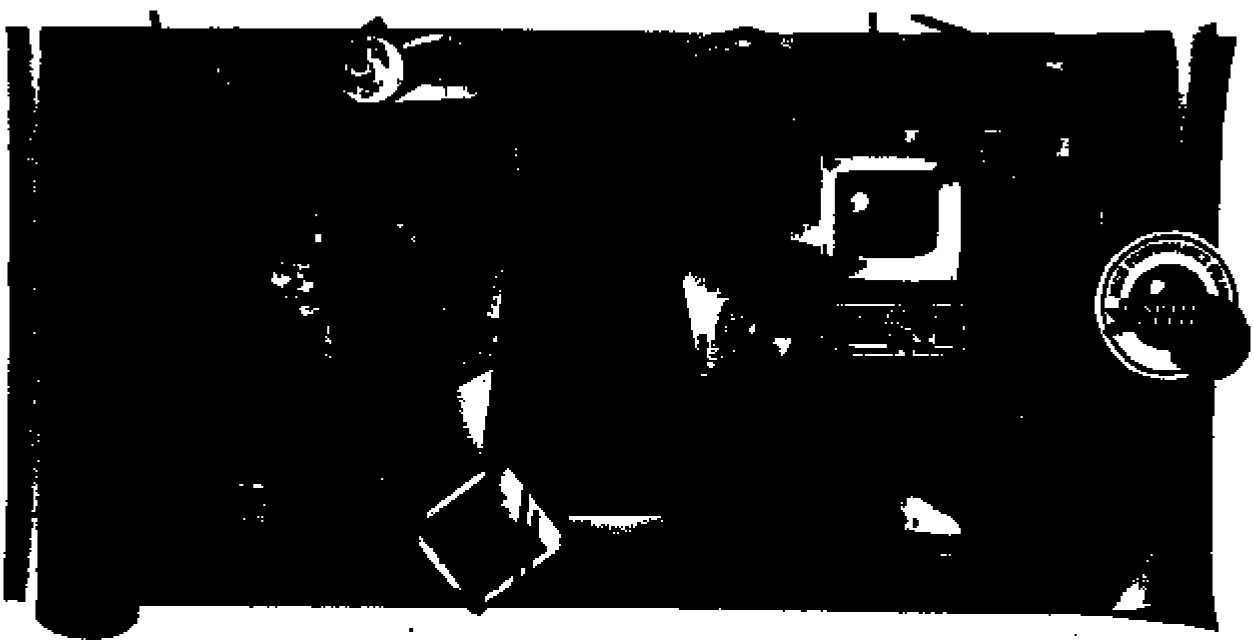
The processing of Kapton® can generate a strong static charge. Unless this charge is bled off as it forms by using ionizing radiation or tinsel, it can build to many thousand of volts and discharge to people or metal equipment. In dust- or solvent-laden air, a flash fire or explosion could result. Precautions 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).

Summary of Properties

DuPont High Performance Films

Kapton® polyimide film



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

DUP 000093

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® does not melt or burn 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), 19 μm (0.75 mil), 25 μm (1 mil), 50 μm (2 mil), 75 μm (3 mil), and 125 μm (5 mil) films.

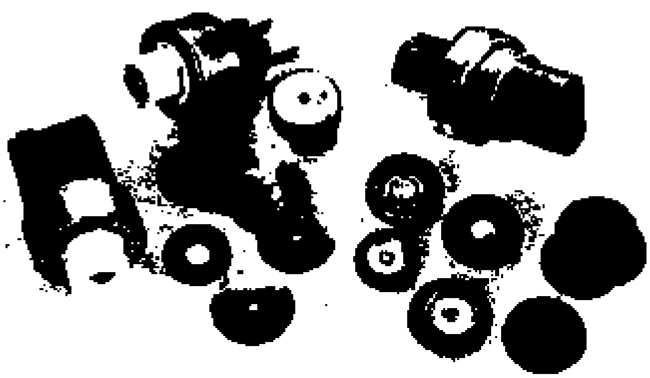
- Kapton® Type VN, all-polyimide film with all of the properties of Type HN, plus superior dimensional stability. Type VN is available as 12.5 μm (0.5 mil), 19 μm (0.75 mil), 25 μm (1 mil), 50 μm (2 mil), 75 μm (3 mil), and 125 μm (5 mil) films.
- Kapton® Type FN, a Type HN film coated on one or both sides with Teflon® 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 Teflon® FEP thicknesses (see Table 16).

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

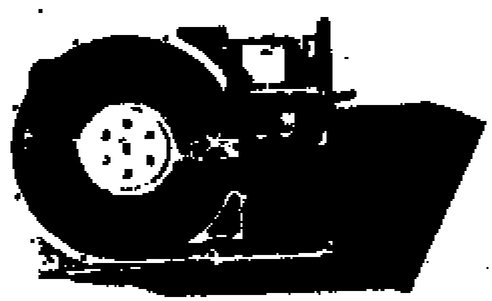
- antistat
- thermally conductive
- polyimides for fine line circuitry
- cryogenic insulation
- corona resistant
- pigmented for color
- conformable
- other films tailored to meet customers' needs

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

The Chemical Abstracts Service Registry Number for Kapton® polyimide film is [25036-53-7].



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



Kapton* is used in numerous electronic applications, including hard disk drives.

Physical and Thermal Properties

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 (−452°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.

Table 1
Physical Properties of Kapton® Type 100 HN Film, 25 μm (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)	139 (20,000)	ASTM D-882-91, Method A*
Yield Point at 3%, MPa (psi)	69 (10,000)	41 (6000)	ASTM D-882-91
Stress to Produce 5% Elongation, MPa (psi)	90 (13,000)	61 (9000)	ASTM D-882-91
Ultimate Elongation, %	72	83	ASTM D-882-91
Tensile Modulus, GPa (psi)	2.5 (370,000)	2.0 (290,000)	ASTM D-882-91
Impact Strength, N·cm (ft·lb)	78 (0.58)		DuPont Pneumatic Impact Test
Folding Endurance (MIT), cycles	285,000		ASTM D-2176-89
Tear Strength—Propagating (Elmendorf), N (lbf)	0.07 (0.02)		ASTM D-1922-89
Tear Strength—Initial (Graves), N (lbf)	7.2 (1.6)		ASTM D-1004-90
Density, g/cc or g/mL	1.42		ASTM D-1505-90
Coefficient of Friction—Kinetic (Film-to-Film)	0.48		ASTM D-1894-90
Coefficient of Friction—Static (Film-to-Film)	0.63		ASTM D-1894-90
Refractive Index (Sodium D Line)	1.70		ASTM D-542-90
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: 25 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-794-85 (1989)
Thermal Coefficient of Linear Expansion	20 ppm/°C (11 ppm/°F)	−14 to 38°C (7 to 100°F)	ASTM D-696-91
Coefficient of Thermal Conductivity, W/m·K	0.12	296 K	ASTM F-433-77 (1987)ε1
$\frac{cal}{cm \cdot sec \cdot °C}$	2.87×10^{-4}	23°C	
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-5214-91
Heat Sealability	Not Heat Sealable		
Limiting Oxygen Index, %	37		ASTM D-2863-87
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.		

Table 3
Physical and Thermal Properties of Kapton® Type VN Film

Property	Typical Value for Film Thickness: 25 µm (1 mil)	50 µm (2 mil)	75 µm (3 mil)	125 µm (5 mil)	Test Method
Ultimate Tensile Strength, MPa (psi)	231 (33,500)	234 (34,000)	231 (33,500)	231 (33,500)	ASTM D-882-91
Ultimate Elongation, %	72	82	82	82	ASTM D-882-91
Tear Strength—Propagating (Elmendorf), N	0.07	0.21	0.38	0.58	ASTM D-1922-89
Tear Strength—Initial (Graves), N	7.2	16.3	26.3	46.9	ASTM D-1004-90
Folding Endurance (MIT), x 10³ cycles	285	55	6	5	ASTM D-2176-89
Density, g/cc or g/mL	1.42	1.42	1.42	1.42	ASTM D-1505-90
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-2863-87

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)	207 (30,000)	162 (23,500)	200 (29,000)
200°C (392°F)	121 (17,500)	89 (13,000)	115 (17,000)
Yield Point at 3%, MPa (psi)			
23°C (73°F)	61 (9000)	49 (7000)	59 (8500)
200°C (392°F)	42 (6000)	43 (6000)	36 (5000)
Stress at 5% Elongation, MPa (psi)			
23°C (73°F)	79 (11,500)	65 (9,500)	76 (11,000)
200°C (392°F)	63 (9000)	41 (6000)	48 (7000)
Ultimate Elongation, %			
23°C (73°F)	75	70	85
200°C (392°F)	80	75	110
Tensile Modulus, GPa (psi)			
23°C (73°F)	2.48 (360,000)	2.28 (330,000)	2.62 (380,000)
200°C (392°F)	1.62 (235,000)	1.14 (165,000)	1.38 (200,000)
Impact Strength at 23°C (73°F), N-cm (ft-lb)	78 (0.58)	68.6 (0.51)	156.9 (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%	80	57	73
FEP, wt%	20	43	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 Teflon® FEP fluoropolymer resin in mils. The symbol 5 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 of Teflon® on each side.

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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)

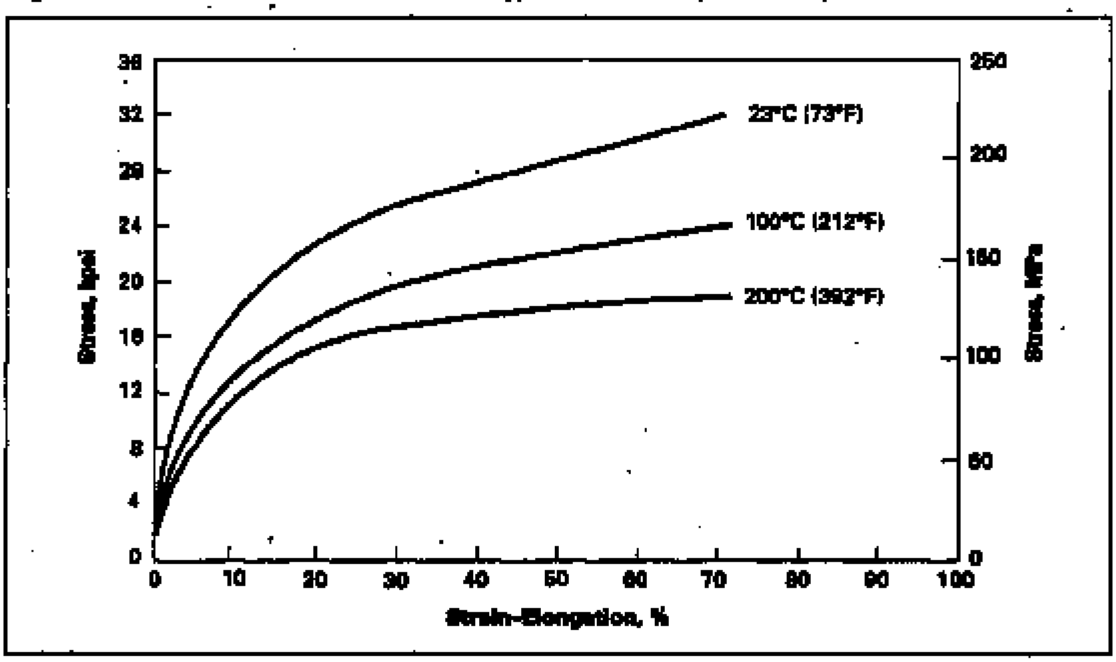
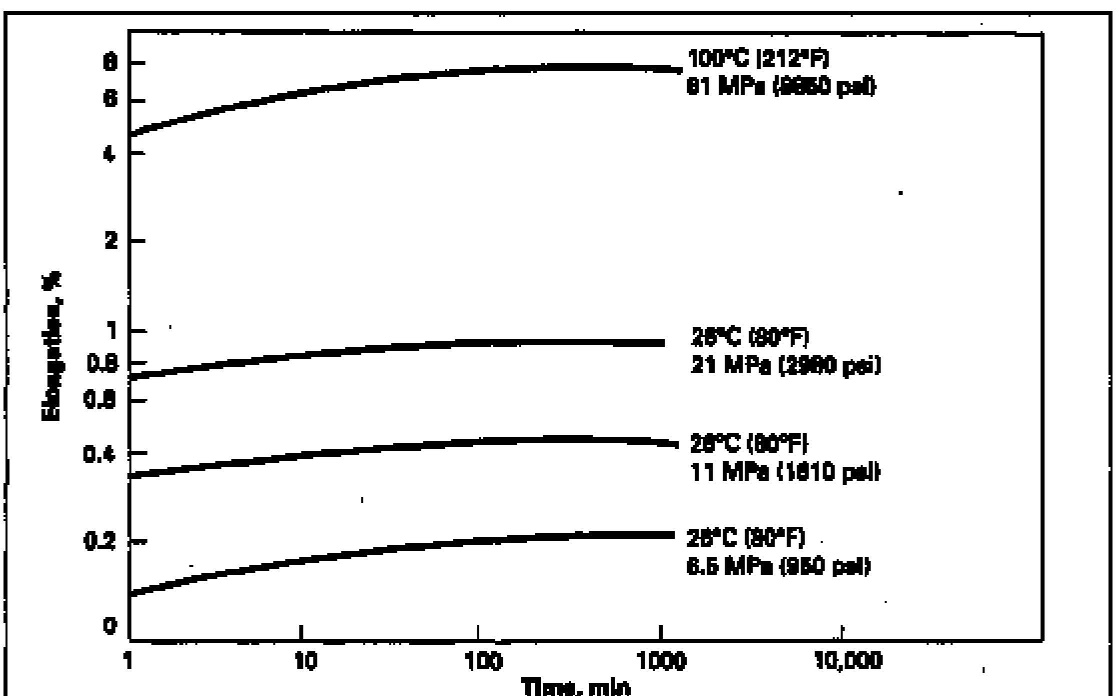


Figure 2. Tensile Creep Properties, Type HN Film, 25 µm (1 mil)



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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)

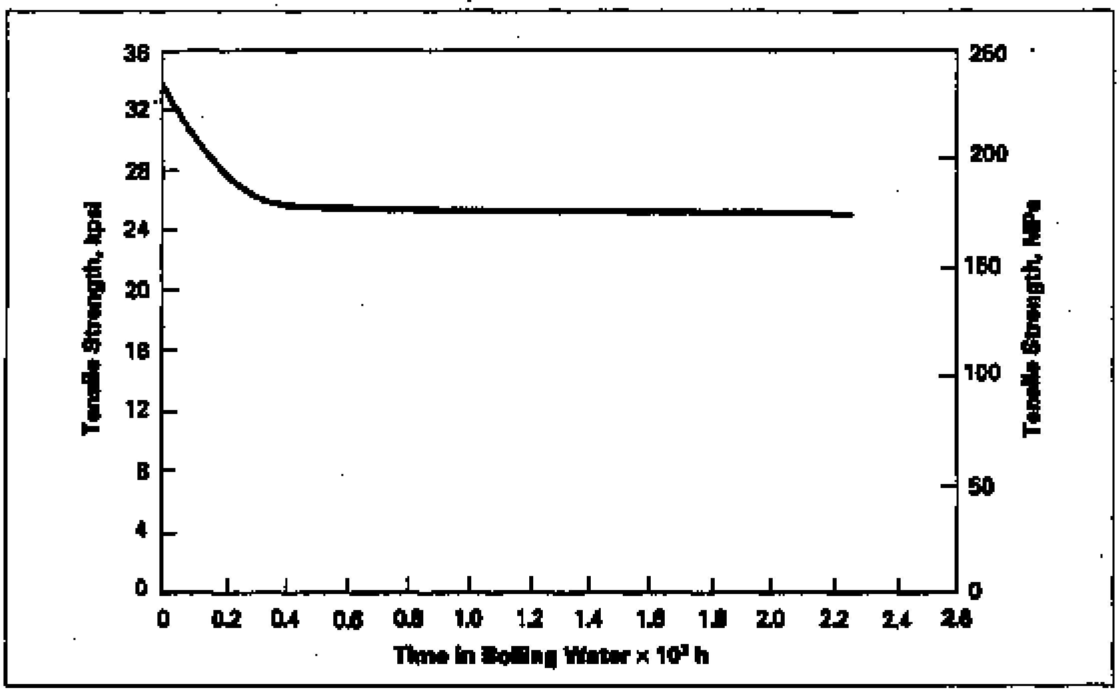
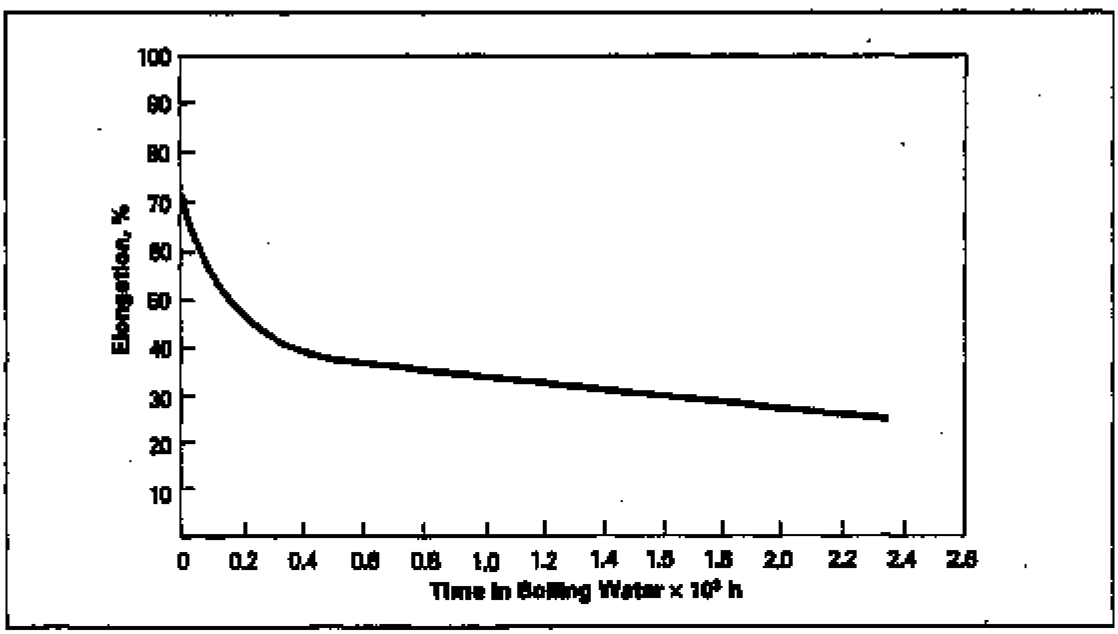


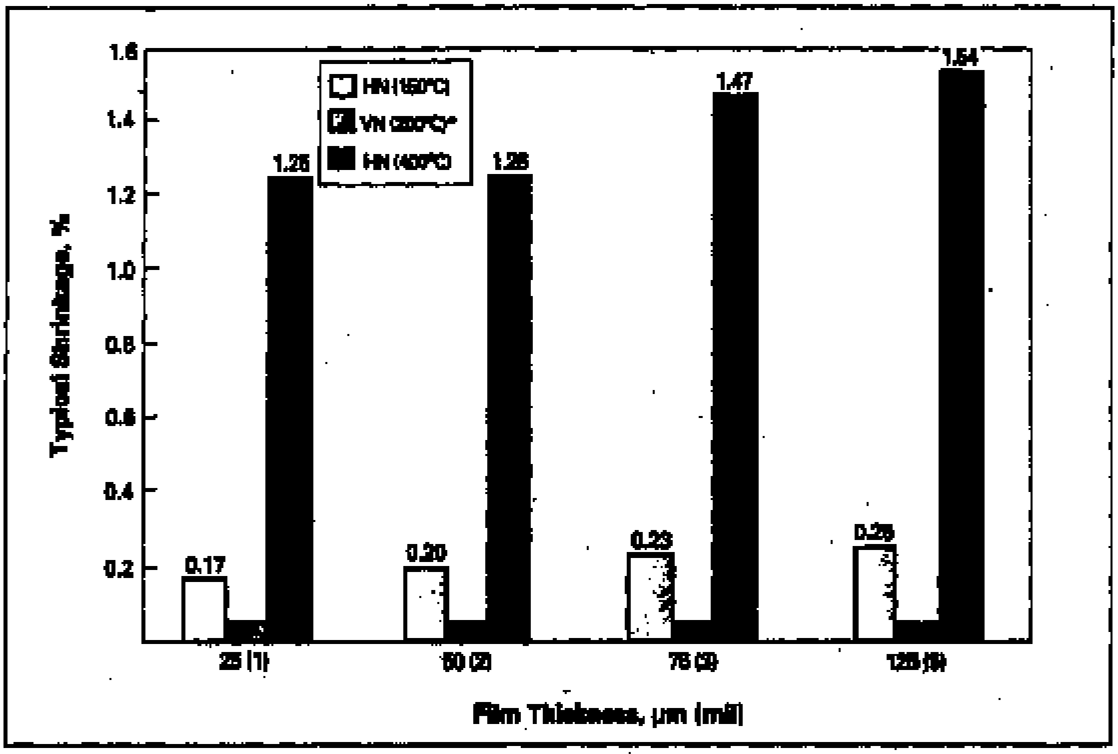
Figure 4. Ultimate Elongation After Exposure to 100°C (212°F) Water, Type HN Film, 25 μm (1 mil)



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 VN Films



*Type VN shrinkage is 0.03% for all thicknesses.

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

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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)

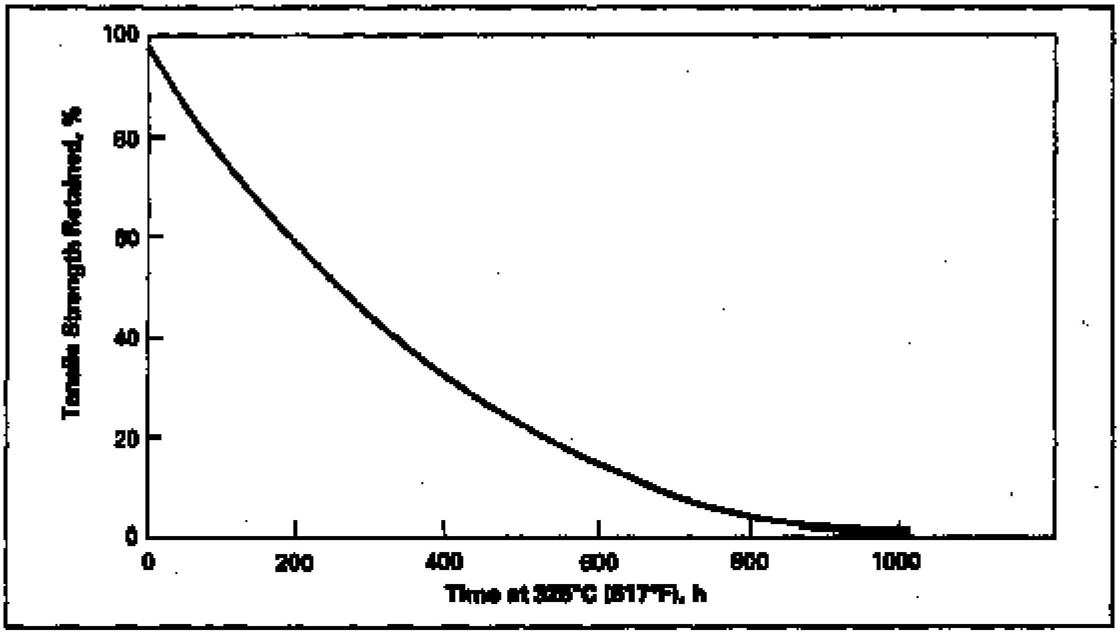


Figure 7. Ultimate Elongation vs. Aging in Air at 325°C (617°F), Type HN Film, 25 µm (1 mil)

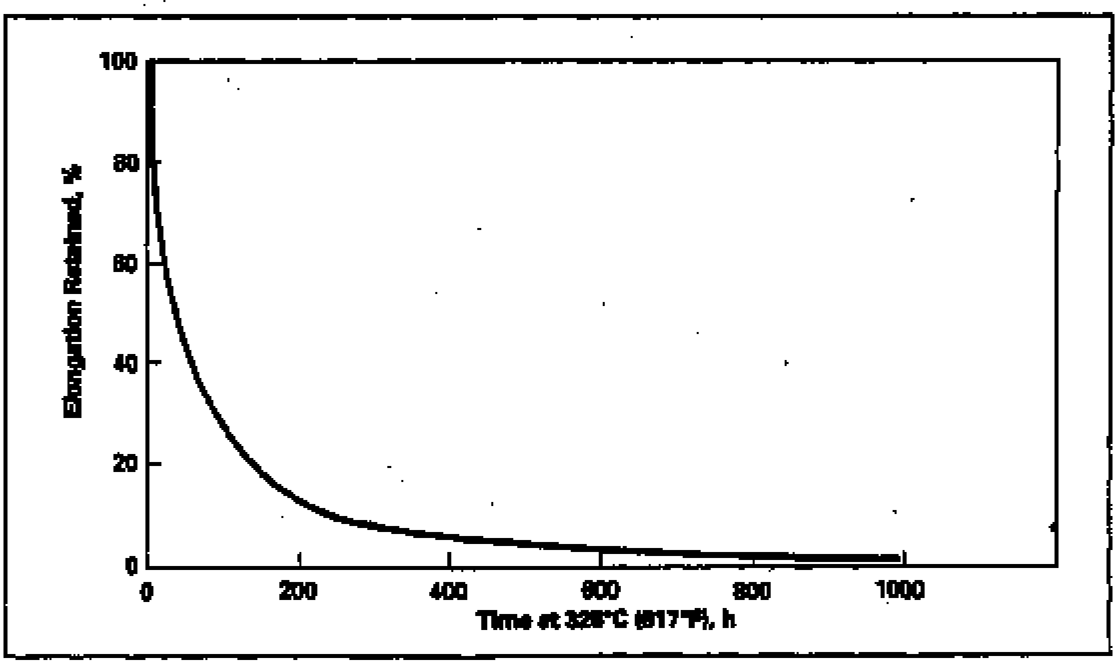
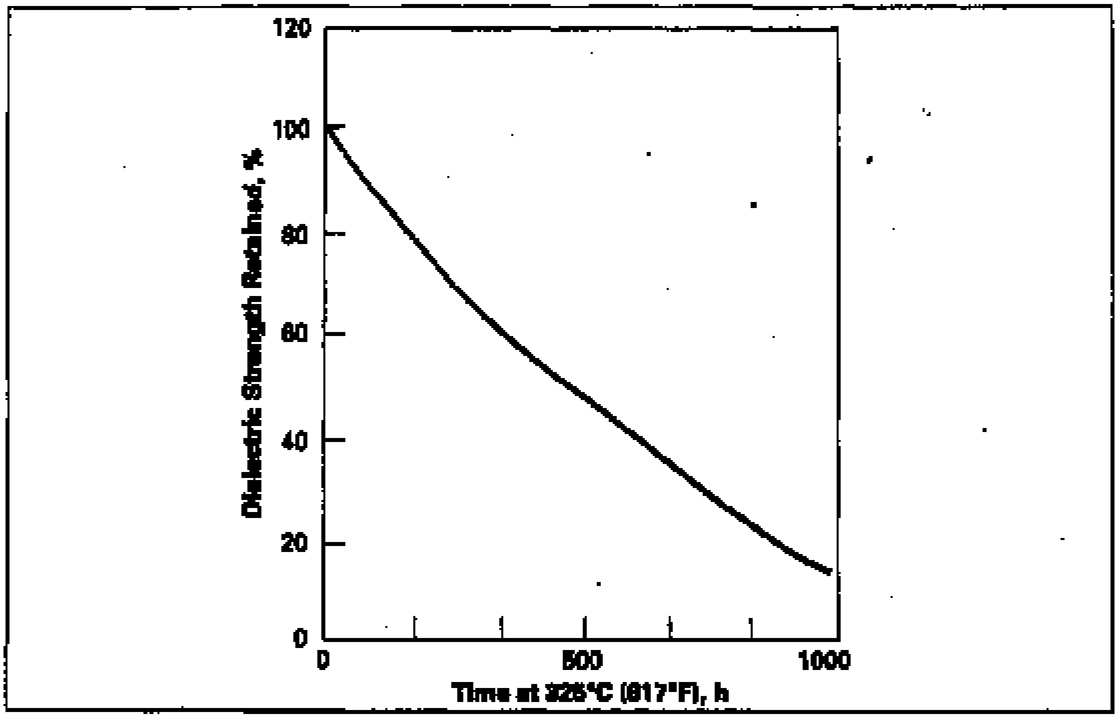
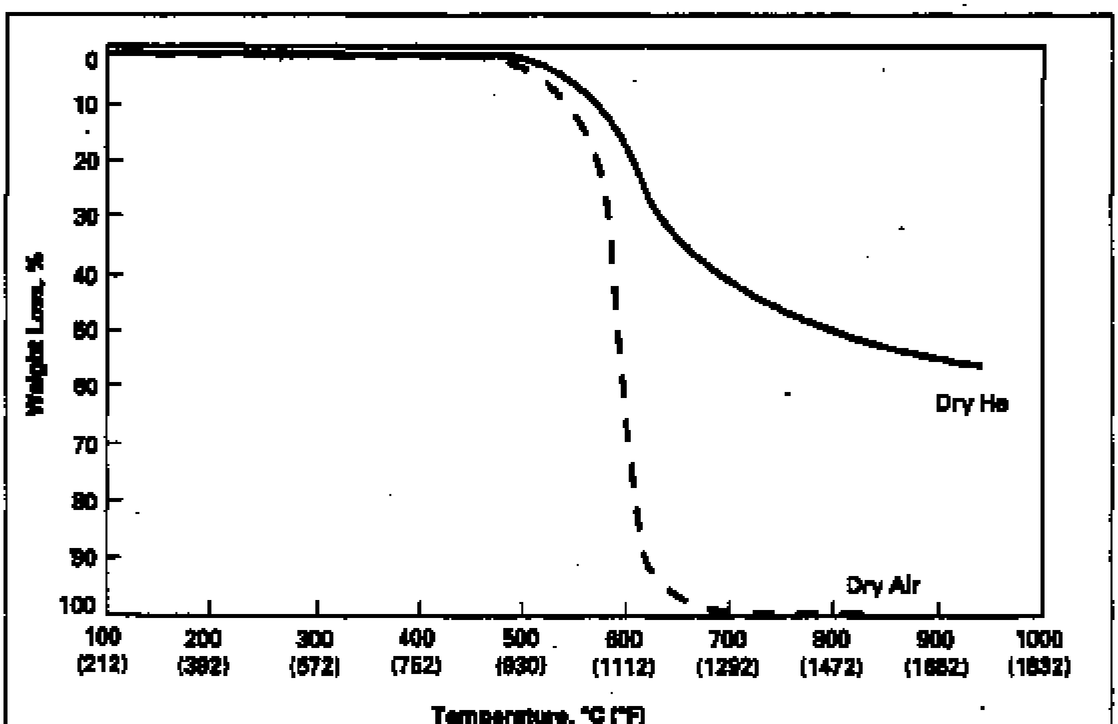


Figure 8. Retained Dielectric Strength at 325°C (617°F) for 25 μm (1 mil) Film, Test Method UL-746B



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.

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



*Rate of temperature rise in °C (°F) was 3°C/min (5.4°F/min).

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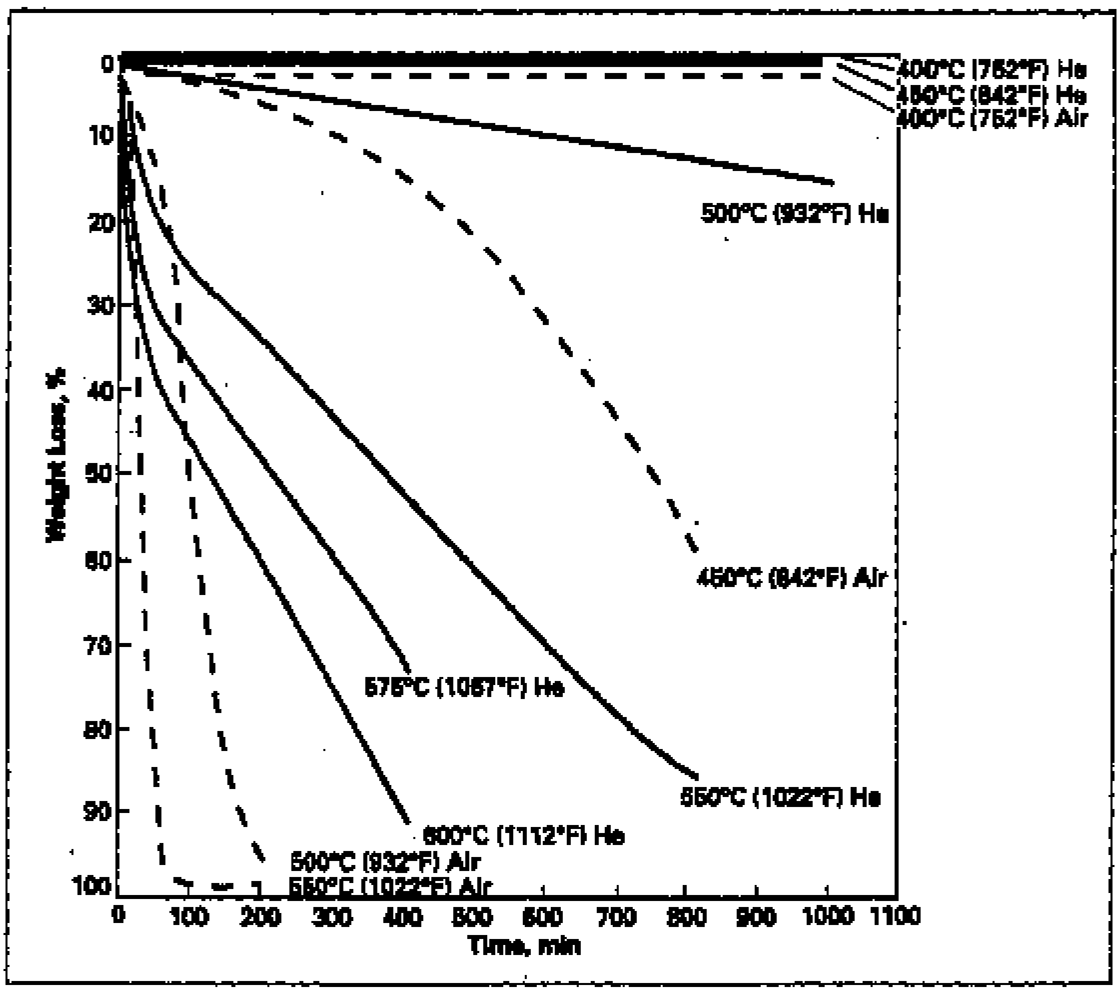
Table 6
Time Required for Reduction in Ultimate Elongation from 70% to 1%, Type HN Film, 25 µm (1 mil)

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



Electrical Properties

The most common electrical properties of Kapton® polyimide film of various gauges are shown in **Tables 6 and 7**. 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 VN Films

Property Film Gauge	Typical Value		Test Condition	Test Method
Dielectric Strength	V/µm (kV/mm)	(V/mil)	60 Hz	ASTM D-149-91
25 µm (1 mil)	303	(7700)	1/4 in electrodes	
50 µm (2 mil)	240	(6100)	500 V/sec rise	
75 µm (3 mil)	205	(5200)		
125 µm (5 mil)	154	(3900)		
Dielectric Constant			1 kHz	ASTM D-150-92
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-150-92
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-257-91
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)	157 (4000)
Dielectric Constant	3.1	2.7	3.0
Dissipation Factor	0.0015	0.0013	0.0013
Volume Resistivity, Ω·cm			
at 23°C (73°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}

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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, 25 µm (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)

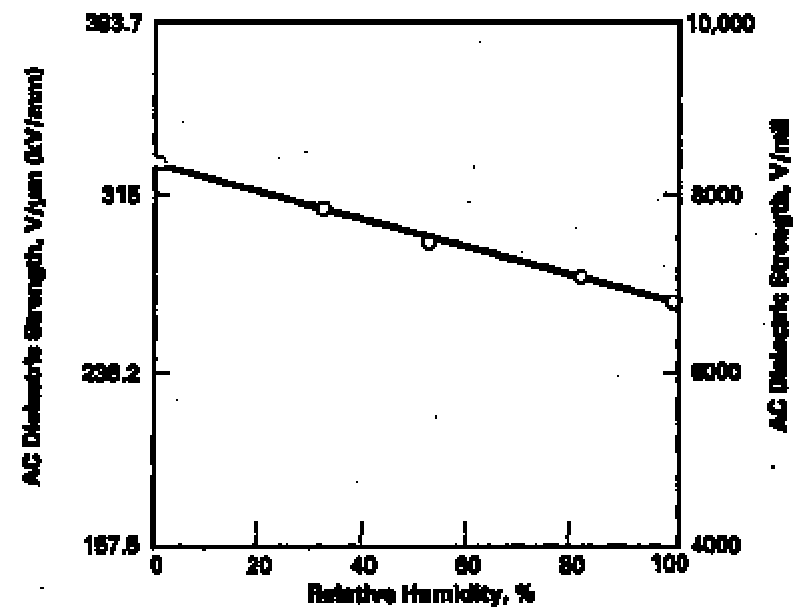

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Figure 12. Dissipation Factor vs. Relative Humidity, Type HN Film, 25 µm (1 mil)

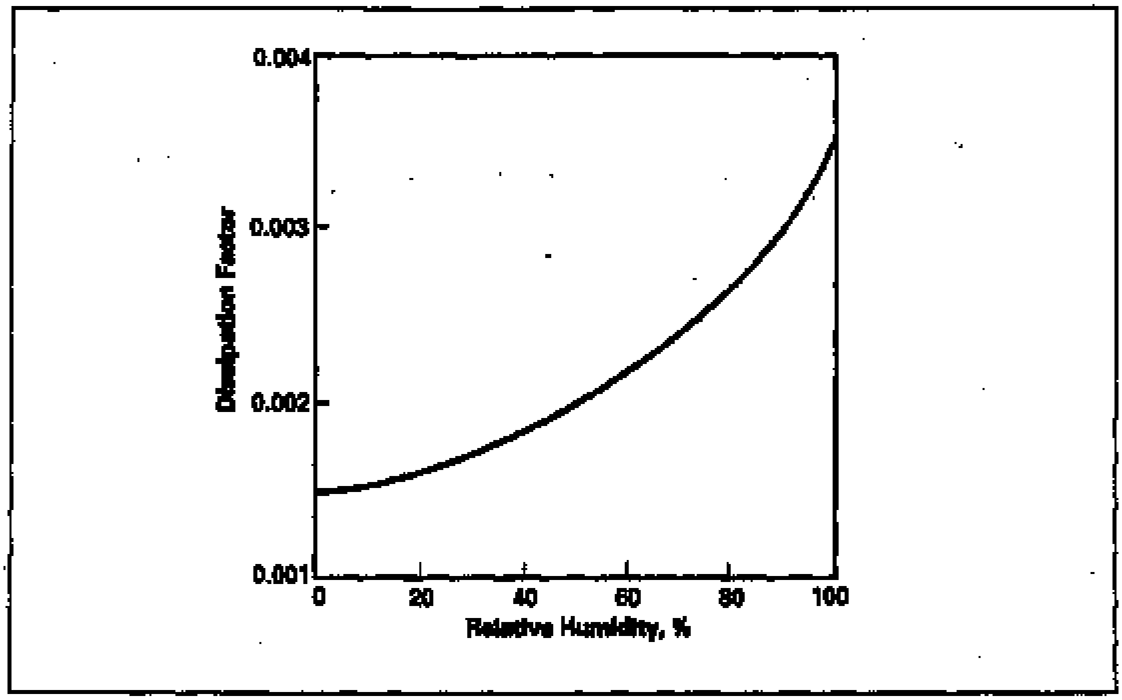
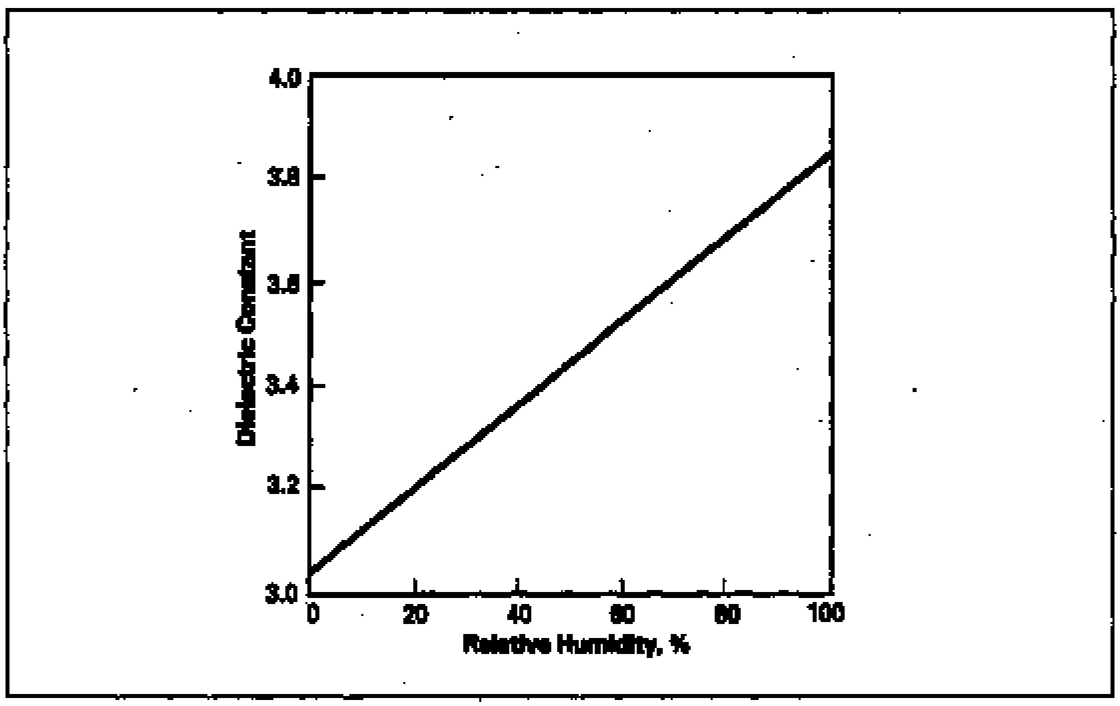


Figure 13. Dielectric Constant vs. Relative Humidity, Type HN Film, 25 µm (1 mil)



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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)

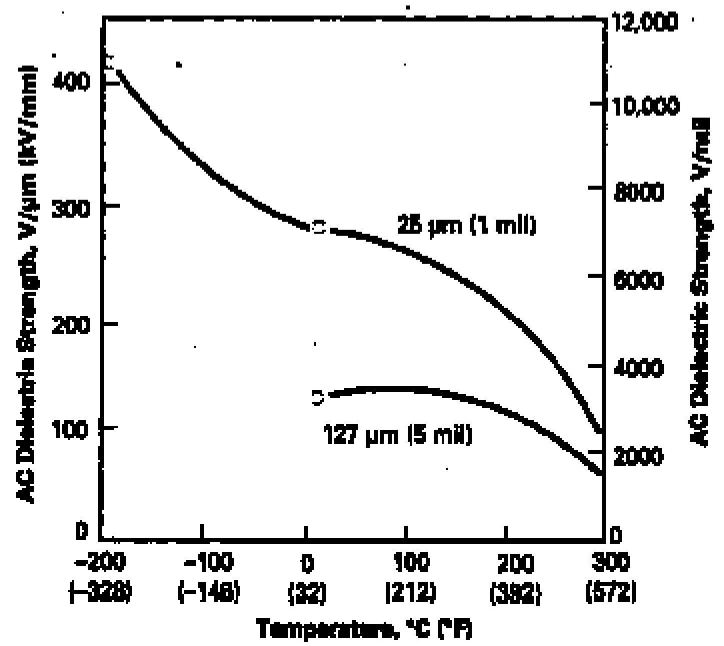

Figure 15. Dielectric Constant vs. Temperature, Type HN Film, 25 μm (1 mil)

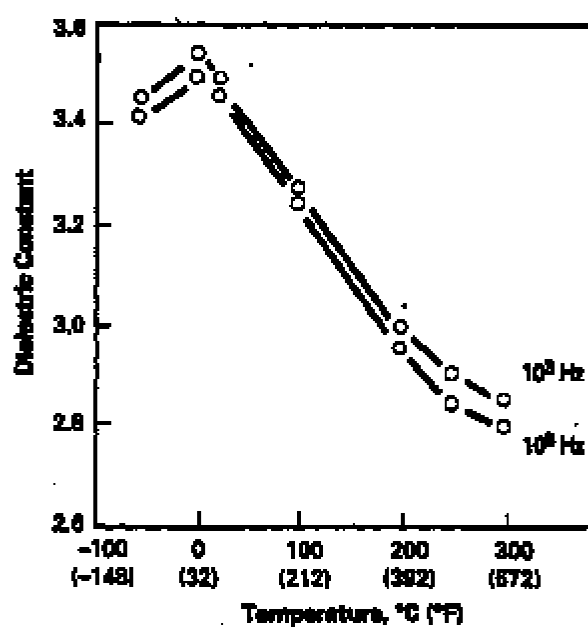

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Figure 16. Dissipation Factor vs. Temperature, Type HN Film, 25 μm (1 mil)

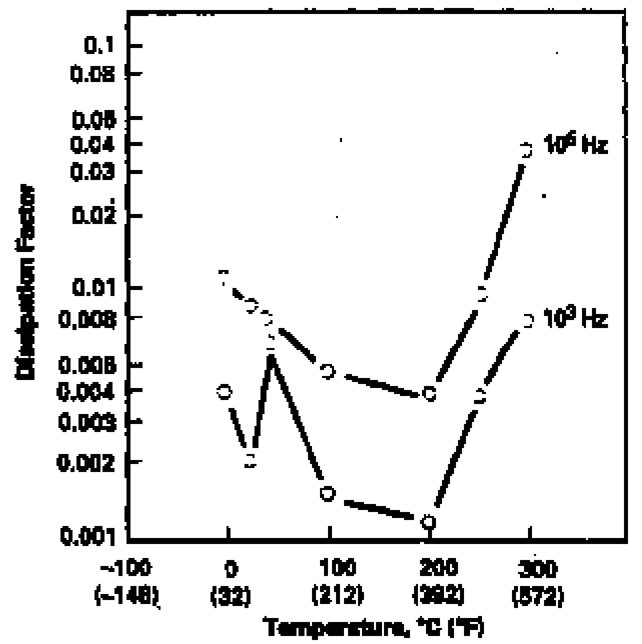
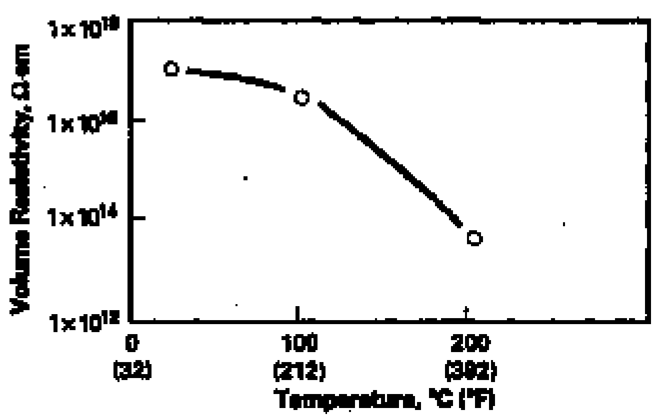


Figure 17. Volume Resistivity vs. Temperature, Type HN Film, 25 μm (1 mil)



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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)

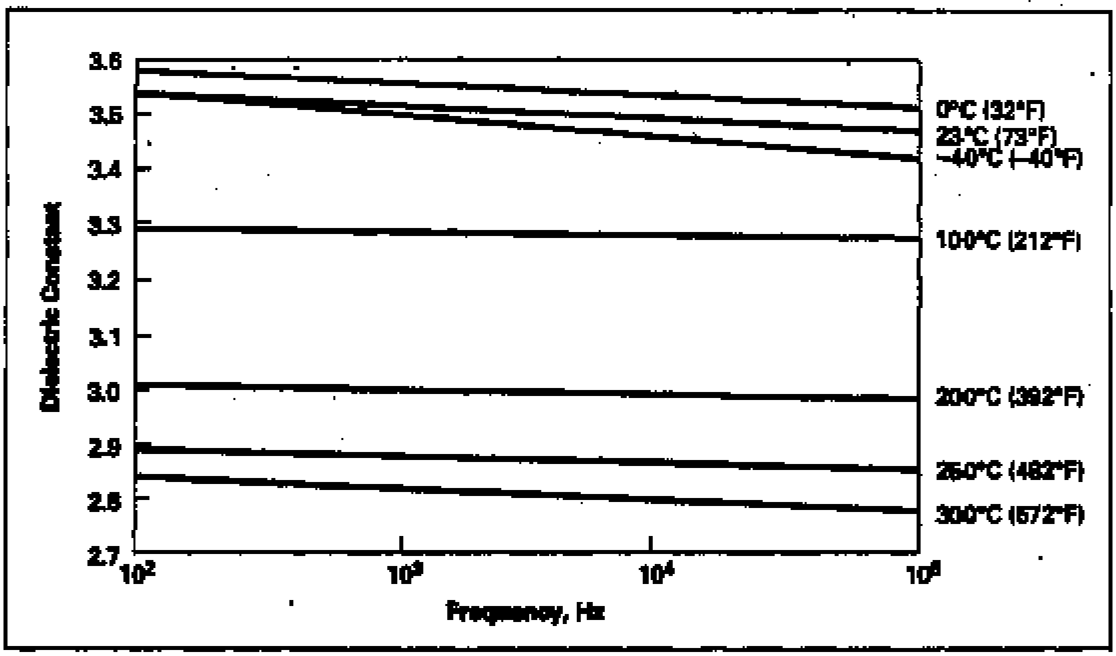


Figure 19. Dissipation Factor vs. Frequency, Type HN Film, 25 µm (1 mil)

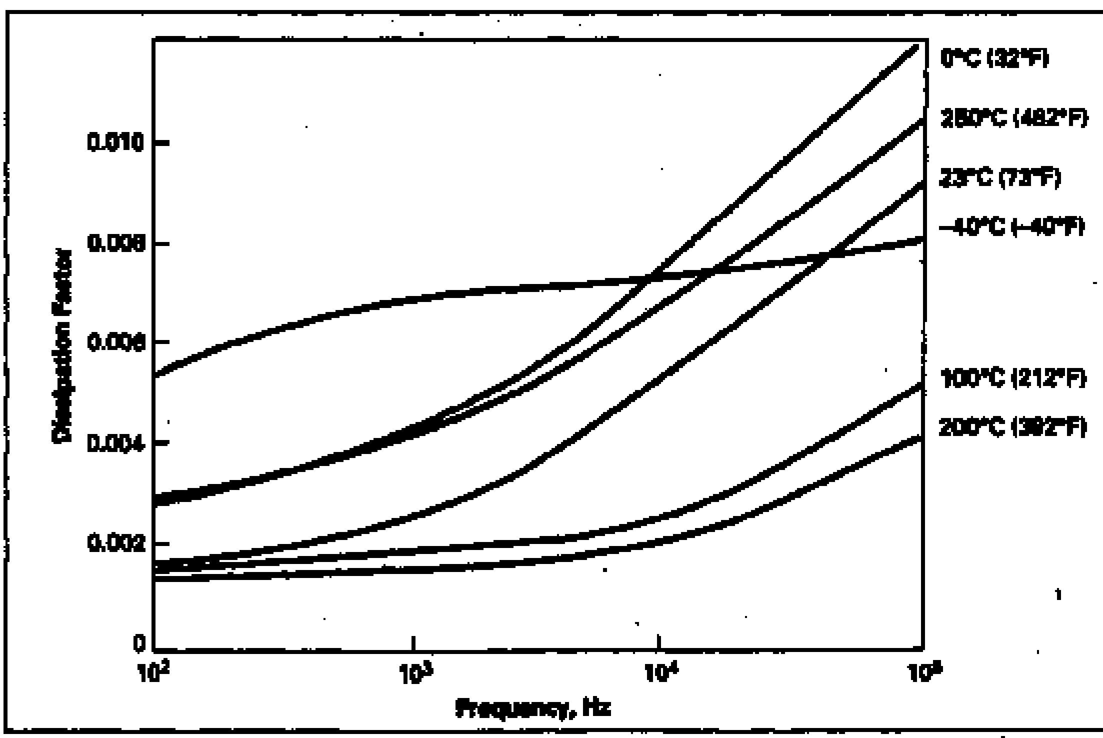


Figure 20. Dielectric Constant vs. Frequency, Type HN Film, 125 µm (5 mil)*

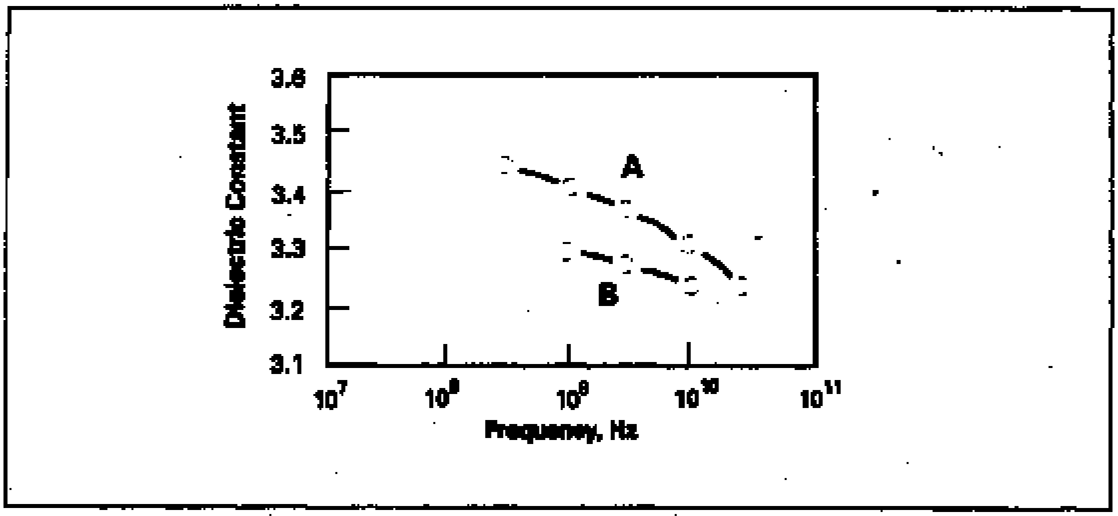
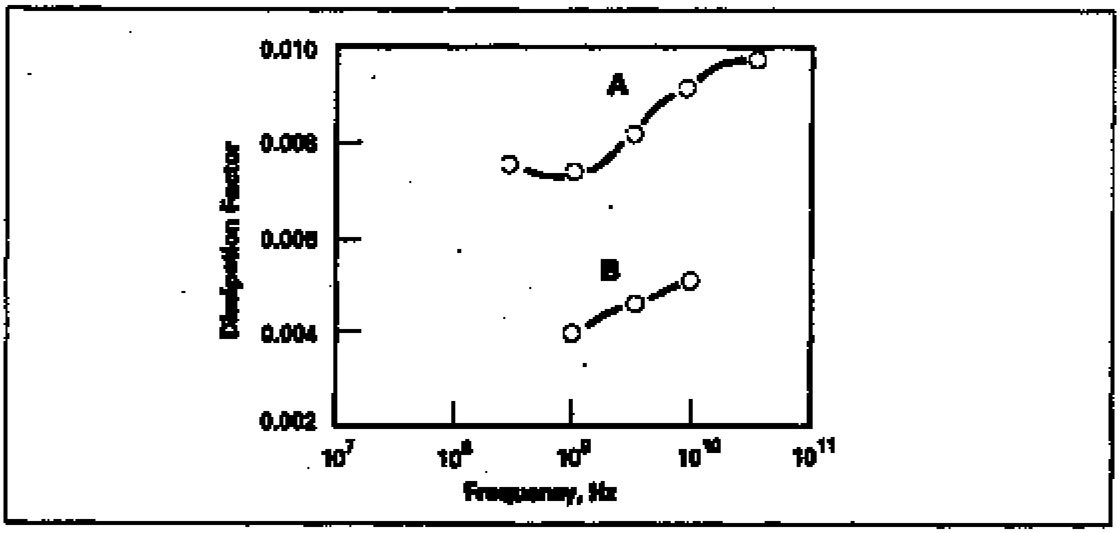


Figure 21. Dissipation Factor vs. Frequency, Type HN Film, 125 µm (5 mil)*



* 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.

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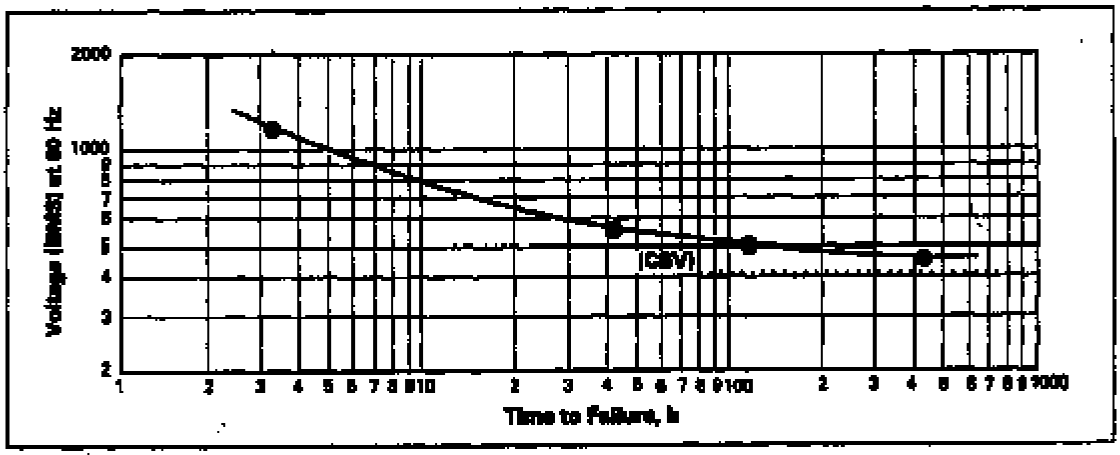
Corona Life

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 a 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

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Chemical Properties

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

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

Property	Typical Value: Tensile Retained, %	Typical Value: Elongation Retained, %	Test Condition	Test Method
Chemical Resistance				
Isopropyl Alcohol	99	94	10 min at 23°C	IPC TM-650
Toluene	99	91		Method 2.2.3B
Methyl Ethyl Ketone	99	90		
Methylene Chloride/ Trichloroethylene (1:1)	98	85		
2 N Hydrochloric Acid	95	89		
2 N Sodium Hydroxide	82	54		
Fungus Resistance	Nonnutrient			IPC TM-650 Method 2.6.1
Moisture Absorption	1.8% Types HN and VN		50% RH at 23°C	ASTM D-570-81 (1988)[1]
	2.8% Types HN and VN		Immersion for	24 h at 23°C (73°F)
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-1434-82 (1988)[1]
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-96-92
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

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 × 10^3)	207 (30)	207 (30)	214 (31)	214 (31)	152 (22)
Elongation, %	80	78	78	79	42
Tensile Modulus, MPa (psi × 10^3)	3172 (460)	3275 (475)	3378 (490)	3275 (475)	2903 (421)
Volume Resistivity Ω·cm × 10^{15} at 200°C (392°F)	4.8	6.6	5.2	1.7	1.6
Dielectric Constant 1 kHz at 23°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

	5×10^5 Gy	10^7 Gy
5×10^{19} neutrons/cm² 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^{-4} mmHg at 50°C (122°F). UV intensity equal to space sunlight to 2600A.

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

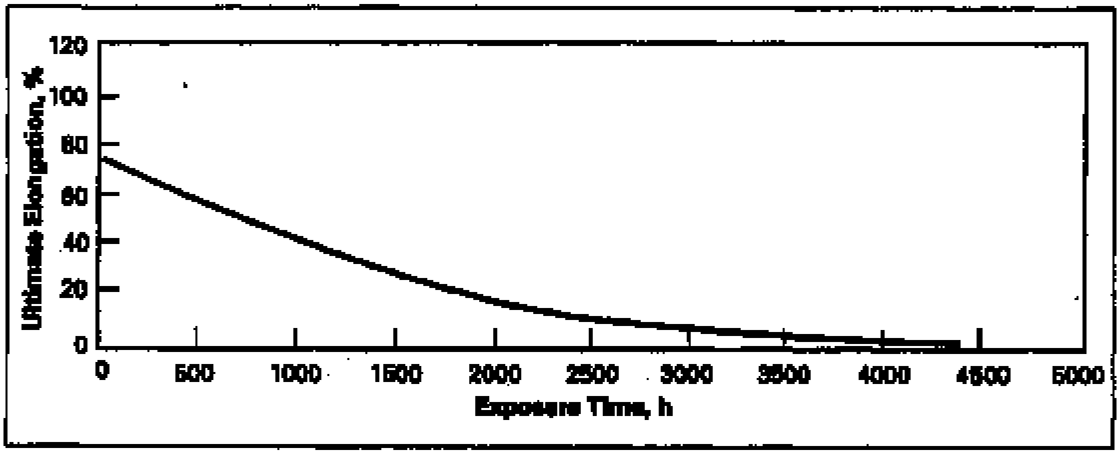
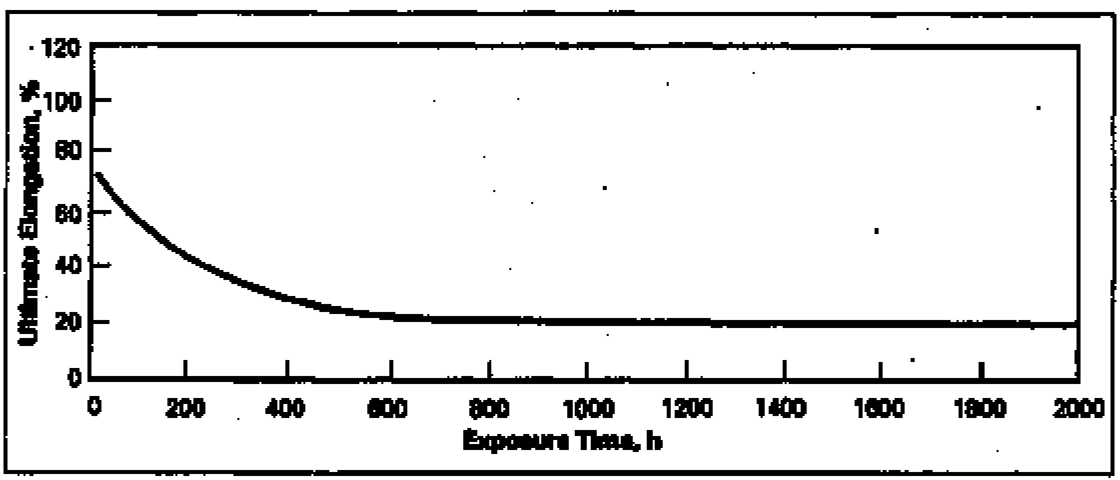
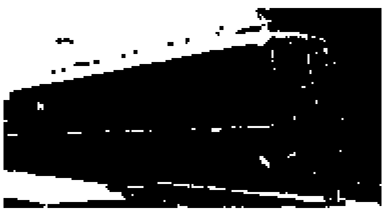


Figure 24. Effect of Weathering on Kapton* Polyimide Film (Atlas Weatherometer)





Kapton[1] 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

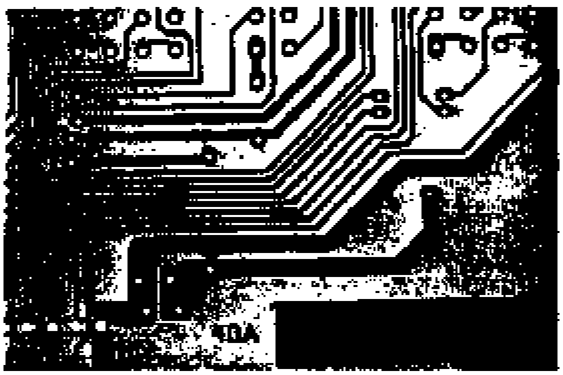
Type	Nominal Thickness µm	Nominal Thickness mil	Area Factor m²/kg	Area Factor ft²/lb
30HN	7.6	0.3	93	455
50HN	12.7	0.5	55	272
75HN	19.1	0.75	37	181
100HN	25.4	1.0	28	136
200HN	50.8	2.0	14	68
300HN	76.2	3.0	9.2	45
500HN	127	5.0	5.5	27
50VN	12.7	0.5	55	272
75VN	19.1	0.75	37	181
100VN	25.4	1.0	28	136
200VN	50.8	2.0	14	68
300VN	76.2	3.0	9.2	45
500VN	127	5.0	5.5	27
100FN099	25.4	1.0	23	110
120FN616	30.5	1.2	21	104
150FN999	38.1	1.5	14	68
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
400FN031	101.6	4.0	6.1	30
500FN131	127	5.0	4.7	23
600FN051	152.4	6.0	4.3	21

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 Teflon® 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 Teflon® on each side. Illustrated in Table 16 are several examples of the many film types available.

Table 16
Type FN Film Constructions

Type	Construction: FEP µm	FEP mil	HN µm	HN mil	FEP µm	FEP mil
100FN099			12.7	0.50	12.7	0.50
120FN616	2.54	0.10	25.4	1.00	2.54	0.10
150FN999	12.7	0.50	12.7	0.50	12.7	0.50
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
400FN031			76.2	3.00	25.4	1.00
500FN131	25.4	1.00	76.2	3.00	25.4	1.00
600FN051			127	5.00	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.

Safety and Handling

Safe handling of Type HN and VN 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. For additional information on the Teflon® FEP coating used on Type FN Kapton®, refer to the booklet "Guide to the Safe Handling of Fluoropolymer Resins" (H-48633).

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 thousand 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).

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Caution: Do not use in medical applications involving permanent implantation in the human body. For other medical applications, see "DuPont Medical Caution Statement," H-50102.

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DuPont High Performance Films

DuPont Films

High Performance Films

Kapton®

polyimide film

General Specifications

Introduction

DuPont High Performance Films manufactures and sells a variety of high-quality plastic film products in conformance with ISO 9002 certification.

These specifications describe the values and tolerances for Kapton® film properties. Where necessary for thorough understanding, test methods and procedures have been included.

Any aspects of the specifications that require further interpretation or clarification should be discussed with representatives of DuPont High Performance Films.

Types of Kapton® Polyimide Film

DuPont makes several types of Kapton® film. Types HN, FN, and VN are used most commonly.

Types H, F, and V are alternative, special versions of these standard types. The specifications in this bulletin apply to them as well. 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 High Performance Films representative.

Type HN Film

Kapton® Type HN is a tough, aromatic polyimide film, exhibiting an excellent balance of physical, chemical, and electrical properties over a wide temperature range, particularly at unusually high temperatures. Chemically, its polyimide polymer makeup is the result of a polycondensation reaction between pyromellitic dianhydride and 4,4'diaminodiphenyl ether. Kapton® HN is available in the following gauges: 30 (7.5 µm), 50 (12.7 µm), 100 (25.4 µm), 200 (50.8 µm), 300 (76.2 µm), and 500 (127 µm). Other gauges, such as 75 (19.1 µm) and 400 (102 µm), are available by special request.

Type FN Film

Kapton® Type FN film is a heat sealable grade that retains the unique balance of properties of Kapton® Type HN over a wide temperature range. This is achieved by combining Type HN with DuPont Teflon® FEP fluorocarbon resin in a composite structure. Table 1 lists the common types of FN film available. Other combinations are available. Consult your DuPont High Performance Films marketing representative for further information.

Table 1
Kapton® FN Polyimide Film Types

	Construction, mil (μm)		
Designation	**FEP**	**HN**	**FEP**
120FN616	0.10 (2.5)	1.00 (25.4)	0.10 (2.5)
120FN616B	0.15 (3.8)	1.00 (25.4)	0.15 (3.8)
150FN019		1.00 (25.4)	0.50 (12.7)
200FN919	0.50 (12.7)	1.00 (25.4)	0.50 (12.7)
200FN011		1.00 (25.4)	1.00 (25.4)
250FN029		2.00 (50.8)	0.50 (12.7)
300FN021		2.00 (50.8)	1.00 (25.4)
300FN929	0.50 (12.7)	2.00 (50.8)	0.50 (12.7)
400FN022		2.00 (50.8)	2.00 (50.8)
500FN131	1.00 (25.4)	3.00 (76.2)	1.00 (25.4)

Type VN Film

Kapton® Type VN is the same tough polyimide film as Type HN Film, exhibiting an excellent balance of physical, chemical, and electrical properties over a wide temperature range, with superior dimensional stability at elevated temperatures. This product is available in 50 (12.7 μm), 75 (19.1 μm), 100 (25.4 μm), 200 (50.8 μm), 300 (76.2 μm), and 500 (127 μm) gauges.

Certification

Kapton® is certified to meet the requirements of the military specification MIL-P-46112 B and ASTM D-5213-95 in addition to the items covered by this specifications bulletin. Written confirmation is available with each delivery upon request.

Thermal Durability

The thermal durability of Kapton® film depends on the environmental conditions under which it is aged and tested. Its lifetime depends on the criterion of failure. Kapton® is routinely tested at the manufacturing site in the following manner:

Sheets of film 8.5" × 11" (216 mm × 279 mm) are freely suspended in an oven at a temperature of 400°C ±2°C (752°F ±3.6°F), monitored with a thermocouple to ensure accuracy. Sheets are removed after 2 hr (1 hr for 30 [7.6 μm] and 50 [12.7 μm] gauge film) and tested on an Instron Tensile Tester as described in Table 2. The elongation of the film at 23.5°C (74.3°F) should not be less than 10% after this aging at 400°C (752°F). This conforms to MIL-P-46112B "Elongation After Aging at 400°C" test (paragraph 4.4.5) and "Elongation, Percent, After Two Hour 400°C" requirement (Table 2).

In addition, Kapton® conforms to ASTM D-5213-95, Standard Specification for Polymeric Resin Film for Electrical Insulation and Dielectric Applications.

Underwriters Laboratories, Inc. lists a thermal index of 200 to 220°C (392 to 428°F) (depending on gauge and type) for mechanical properties and 220 to 240°C (428 to 464°F) (depending on gauge and type) for electrical properties, under their file number E39505 for Kapton® polyimide film.

Properties of Type FN Film

Heat Seal Strength

Film-to-Film Seals

The peel strength of heat seals between the coated and uncoated sides of one-side coated Kapton® or between the coated sides of both one- and two-side coated Kapton® is determined as follows.

Seals are made in a jaw sealer at 350°C (662°F), 20 psi (1.4 bar), with a 20-sec dwell time. After cooling, the seals are cut into 1" (25.4-mm) wide strips using a Thwing-Albert JDC sample cutter or its equivalent. The seal strength is measured with an Instron-type tensile tester. Seal strength is defined as the peak instantaneous strength occurring in each seal. Five specimen values are averaged.

The minimum peel strength between the coated sides of one- or two-side coated Kapton® film will be 700 g/in (2.7 N/cm), except for 120FN616 and 120FN616B, which will be 450 g/in (1.7 N/cm). The minimum peel strength between the coated and uncoated side of one-side coated Kapton® will be 450 g/in (1.7 N/cm).

Film-to-Copper Seals

The ability of FEP film to adhere to copper is measured using the same heat seal peel strength technique as described in "Film-to-Film Seals."

The peel strength is measured with the FEP side sealed to the untreated side of 1 mil (25.4 μm), ¾ oz GT copper foil; it will be a minimum of 300 g/in (1.2 N/cm).

As-Received Strength (Cold Peel) of Bonds Between Kapton® Type HN and Teflon® Layers

The bond between the Kapton® Type HN and Teflon® fluorocarbon resin layers on all Type FN products except 120FN616 and 120FN616B will have a minimum peel strength of 225 g/in (0.87 N/cm), measured using an Instron-type tensile tester and a 180° peel.

Table 2
Mechanical Properties of Kapton[*] Type HN Polyimide Film

Property	Property Value—Film Thickness, mil (µm)						Method
	0.30 (7.6)	0.50 (12.7)*	1.00 (25.4)*	2.00 (50.8)*	3.00 (76.2)*	5.00 (127)*	
Tensile Strength, psi (MPa) at 23°C (73°F). Machine Direction (MD) and Transverse Direction (TD), min.	16,000 (110)	20,000 (138)	24,000 (165)	24,000 (165)	24,000 (165)	24,000 (165)	ASTM D-882-91, Method A, using an Instron Tensile Tester (specimen size: ½" × 6" [12.7 mm × 152 mm]; jaw separation: 4" [102 mm]; jaw speed: 2"-min [51 mm/min]). Calculate the average of five specimens based on original measured thickness.
Elongation, %, MD and TD, min.	25	35	40	45	50	50	Same as above.
Shrinkage, %, MD and TD at 400°C (752°F), max.	4.0	4.0	2.5	2.5	2.5	2.5	MIL-P-46112B. The percent shrinkage is obtained for either the MD or TD using the average of three measurements in either direction before and after conditioning. Prior to measurement, the 8½" × 11" (216 mm × 279 mm) specimen is conditioned by freely suspending it for 2 hr** in an oven controlled to 400°C (752°F).
Moisture Absorption, %, max.	4.0	4.0	4.0	4.0	4.0	4.0	ASTM D-570-82, using 24-hr immersion at 23°C (73°F). Average of three specimens.

*Also applies to Type VN, except shrinkage, which is shown in Table 5.
**1 hr for 30 and 50 gauge film

Table 3
Electrical Properties of HN Film

Property	Property Value—Film Thickness, mil (µm)						Method
	0.30 (7.6)	0.50 (12.7)*	1.00 (25.4)*	2.00 (50.8)*	3.00 (76.2)*	5.00 (127)*	
Dielectric Strength, AC V/mil (kV/mm), min.	3,000 (118)	3,000 (118)	6,000 (236)	5,000 (197)	4,500 (177)	3,000 (118)	ASTM D-149-94. (Average of ten specimens.) Flat sheets in air placed between ¼" (6 mm) diameter brass electrodes with 1/32" (0.8 mm) edge radius subjected to 60 cycles AC voltage at 500 V/sec rate of rise to the breakdown voltage.
Volume Resistivity, ohm-cm at 200°C (392°F), min.	10^{12}	10^{12}	10^{11}	10^{11}	10^{12}	10^{12}	ASTM D-257-93
Dielectric Constant at 1 kHz, max.	4.0	4.0	3.9	3.9	3.9	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.
Dissipation Factor at 1 kHz, max.	0.0070	0.0050	0.0036	0.0036	0.0036	0.0036	Same as above.

*Also applies to Type VN

Table 4
Dielectric Strength of Kapton® Type FN Polyimide Films

Gauge Construction	Minimum Breakdown V/mil (kV/mm)
120FN616	4,200 (165)
120FN616B	4,200 (165)
150FN019	3,700 (146)
200FN919	3,200 (126)
200FN011	3,200 (126)
250FN029	2,750 (108)
300FN021	2,700 (106)
300FN929	2,700 (106)
400FN022	2,200 (87)
500FN131	2,200 (87)

Test Method
Average of ten specimens tested per ASTM D-149-92. Flat sheets in air placed between ¼" (6 mm) diameter brass electrodes with 1/32" (0.8 mm) edge radius subjected to 60 cycles AC voltage. Rise is 500 V/sec to the breakdown voltage.

General

Materials

Kapton® Type HN and Type VN films are polyimide polymers in the form of a film.

Kapton® Type FN film is a combination of Type HN film with Teflon® FEP fluorocarbon resin on one or both sides.

Uniformity

Material shall be uniform in composition and free from defects that impair serviceability and/or appearance in proven applications.

U.S. Cores

Cores shall be of sufficient strength to prevent collapsing from handling. Standard core internal diameters (I.D.) are nominally 3" and 6" (76 mm and 152 mm) with the following specifications:

Paper

3" (76 mm) I.D.	3.032" ± 0.008" (77.01 mm ± 0.2 mm)
6" (152 mm) I.D.	6.028" ± 0.010" (153.11 mm ± 0.25 mm)

Plastic

3" (76 mm) I.D.	3.024" ± 0.005" (76.81 mm ± 0.1 mm)
6" (152 mm) I.D.	6.041" ± 0.010" (153.44 mm ± 0.25 mm)

Core material will be plastic for 3" (76 mm) I.D. cores less than ⅝" (16 mm) wide.

Core material will be fiber for 3" (76 mm) I.D. cores wider than ⅝" (16 mm) and for 6" (152 mm) I.D. cores. A split 3" (76 mm) I.D. fiber core is standard for all universal and Step-Pac™ rolls.

If these cores are not suitable, further information on other options may be obtained from your DuPont High Performance Films representative.

Table 5
Shrinkage of Kapton® Type VN Polyimide Film

Property	Property Value Film Thickness, mil (µm)				
	0.50 (12.7)	1.00 (25.4)	2.00 (50.8)	3.00 (76.2)	5.00 (127)
Shrinkage, %, MD and TD at 200°C (392°F), max.	0.10	0.10	0.10	0.10	0.10

Test Method
The percent shrinkage obtained for either the MD or TD by using the average of three measurements in either direction before and after conditioning. Temperature exposure 200°C ±2°C (392°F ±3.6°F) for 1 hr. Measurements must be made at the same temperature and humidity conditions before and after conditioning. To ensure sample/ambient equilibrium before and after conditioning, specimens should be exposed for 3 hr.

Width Tolerance
The maximum variation in film width from that specified on the order shall be as follows:

Slit Width Range	Tolerance
1½" (38 mm) or less	±0.005" (0.13 mm)
1½" to 4" (38 mm to 102 mm)	±0.030" (0.76 mm)
>4" (>102 mm)	±0.060" (1.5 mm)

Luxembourg Supply

Cores shall be of sufficient strength to prevent collapsing from handling. Luxembourg supplies pad rolls in widths below 9½" (240 mm) and universal wound rolls.

Standard core internal diameter for Luxembourg is 3" (76 mm) (nominal 3" ±0.008" [76 mm ±0.2 mm]).

Standard cores for pad rolls are paper cores, except for widths below ½" (13 mm), where it will be plastic.

Standard universal: core length
2.8" ±0.08" (70 mm ±2 mm) (split core)

Wide universal: core length
4.3" ±0.08" (110 mm ±2 mm) (non-split core)

A different put-up called Step-Pac™ is available from the U.S. Contact your DuPont High Performance Films representative for more information.

Width Tolerance
The maximum variation in film width from that specified on the order shall be as follows:

Slit Width Range	Tolerance
0.9" (22 mm) or less Universal	0.008" (0.20 mm)
6" (152 mm) or less Pad rolls	0.016" (0.40 mm)
6" to 9½" (153 mm to 240 mm) Pad rolls	0.04" (1.00 mm)

Outside diameter tolerance: ±0.4" (10 mm)

Table 6
Kapton[1] Polyimide Film Specifications and Tolerances

Film Type	Thickness Nominal mil (µm)*	Thickness Tolerance Min. mil (µm)	Thickness Tolerance Max. mil (µm)	Width Range Min. in (mm)	Width Range Max. in (mm)	Unit Weight Min. g/m²	Unit Weight Max. g/m²	Area Factor ft²/lb	Area Factor (m²/kg)
30HN	0.30 (7.6)	0.24 (6.1)	0.36 (9.1)	3/16 (4.8)	52 (1320)	7.3	14.0	453	92.8
50HN	0.50 (12.7)	0.35 (8.9)	0.65 (16.5)	3/16 (4.8)	52 (1320)	14.0	26.0	272	55.7
100HN	1.00 (25.4)	0.85 (21.6)	1.15 (29.2)	3/16 (4.8)	52 (1320)	32.7	38.7	136	27.9
200HN	2.00 (50.8)	1.75 (44.5)	2.25 (57.2)	3/16 (4.8)	52 (1320)	66.8	77.8	68	13.9
300HN	3.00 (76.2)	2.72 (69.1)	3.28 (83.3)	3/16 (4.8)	52 (1320)	101.9	116.4	45	9.2
500HN	5.00 (127)	4.65 (118)	5.35 (136)	3/16 (4.8)	52 (1320)	169.5	192.6	27	5.5
50VN	0.50 (12.7)	0.35 (8.9)	0.65 (16.5)	3/16 (4.8)	52 (1320)	14.0	26.0	272	55.7
100VN	1.00 (25.4)	0.85 (21.6)	1.15 (29.2)	3/16 (4.8)	52 (1320)	32.7	38.7	136	27.9
200VN	2.00 (50.8)	1.75 (44.5)	2.25 (57.2)	3/16 (4.8)	52 (1320)	66.8	77.8	68	13.9
300VN	3.00 (76.2)	2.72 (69.1)	3.28 (83.3)	3/16 (4.8)	50 (1270)	101.9	116.4	45	9.2
500VN	5.00 (127)	4.65 (118)	5.35 (136)	3/16 (4.8)	50 (1270)	169.5	192.6	27	5.5
120FN616	1.20 (30.5)	1.10 (27.9)	1.40 (35.6)	3/16 (4.8)	44 (1118)	41.0	50.0	104	21.3
120FN616B	1.30 (33.0)	1.20 (30.5)	1.50 (38.1)	3/16 (4.8)	44 (1118)	47.0	54.0	92	18.8
150FN019	1.50 (38.1)	1.25 (31.8)	1.75 (44.5)	3/16 (4.8)	44 (1118)	63.0	74.0	77	15.8
200FN011	2.00 (50.8)	1.70 (43.2)	2.30 (58.4)	3/16 (4.8)	44 (1118)	77.0	104.0	54	11.1
200FN919	2.00 (50.8)	1.70 (43.2)	2.30 (58.4)	3/16 (4.8)	44 (1118)	77.0	104.0	54	11.1
250FN029	2.50 (63.5)	2.25 (57.2)	2.75 (69.9)	3/16 (4.8)	44 (1118)	87.0	113.0	49	10.0
300FN021	3.00 (76.2)	2.60 (66.0)	3.40 (86.4)	3/16 (4.8)	44 (1118)	111.0	142.0	39	8.0
300FN929	3.00 (76.2)	2.60 (66.0)	3.40 (86.4)	3/16 (4.8)	44 (1118)	111.0	142.0	39	8.0
400FN022	4.00 (102)	3.50 (88.9)	4.50 (114)	3/16 (4.8)	44 (1118)	163.0	200.0	27	5.5
500FN131	5.00 (127)	4.50 (114)	5.50 (140)	3/16 (4.8)	44 (1118)	188.0	238.0	23	4.7

*Reference: ASTM D-374-94, Method A, C, or D.

The usual dimensions of pad rolls are 3" (76 mm) I.D. × 6" (152 mm) or 9" (230 mm) outside diameter (O.D.) for widths up to 4" (102 mm). In Luxembourg, 152 mm, 180 mm, 203 mm, and 240 mm O.D. rolls are available. For wider rolls, the usual dimensions are 6" (152 mm) I.D. × 9½" (240 mm) or 11" (280 mm) O.D. For Universal and Step-Pac™ rolls, the dimensions are 3" (76 mm) I.D. × 6" (152 mm), 8" (203 mm), or 12" (305 mm) O.D. If these dimensions are not suitable, information on other options is available from your DuPont High Performance Films technical or customer service representative.

Roll Types

Kapton® polyimide film is supplied in three types of rolls: pad, universal, and Step-Pac™ wind.

Pad Roll Specifications

- Core width will be the film width +⅛" (+3.2 mm), –0.
- Core edges shall not project more than 1/16" (1.6 mm) beyond the 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 a manner to prevent unwinding.
- "Dishing" or "cupping" may not exceed 1/16" (1.6 mm), measured with a straightedge across the diameter of the roll.

Universal and Step-Pac™ Roll Specifications

- The difference between the lengths of the projecting core on each side shall not exceed 3/16" (4.8 mm).
- Film shall not project from the main body of the roll more than ⅛" (3.2 mm).
- The outside and starting ends of the film shall be fastened in a manner to prevent unwinding.
- Roll face depression, the difference between the highest and lowest points of the roll, unstressed, shall not exceed 3/16" (4.8 mm).

Table 7
Reference Guide: Standard Length versus Roll O.D. (U.S. Supply)

Type	Standard Length Roll	Roll O.D. 3" Core I.D.	Roll O.D. 6" Core I.D.
100HN	5,000 ft (1,525 m)	9½" (241 mm)	11" (279 mm)
	10,000 ft (3,050 m)	11" (279 mm)	14" (356 mm)
200HN	2,500 ft (763 m)	9½" (241 mm)	11" (279 mm)
300HN	1,670 ft (509 m)	9½" (241 mm)	11" (279 mm)
500HN	1,000 ft (305 m)	9½" (241 mm)	11" (279 mm)

Splices

Description

Three types of splice are available.

- Mylar® polyester film-based yellow tape (standard).
- Kapton® polyimide film-based tape (special requirements only).
- Heat seal splice, 12" (305 mm) or less in width (Type FN).

Splices will be centered on the joint to ±¼" (±6 mm). They will be smooth and wrinkle-free to avoid distortion of the adjacent film layers in the roll.

Tape Splices

Tape splices are standard on all gauges of HN and VN film and on all gauges of FN film more than 12" (305 mm) wide.

Tape splices are made with the butt edges of the film covered on both sides with pressure-sensitive adhesive tape. Two-inch (50 mm) wide splicing tape is used.

Heat Seal Splices

Overlap heat seal splices are made on all FN films, except 250FN029, with an overlap that is a minimum of ⅜" (9.5 mm) wide.

On 250FN029, a butt splice is made using 120FN616 as the joining tape applied on the FEP surface. The butt splice is oriented with the 120FN616 tape on the top of the film as it unwinds from a universal put-up and on the bottom as it unwinds from a pad.

Overlap heat seal splices for one-side and two-side FEP composites are oriented with the leading edge of the new film on the bottom for universal and Step-Pac™ put-ups. Pad put-ups of one- or two-side FEP composites have the leading edge of the new film on the top.

DUP 000125

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Packaging and Marking

Packaging

Kapton® polyimide film shall be adequately packed to prevent loss of contents or damage during shipment.

All film will be wrapped with a non-fibrous material.

Marking

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

Arrangements for special markings can be made (such as part or specification number). Consult with your DuPont High Performance Films technical or customer service representative for details.

All package marking information is available with bar code labels.

Table 8
Package Marking

	Shipping Container	Package	Core Label*
Scheduled Date	X	X	X
Customer Order Number	X	X	
DuPont Order Number	X	X	X
Gauge	X	X	X
Type	X	X	X
Width	X	X	X
Number of Rolls per Container	X	X	
Net Weight	X	X	
Actual Footage			X
Mill Roll Number	X	X	X
I.D. and O.D.**	X	X	

*Affixed to the core on all cores 2.25" (57 mm) wide and over. Included with the package on all cores less than 2.25" (57 mm) wide

**Inside diameter of core and nominal outside diameter of roll

DUP 000126

DI/NHTSA No. 3
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DUPONT
DuPont Films

DUP 000127

DuPont Films

High Performance Films

Teflon® FEP Film

Fluorocarbon Film

Teflon FEP Fluorocarbon Film Types A, C, C-20 and L

Introduction

This specification covers Teflon FEP fluorocarbon film sold by DuPont Electronics.

Film types included in this specification meet requirements of fluorocarbon film specified by ASTM D-3368 as follows:

ASTM D-3368	
Type I	Teflon FEP Type A
Type II, Grade 1	Teflon FEP Type C
Type II, Grade 2	Teflon FEP Type C-20
Type III	Teflon FEP Type L

Where minimum or maximum tolerances are given, these represent limiting conditions approached by only a small portion of the film. A majority of the film will have properties falling within a range narrower than that specified.

Current product availability is shown in Table 1.

Manufacturing

Material

Copolymer of tetrafluoroethylene and hexafluoropropylene in the form of a film.

Color

The color of the film is uniform and ranges from clear to translucent depending on the thickness.

Defects

The material shall be uniform in appearance and shall be sufficiently free of contamination, wrinkles, holes, scratches, and other imperfections so as to be functionally acceptable.

Cores

Shall be of sufficient strength to prevent collapsing on handling. Sizes 3 in.(76.2 mm), or 6 in. (152.4 mm) I.D. should be specified on orders.

Order Tolerance

The tolerance for under or overrun on pounds ordered is ±10%.

Splices

Description

Splices for all gauges are butt type and are made with yellow pressure sensitive tape. One strip is applied to each side of the splice and shall be 2 in. (50.8 mm) wide for 200 gauge and above and 1 in. (25.4 mm) wide for below 200 gauge.

Frequency

See Table 2.

Width

The maximum variation in film width from that required on the order varies with the gauge and width of film and is shown in Table 4.

Thickness and Coverage

The average thickness is determined by measurement of the average weight of the film. The average unit weight will meet the specifications as shown in Table 3, Section A. In addition, no single point will fall outside the minimum and maximum thickness as shown in Table 3, Section B. Point thickness is determined through at least ten measurements across the width of the film in accordance with ASTM D-374 Method A or C.

General

Packaging

Teflon film is wound on 3 in. or 6 in. cores and is overwrapped in polyethylene. The film is then boxed to prevent loss of contents or damage during shipment. Each container is labeled with DuPont and customer's name, purchase order number, film thickness, type, mill roll number, and shipping date.

A label containing similar information is also affixed to the core for roll widths 2⅛ in. (54 mm) and above; for rolls less than 2⅛ in. (54 mm) wide the core label is in the package.

Assurance

Statistical sampling techniques are used to assure specified properties in the following tables are met.

Table 1
Availability of Teflon FEP Fluorocarbon Film

	Gauge													
Type	**50**	**100**	**200**	**300**	**500**	**750**	**1000**	**1500**	**2000**	**3000**	**6000**	**9000**	**12500**	**19000**
A	*	*	*	*	*	*	*	—	*	—	—	—	—	—
C	*	*	*	*	*	—	—	—	—	—	—	—	—	—
C-20	*	*	*	*	*	—	—	—	—	—	—	—	—	—
L	—	—	—	—	*	—	*	*	*	*	*	*	*	*

*Available

Note: Specifications apply to gauges and type available as indicated.

Table 2
Maximum Allowable Splices/Roll

Types: A, C, and C-20

	Put-Up						
	3" Cores				6" Cores		
Gauge	**5" O.D.**	**<7½"**	**7½"**	**9½"**	**<9½"**	**9½"**	**11"**
50	—	—	—	—	3	4	7
100	2	2	3	4	2	3	4
200	1	1	2	3	1	2	3
300	1	1	2	3	1	2	3
500	1	1	2	3	1	2	3
750	1	1	2	3	1	2	3
1000	—	—	—	—	1	1	3
2000	—	—	—	—	1	1	2

Note: Minimum distance between splices or between a splice and the end or start of a slit roll shall not be less than 100 ft for film under 2000 gauge and 50 ft for 2000 gauge.

Type: L

Gauge	3" × 9½" Roll	3" × 11" Roll
500	3	3
1000	—	3
1500	—	3
2000	—	2
3000	—	2
6000	—	1
9000	—	2

Note: Minimum distance between the end of a splice and the end or start of a slit roll shall not be less than 100 ft for 500L, 60 ft for 1000L, 50 ft for 2000L and 3000L, 30 ft for 6000L, and 14 ft for 9000L.

DUP 000129

Table 3
Teflon FEP Film Thickness Tolerance

Nominal Gauge	Nominal Thickness (in.)	A: Average Thickness Unit Wt (gm/m²) Nom	Min	Max	% Var	B: Single Point Thickness* Min	Max	C: Area Factor (ft²/lb) Nom	Min	Max
Types: A, C, and C-20										
50	0.0005	27.28	24.55	30.01	±10	0.00035	0.00065	178.97	162.70	196.87
100	0.0010	54.56	49.10	60.02	±10	0.00070	0.00130	89.49	81.35	99.43
200	0.0020	109.12	98.20	120.03	±10	0.00150	0.00250	44.74	40.67	49.72
300	0.0030	163.68	147.31	180.05	±10	0.00225	0.00375	29.83	27.11	33.14
500	0.0050	272.80	253.70	291.90	±7	0.00400	0.00600	17.90	16.72	19.25
750	0.0075	409.20	380.55	437.84	±7	0.00622	0.00877	11.93	11.16	12.83
1000	0.0100	545.60	507.40	583.79	±7	0.00850	0.01150	8.95	8.36	9.62
2000	0.0200	1091.20	1014.82	1167.58	±7	0.01700	0.02300	4.47	4.18	4.81
Type: L										
500	0.0050	272.80	245.52	300.08	±10	0.0040	0.0060	17.90	16.27	19.89
1000	0.0010	545.60	491.04	600.16	±10	0.0085	0.0115	8.95	8.13	9.94
1500	0.0015	818.40	736.56	900.24	±10	0.0128	0.0173	5.97	5.42	6.63
2000	0.0200	1091.20	982.08	1200.32	±10	0.0170	0.0230	4.47	4.06	4.97
3000	0.0300	1636.80	1473.12	1800.48	±10	0.0255	0.0345	2.98	2.71	3.31
6000	0.0600	3273.60	2946.24	3600.24	±10	0.0540	0.0660	1.49	1.35	1.66
9000	0.0900	4910.40	4419.36	5401.44	±10	0.0810	0.0990	0.99	0.90	1.10
12500	0.125	6820.00	6480.00	7160.00	±10	0.106	0.144	0.72	0.68	0.76
19000	0.190	10366.00	9885.00	10847.00	±10	0.161	0.218	0.47	0.45	0.49

*Determined by using lowest and highest thickness readings of ten measurements across the film per ASTM D-374 Method A or C.

Table 4
Roll Width Tolerance

Gauge	Web Width: 1/2–15/16 in.	1–6 in.	Over 6 in.
50 and 100	±1/16	±1/16	±1/16
200 through 400	±1/16	±1/16	±1/16
500 through 1500	±1/16	±1/32	±1/16
2000	±1/16	±1/16	±1/16
Over 2000	±1/8	±1/8	±1/8

Note: Variation in film width shall not exceed these limits.

DUP 000130

Table 5
Property Value, Types A, C, C-20, L

Property	Film Gauges									Method
	50	100	200	300	500	750	1000	1500	2000	
Dielectric Strength volts/mil, AC	4000	4000	3500	3000	2500	2000	1800	1500	1400	Avg. of 10 samples tested per ASTM D-149 Method A. Flat sheets in air placed between 1/4" diameter brass electrodes with 1/32" edge radius and subjected to 60 Hz A.C. voltage rise at 500 volts/sec. to the breakdown voltage.
Dielectric Constant, (at 25°C, 1000 Hertz) Maximum	2.15									ASTM D-150. Result is average of 5 tests using measured sample thickness.
Dissipation Factor, (at 25°C, 1000 Hertz), Maximum	.0003									ASTM D-150, same as above.
Volume Resistivity, ohm-cm, at 170°C, Minimum	1×10^{17}									ASTM D-257.
Surface Resistivity, ohm (per sq.) at 23°C, 35% R.H., Minimum	1×10^{16}									

Table 6
Property Value, Types A, C, C-20

Property	Film Gauges								Method
	50	100	200	300	500	750	1000	2000	
Tensile Strength, psi, 25°C minimum	2000	2500	2500	2500	2500	2500	2500	2500	ASTM D-882 for ≤10 mil thickness. ASTM D-638 for >10 mil thickness. 2 inch per minute testing speed.
Elongation at Break, % (minimum)	175	200	250	250	250	250	250	250	Same as above method.
Shrinkage, % (maximum at 200°C) MD	±5	±5	±3	±2	±2	±2	±2	±2	Average of five measurements on room temperature samples before and after each test. Each specimen, 4" × 4" freely suspended in an oven controlled to 200°C ±1°C Exposure time 0.5 hours.
TD	±5	±5	±3	±2	±2	±2	±2	±2	
Cementability (Type C film only) Minimum peel strength in g/in of width	170	300	750	800	2000	2000	3000	—	Use DuPont adhesive #68040 on Aldine #1200 aluminum sheet (0.019" thick.). Peel Test at 180° angle at peel rate 12 in/min.
Melt Temperature (Melting Endotherm Peak), °C	260–280								ASTM D-3418 (DTA).
Density (g/cm³), 23°C	2.12–2.17								ASTM D-1505.

DUP 000131

Table 7
Property Value, Type L

Property	Film Gauges								Method
	500	1000	1500	2000	3000	5000	9000	12500	
Tensile Strength, psi, 25°C	2500	2500	2500	2500	2500	2500	2500	2500	ASTM D-882 for ≤10 mil thickness. ASTM D-638 for >10 mil thickness. 2 in/ min. testing speed.
Elongation, %, minimum	250	250	250	250	250	250	250	250	Same as above method.
Shrinkage, % (max at 200°C)									Average of five measurements on room temperature samples before and after each test. Each specimen, 4" x 4" freely suspended in an oven controlled to 200°C ±1°C. Exposure time 0.5 hours.
MD	±2	±2	±2	±2	±4	±4	±5	±5	
TD	±2	±2	±2	±2	±4	±4	±5	±5	
Melt Temperature (Melting Endotherm Peak), °C	260–280								ASTM D-3418 (DTA)
Density (g/cm³), 23°C	2.13–2.17								ASTM D-1505.

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DuPont Films

Summary of Properties

DuPont High Performance Films

Kapton® polyimide film

TI 0010835

DD/NHTSA No. 3
00099

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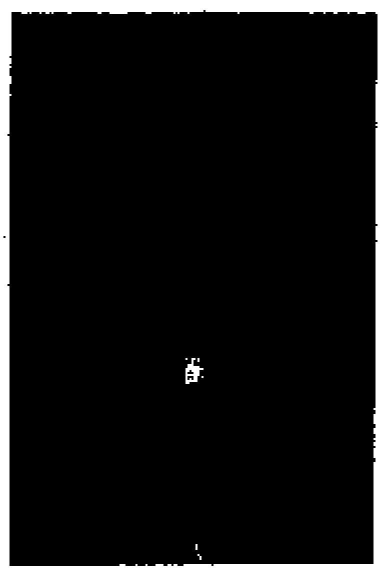


Kapton® is used in applications such as the solar array and for thermal management in the United States space program.

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® does not melt or burn 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), 19 µm (0.75 mil), 25 µm (1 mil), 50 µm (2 mil), 75 µm (3 mil), and 125 µm (5 mil) films.
- Kapton® Type VN, all-polyimide film with all of the properties of Type HN, plus superior dimensional stability. Type VN is available as 12.5 µm (0.5 mil), 19 µm (0.75 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 on one or both sides with Teflon® 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 Teflon® 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

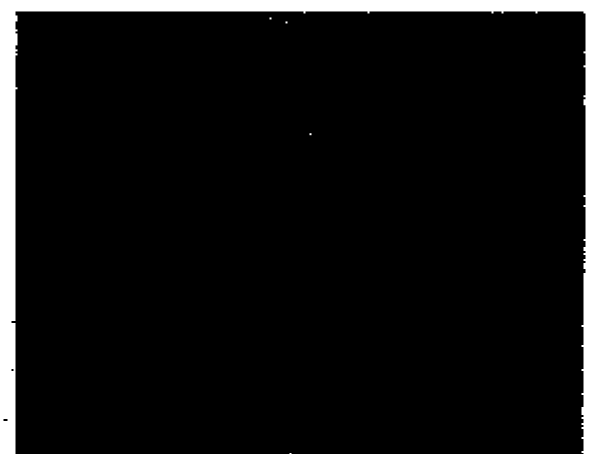
Data for these films are covered in separate product bulletins, which can be obtained from your DuPont representative.

The Chemical Abstracts Service Registry Number for Kapton® polyimide film is [25036-53-7].

TI 0010837

DD/NHTSA No. 3
00141

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



Kapton® is used in numerous electronic applications, including hard disk drives.

TI 0010838

DD/NHTSA No. 3
00102

Physical and Thermal Properties

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 (−452°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.

Table 1
Physical Properties of Kapton® Type 100 HN Film, 25 μm (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)	139 (20,000)	ASTM D-882-91, Method A*
Yield Point at 3%, MPa (psi)	69 (10,000)	41 (6000)	ASTM D-882-91
Stress to Produce 5% Elongation, MPa (psi)	90 (13,000)	61 (9000)	ASTM D-882-91
Ultimate Elongation, %	72	83	ASTM D-882-91
Tensile Modulus, GPa (psi)	2.5 (370,000)	2.0 (290,000)	ASTM D-882-91
Impact Strength, N·cm (ft·lb)	78 (0.58)		DuPont Pneumatic Impact Test
Folding Endurance (MIT), cycles	285,000		ASTM D-2176-89
Tear Strength—Propagating (Elmendorf), N (lbf)	0.07 (0.02)		ASTM D-1922-89
Tear Strength—Initial (Graves), N (lbf)	7.2 (1.6)		ASTM D-1004-90
Density, g/cc or g/mL	1.42		ASTM D-1505-90
Coefficient of Friction—Kinetic (Film-to-Film)	0.48		ASTM D-1894-90
Coefficient of Friction—Static (Film-to-Film)	0.63		ASTM D-1894-90
Refractive Index (Sodium D Line)	1.70		ASTM D-542-90
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: 25 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-794-85 (1989)
Thermal Coefficient of Linear Expansion	20 ppm/°C (11 ppm/°F)	−14 to 38°C (7 to 100°F)	ASTM D-696-91
Coefficient of Thermal Conductivity, W/m·K	0.12	296 K	ASTM F-433-77 (1987)ε1
$\frac{cal}{cm \cdot sec \cdot °C}$	2.87×10^{-4}	23°C	
Specific Heat, J/g·K (cal/g·°C)	1.09 (0.261)		Differential Calorimetry
Flammability	94V-0		UL-94 (2-2-85)
Shrinkage, %	0.17 1.25	30 min at 150°C 120 min at 400°C	IPC TM 650, Method 2.2.4A ASTM D-5214-91
Heat Sealability	Not Heat Sealable		
Limiting Oxygen Index, %	37		ASTM D-2863-87
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.		

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Table 3
Physical and Thermal Properties of Kapton® Type VN 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-882-91
Ultimate Elongation, %	72	82	82	82	ASTM D-882-91
Tear Strength—Propagating (Elmendorf), N	0.07	0.21	0.38	0.58	ASTM D-1922-89
Tear Strength—Initial (Graves), N	7.2	16.3	26.3	46.9	ASTM D-1004-90
Folding Endurance (MIT), × 10³ cycles	285	55	6	5	ASTM D-2176-89
Density, g/cc or g/mL	1.42	1.42	1.42	1.42	ASTM D-1505-90
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-2863-87

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)	207 (30,000)	162 (23,500)	200 (29,000)
200°C (392°F)	121 (17,500)	89 (13,000)	115 (17,000)
Yield Point at 3%, MPa (psi)			
23°C (73°F)	61 (9000)	49 (7000)	58 (8500)
200°C (392°F)	42 (6000)	43 (6000)	36 (5000)
Stress at 5% Elongation, MPa (psi)			
23°C (73°F)	79 (11,500)	65 (9,500)	76 (11,000)
200°C (392°F)	53 (8000)	41 (6000)	48 (7000)
Ultimate Elongation, %			
23°C (73°F)	75	70	85
200°C (392°F)	80	75	110
Tensile Modulus, GPa (psi)			
23°C (73°F)	2.48 (360,000)	2.28 (330,000)	2.62 (380,000)
200°C (392°F)	1.62 (235,000)	1.14 (165,000)	1.38 (200,000)
Impact Strength at 23°C (73°F), N-cm (ft-lb)	78 (0.58)	68.8 (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 (2.4)	11.6 (2.6)	17.8 (4.0)
Polyimide, wt%	80	57	73
FEP, wt%	20	43	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 Teflon® 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 of Teflon® on each side.

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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)

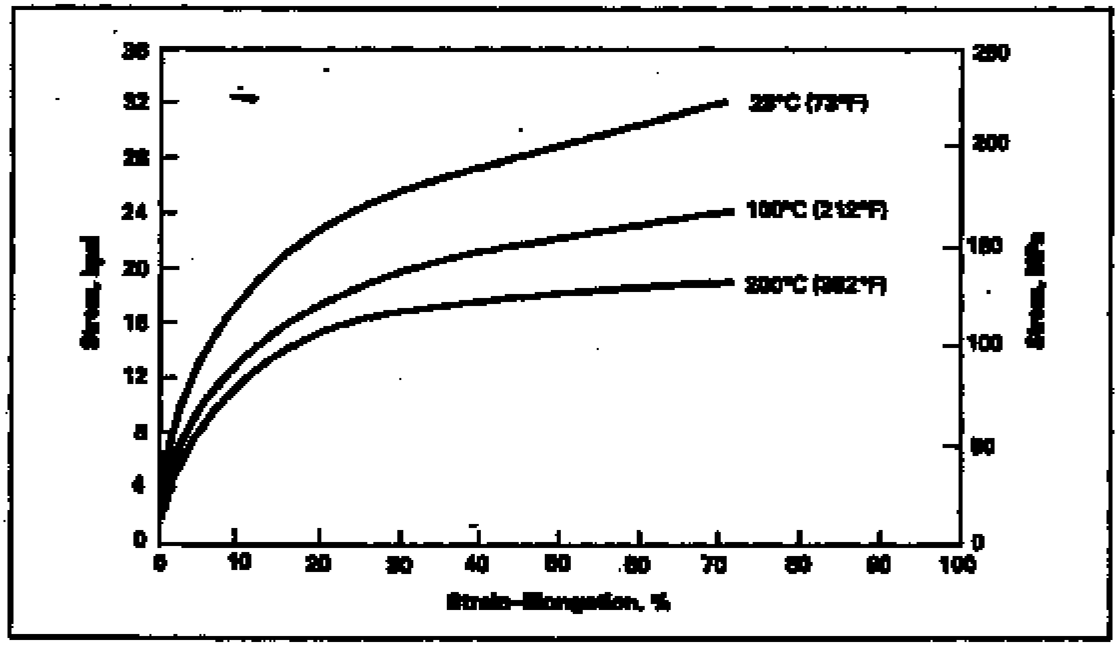

Figure 2. Tensile Creep Properties, Type HN Film, 25 μm (1 mil)

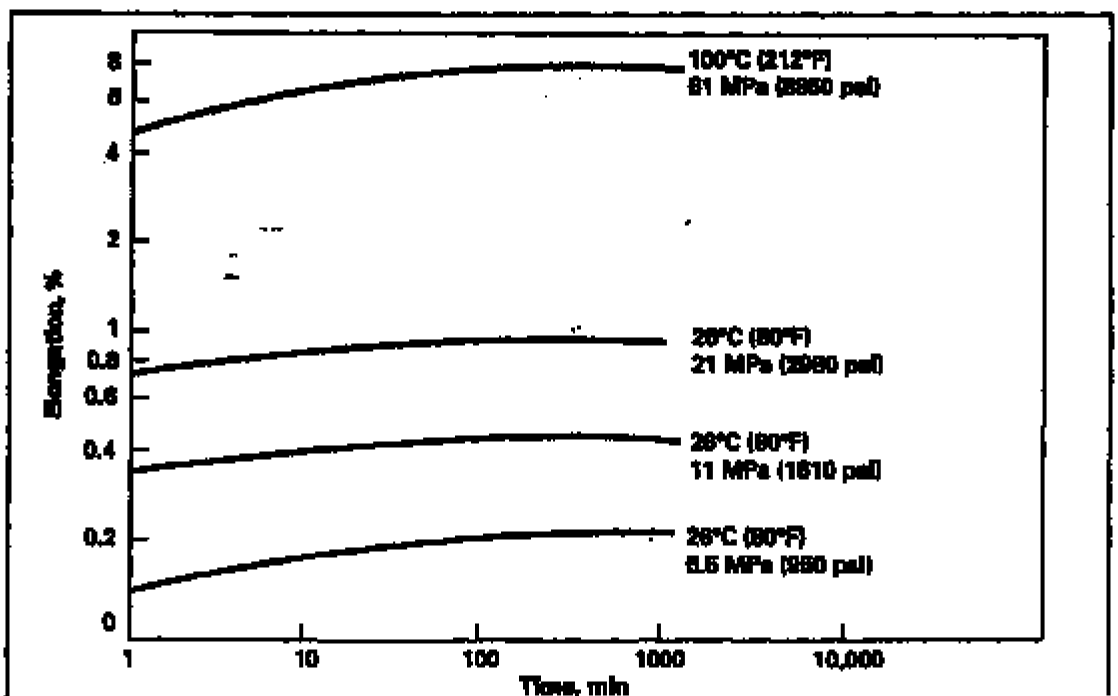

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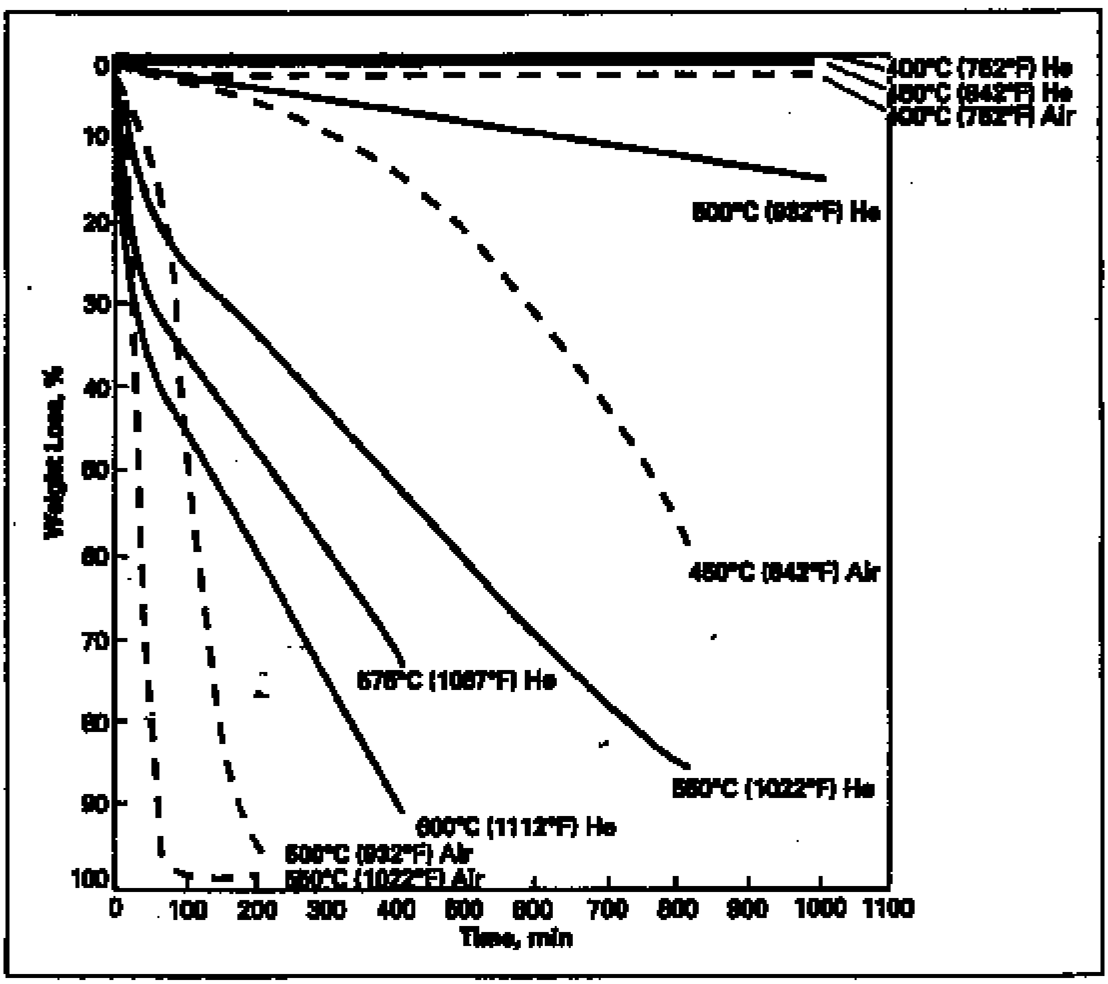
Table 6
Time Required for Reduction in Ultimate Elongation from 70% to 1%, Type HN Film, 25 µm (1 mil)

Temperature	Air Environment
450°C (842°F)	2 hours
425°C (797°F)	5 hours
400°C (752°F)	12 hours
375°C (707°F)	2 days
350°C (662°F)	6 days
325°C (617°F)	1 month
300°C (572°F)	3 months
275°C (527°F)	1 year
250°C (482°F)	8 years

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



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Electrical Properties

The most common electrical properties of Kapton® polyimide film of various gauges are shown in Tables 6 and 7. 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 VN Films

Property Film Gauge	Typical Value		Test Condition	Test Method
Dielectric Strength	V/μm (kV/mm)	(V/mil)	60 Hz 1/4 in electrodes 500 V/sec rise	ASTM D-149-91[1]
25 μm (1 mil)	303	(7700)		
50 μm (2 mil)	240	(6100)		
75 μm (3 mil)	205	(5200)		
125 μm (5 mil)	154	(3900)		
Dielectric Constant			1 kHz	ASTM D-150-92
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-150-92
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-257-91
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)	167 (5000)
Dielectric Constant	3.1	2.7	3.0
Dissipation Factor	0.0015	0.0013	0.0013
Volume Resistivity, Ω·cm			
at 23°C (73°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}

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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)

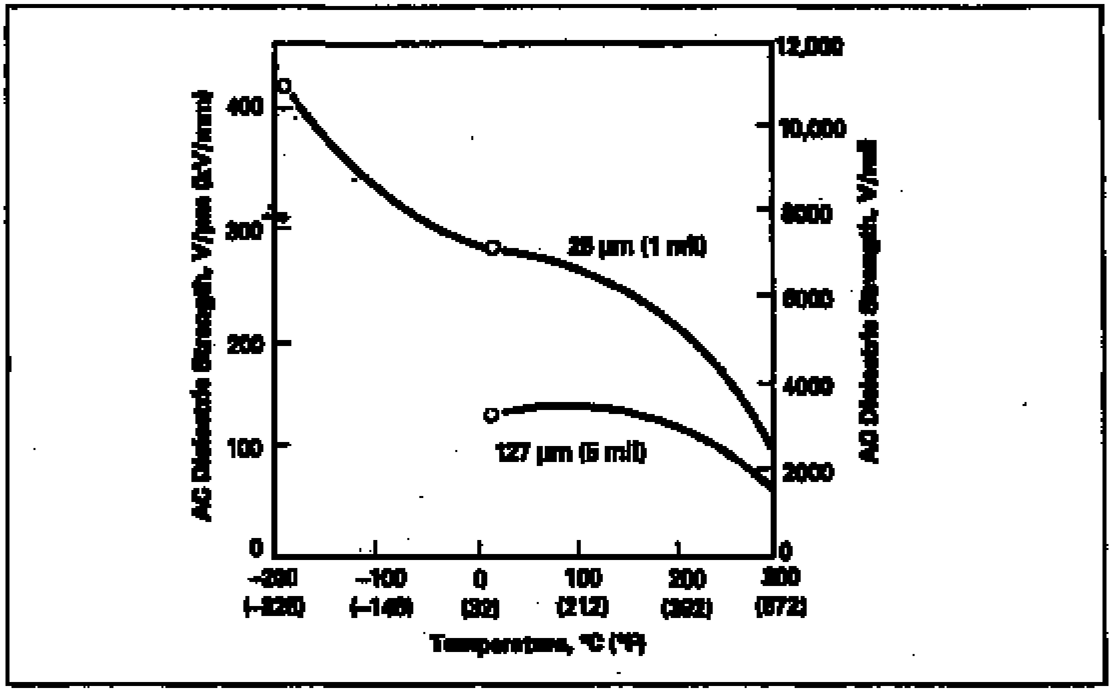

Figure 15. Dielectric Constant vs. Temperature, Type HN Film, 25 µm (1 mil)

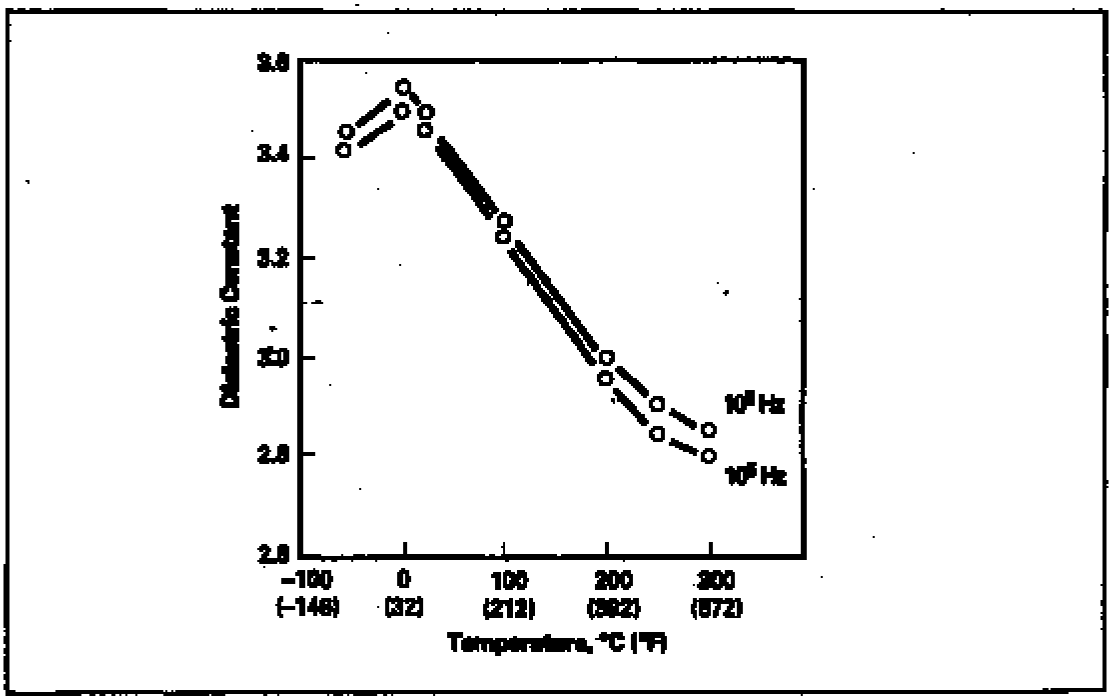

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Figure 16. Dissipation Factor vs. Temperature, Type HN Film, 25 μm (1 mil)

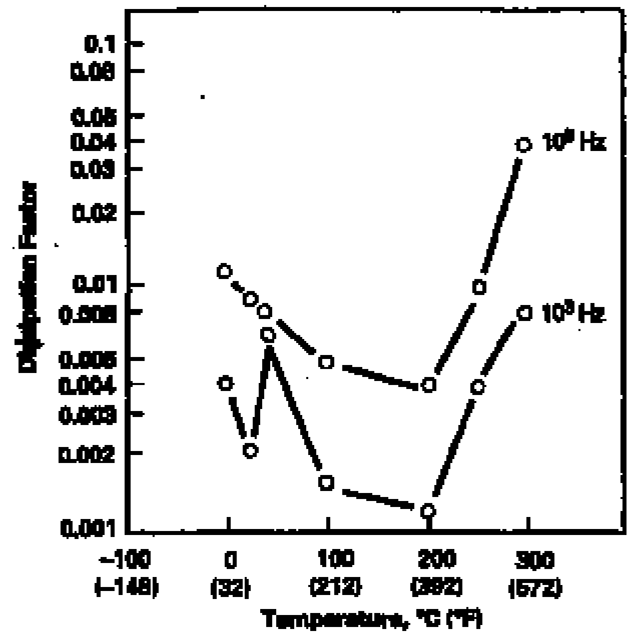
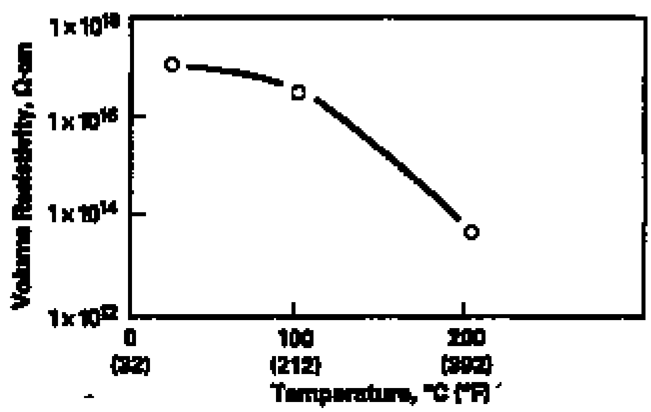


Figure 17. Volume Resistivity vs. Temperature, Type HN Film, 25 μm (1 mil)



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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)

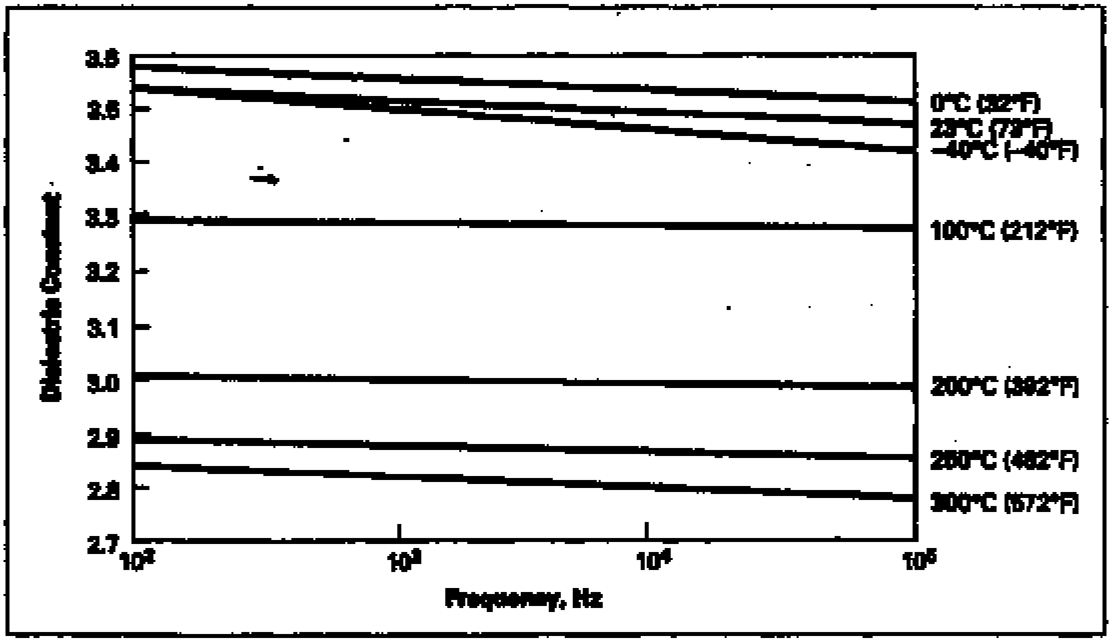


Figure 19. Dissipation Factor vs. Frequency, Type HN Film, 25 µm (1 mil)

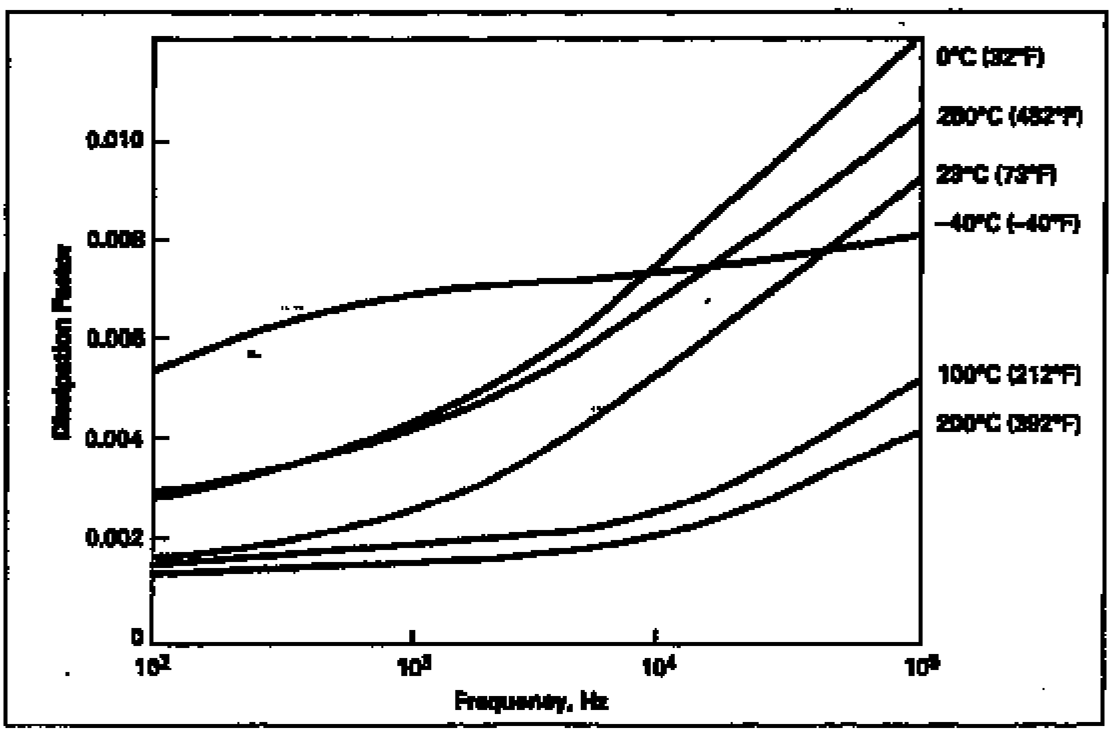


Figure 20. Dielectric Constant vs. Frequency, Type HN Film, 125 µm (5 mil)*

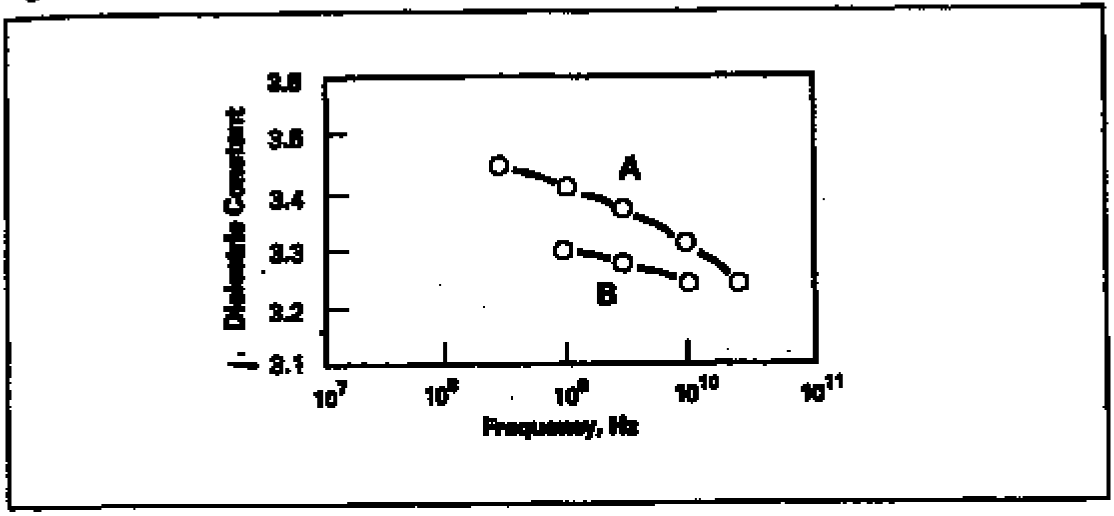
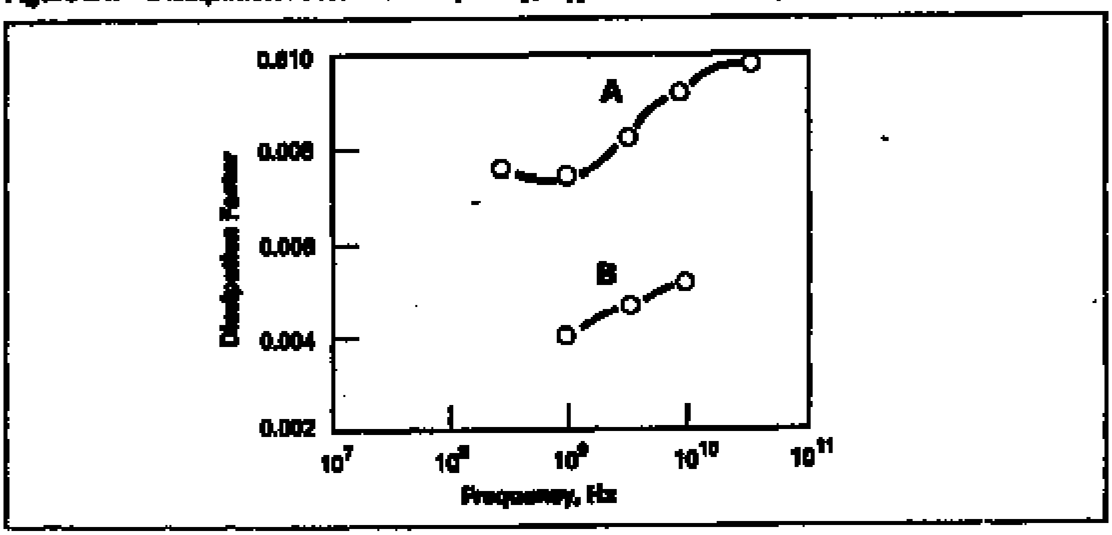


Figure 21. Dissipation Factor vs. Frequency, Type HN Film, 125 µm (5 mil)*



* Technical Report AFML-TR-72-38—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.

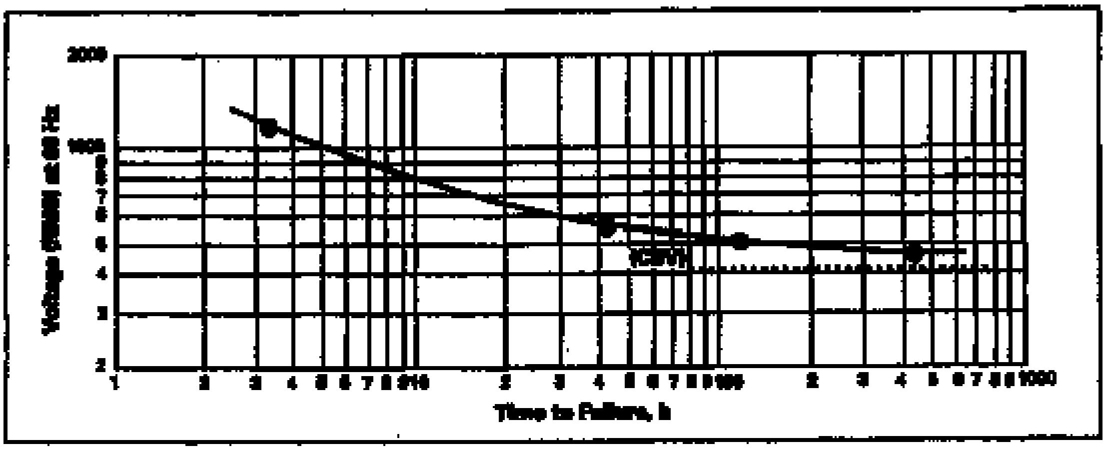
Corona Life

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 a 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) = 435 V

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Chemical Properties

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

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

Property	Typical Value: Tensile Retained, %	Typical Value: Elongation Retained, %	Test Condition	Test Method
Chemical Resistance				
Isopropyl Alcohol	[illegible]	94	10 min at 23°C	IPC TM-650 Method 2.3.2
Toluene	[illegible]	91		
Methyl Ethyl Ketone	[illegible]	90		
Methylene Chloride/ Trichloroethylene (1:1)	[illegible]	[illegible]		
2 N Hydrochloric Acid	[illegible]	[illegible]		
2 N Sodium Hydroxide	82	54		
Fungus Resistance	Nonnutrient			IPC TM-650 Method 2.6.1
Moisture Absorption	1.8% Types HN and VN		50% RH at 23°C	ASTM D-570-81 (1988)[ε1]
	2.8% Types HN and VN		Immersion for 24 h at 23°C (73°F)	
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-1434-82 (1988)[ε1]
Carbon Dioxide	[illegible]	45		
Oxygen	[illegible]	25		
Hydrogen	38,000	250		
Nitrogen	910	6		
Helium	63,000	415		
Vapor	g/(m²·24 h)	g/(100 in²·24 h)		ASTM E-96-92
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

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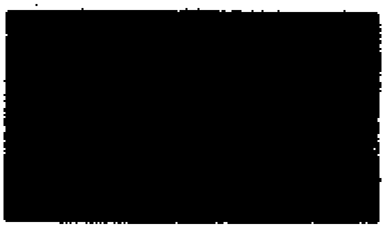


Kapton® is used as primary insulation for traction motors because of its outstanding combination of thermal, mechanical, and electrical properties.

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

Kapton® Film Type Information

Table 16
Type and Thickness

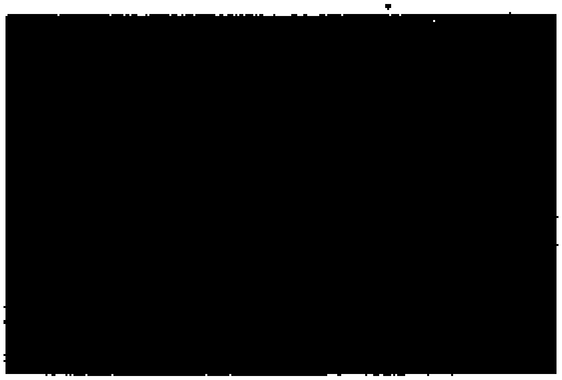
Type	Nominal Thickness µm	Nominal Thickness mil	Area Factor m²/kg	Area Factor ft²/lb
30HN	7.6	0.3	93	455
50HN	12.7	0.5	55	272
75HN	19.1	0.75	37	181
100HN	25.4	1.0	28	136
200HN	50.8	2.0	14	68
300HN	76.2	3.0	9.2	45
500HN	127	5.0	5.5	27
50VN	12.7	0.5	55	272
75VN	19.1	0.75	37	181
100VN	25.4	1.0	28	136
200VN	50.8	2.0	14	68
300VN	76.2	3.0	9.2	45
500VN	127	5.0	5.5	27
100FN099	25.4	1.0	23	110
120FN616	30.5	1.2	21	104
150FN999	38.1	1.5	14	68
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	6.6	27
400FN031	101.6	4.0	6.1	30
500FN131	127	5.0	4.7	23
600FN051	152.4	6.0	4.3	21

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 Teflon® 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 Teflon® on each side. Illustrated in Table 16 are several examples of the many film types available.

Table 18
Type FN Film Constructions

Type	*Construction* FEP *µm*	FEP *mil*	HN *µm*	HN *mil*	FEP *µm*	FEP *mil*
100FN099			12.7	0.50	12.7	0.50
120FN616	2.54	0.10	25.4	1.00	2.54	0.10
150FN999	12.7	0.50	12.7	0.50	12.7	0.50
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
400FN031			76.2	3.00	25.4	1.00
500FN131	25.4	1.00	76.2	3.00	25.4	1.00
600FN051			127	5.00	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.

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Safety and Handling

Safe handling of Type HN and VN 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. For additional information on the Teflon® FEP coating used on Type FN Kapton®, refer to the booklet "Guide to the Safe Handling of Fluoropolymer Resins" (H-48633).

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 thousand 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).

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DuPont High Performance Films

High Performance Films

DuPont FEP

fluorocarbon film

Types A, C, C-20, and L

Introduction

This specification covers FEP fluorocarbon film sold by DuPont Films.

Film types included in this specification meet requirements of fluorocarbon film specified by ASTM D-3368 as follows:

ASTM D-3368	
Type I	FEP Type A
Type II, Grade 1	FEP Type C
Type II, Grade 2	FEP Type C-20
Type III	FEP Type L

Where minimum or maximum tolerances are given, these represent limiting conditions approached by only a small portion of the film. A majority of the film will have properties falling within a range narrower than that specified.

Current product availability is shown in Table 1.

Manufacturing

Material

Copolymer of tetrafluoroethylene and hexafluoropropylene in the form of a film.

Color

The color of the film is uniform and ranges from clear to translucent depending on the thickness.

Defects

The material shall be uniform in appearance and shall be sufficiently free of contamination, wrinkles, holes, scratches, and other imperfections so as to be functionally acceptable.

Cores

Shall be of sufficient strength to prevent collapsing on handling. Sizes 3 in (76.2 mm) or 6 in (152.4 mm) I.D. should be specified on orders.

Order Tolerance

The tolerance for under or overrun on pounds ordered is ±10%.

Splices

Description
Splices for all gauges are butt type and are made with yellow pressure-sensitive tape. One strip is applied to each side of the splice and shall be 2 in (50.8 mm) wide for 200 gauge and above and 1 in (25.4 mm) wide for below 200 gauge.

Frequency
See Table 2.

Thickness and Coverage

The average thickness is determined by measurement of the average weight of the film. The average unit weight will meet the specifications as shown in Table 3, Section A. In addition, no single point will fall outside the minimum and maximum thickness as shown in Table 3, Section B. Point thickness is determined through at least ten measurements across the width of the film in accordance with ASTM D-374 Method A or C.

Width

The maximum variation in film width from that required on the order varies with the gauge and width of film and is shown in Table 4.

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Table 3
DuPont FEP Fluorocarbon Film Thickness Tolerance

Nominal Gauge	Nominal Thickness, in	A Average Thickness Unit Weight, g/m²				B Single Point Thickness*		C Area Factor, ft²/lb		
		Nom.	Min.	Max.	% Var.	Min.	Max.	Nom.	Min.	Max.
Types: A, C, and C-20										
50	0.0005	27.28	24.55	30.01	±10	0.00035	0.00065	178.97	162.70	198.87
100	0.0010	54.56	49.10	60.02	±10	0.00070	0.00130	89.49	81.35	99.43
175	0.0017	95.48	85.93	105.03	±10	0.00130	0.00220	51.14	46.50	55.28
200	0.0020	109.12	98.20	120.03	±10	0.00160	0.00250	44.74	40.67	49.72
300	0.0030	163.68	147.31	180.05	±10	0.00225	0.00375	29.83	27.11	33.14
500	0.0050	272.80	253.70	291.90	±7	0.00400	0.00600	17.90	16.72	19.25
750	0.0075	409.20	380.55	437.84	±7	0.00622	0.00877	11.93	11.15	12.83
1000	0.0100	545.60	507.40	583.79	±7	0.00850	0.01150	8.95	8.36	9.62
2000	0.0200	1091.20	1014.82	1167.58	±7	0.01700	0.02300	4.47	4.18	4.81
Type: L										
500	0.0050	272.80	245.52	300.08	±10	0.0040	0.0060	17.90	16.27	19.89
1000	0.0010	545.60	491.04	600.16	±10	0.0085	0.0115	8.95	8.13	9.94
1500	0.0015	818.40	736.56	900.24	±10	0.0128	0.0173	5.97	5.42	6.63
2000	0.0200	1091.20	982.08	1200.32	±10	0.0170	0.0230	4.47	4.06	4.97
3000	0.0300	1636.80	1473.12	1800.48	±10	0.0255	0.0345	2.98	2.71	3.31
4500	0.0400	2455.20	2209.68	2700.72	±10	0.0383	0.0518	1.99	1.80	2.20
6000	0.0600	3272.60	2946.24	3600.34	±10	0.0540	0.0690	1.49	1.36	1.66
7500	0.0750	4092.00	368.28	4501.20	±10	0.0638	0.0863	1.19	1.07	1.31
9000	0.0900	4910.40	4419.36	5401.44	±10	0.0810	0.0990	0.99	0.90	1.10
12500	0.125	6820.00	6490.00	7160.00	±10	0.106	0.144	0.72	0.68	0.76
19000	0.190	10366.00	9855.00	10847.80	±10	0.161	0.219	0.47	0.45	0.49

*Determined by using lowest and highest thickness readings of ten measurements across the film per ASTM D-374 Method A or C.

Table 4
Roll Width Tolerance, in

Gauge	Web Width, in		
	1/2–15/16	1–6	Over 6
50 and 100	±1/16	±1/16	±1/16
200 through 400	±1/16	±1/16	±1/16
500 through 1500	±1/16	±1/32	±1/16
2000	±1/16	±1/16	±1/16
Over 2000	±1/8	±1/8	±1/8

Note: Variation in film width shall not exceed these limits.

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Table 7
Property Value, Type L

Property	Film Gauge										Method
	500	1000	1500	2000	3000	4000	5000	7500	9000	12000	
Tensile Strength, psi, 23°C	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	ASTM D-882 for ≤10 mil thickness. ASTM D-638 for >10 mil thickness. 2 in/min testing speed.
Elongation, %, Min.	250	250	250	250	250	250	250	250	250	250	Same as above method.
Shrinkage, %, Max. at 200°C											Average of five measurements on room temperature samples before and after each test. Each specimen, 4 in x 4 in freely suspended in an oven controlled to 200°C ±1°C. Exposure time 0.5 hr.
MD	±2	±2	±2	±2	±4	±4	±4	±4	±5	±5	
TD	±2*	±2	±2	±2	±4	±4	±4	±4	±5	±5	
Melt Temperature, Melting Endotherm Peak, °C	[illegible]										ASTM D-3418 (DTA).
Density, g/cm³, 23°C	2.13-2.17										ASTM D-1505.

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DuPont Films

High Performance Films

Teflon® FEP

fluorocarbon film

Techniques for Fabricating Teflon® FEP

Introduction

Teflon® FEP fluorocarbon film offers the outstanding properties of Teflon® in a convenient, easy-to-use form. The film is used "as received" in a number of applications. However, in many instances, the film must be fabricated into a product suitable for a specific application. Some examples would be:

- Metallizing the film to produce a substrate for flexible printed circuits
- Sealing the film to produce a bag or pouch
- Melt bonding the film to a metal substrate
- Using the film as a melt adhesive to bond two pieces of copper tubing
- Adhesive bonding the film to vinyl sheeting (laminating)
- Thermoforming the film into useful shapes such as corrosion-resistant labware (funnels, beakers, etc.)

This brochure will describe the techniques employed in fabricating Teflon® FEP films. The following topics will be covered:

- Heat sealing
- Heat bonding
- Teflon® FEP film as an adhesive
- Adhesive laminating
- Metallizing
- Thermoforming

Note that all of the information in this brochure is related to techniques for the fabrication of Teflon® FEP films. The techniques for fabricating Teflon® PFA film are very similar to those for Teflon® FEP. The major difference is in the melting behavior of these films. Teflon® PFA film melts about 28–42°C (50–75°F) higher than Teflon® FEP. In all procedures requiring the film to be in the formable or melted state, equipment temperature should be modified accordingly. Procedures not requiring the Teflon® PFA films to be formable or melted would be the same as for Teflon® FEP films.

Heat Sealing Principles

In many areas of application, the heat sealability of Teflon® FEP fluorocarbon film will be of interest as a method of fabrication. This section discusses some of the methods that may be employed to obtain heat seals with Types A and L films.

General

Teflon® FEP film may be heat sealed by any method that heats the contacting surfaces of the film above the melt temperature of the polymer and, at the same time, provides intimate contact of those surfaces.

A fusion heat seal of Teflon® FEP film is a non-peeling type of seal, and a wide seal area is not necessary. Better appearing seals with minimum distortion and puckering of the film are obtained

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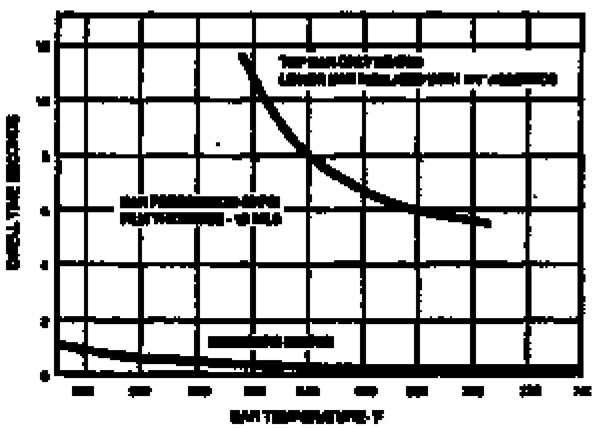
Figure 3 illustrates the considerable effect heating both bars vs. one bar of the sealer has upon the temperature-time relationship for obtaining a fusion heat seal. For example, at 338°C (640°F), it requires only 0.2 sec with two bars heated to obtain a fusion heat seal with 10-mil film, while with only one heated bar, 8.1 sec are required at this temperature. Theoretically, it should require four times as long to heat the film interfaces to the fusion temperature from one side as it should from both sides. However, lacking perfect insulation, heat losses to the surroundings and unheated bar increase this difference.

Figure 3. Effect of Bar Heating Upon Temperature-Time Relationship for Heat Sealing Teflon® FEP Film



Figures 4 and 5 summarize the data obtained for heated bar sealing of Teflon® FEP fluorocarbon film. Figure 4 is for use when both bars are heated; Figure 5 when only one bar is heated and the other one is insulated. In both figures, the selection of a temperature-dwell time combination above the indicated curve for a particular gauge film will result in a fusion heat seal of the selected gauge film.

In general, a selection of conditions just slightly in excess of the minimum indicated conditions should prove most satisfactory. This should minimize overheating and distortion of the film. The use of a different slip-sheet or different equipment may affect the selection of optimum temperature-dwell time conditions.

Figure 4. Temperature-Time Relationship for Obtaining Fusion Heat Seal with Teflon® FEP Film

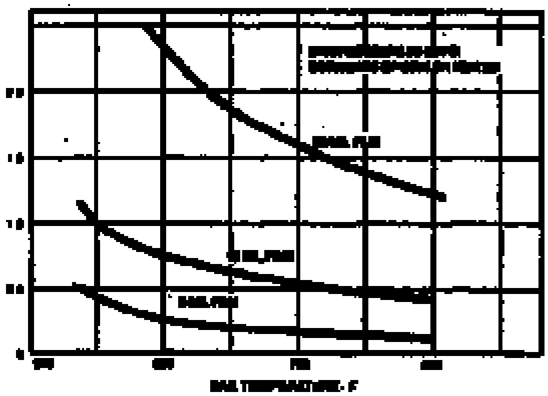
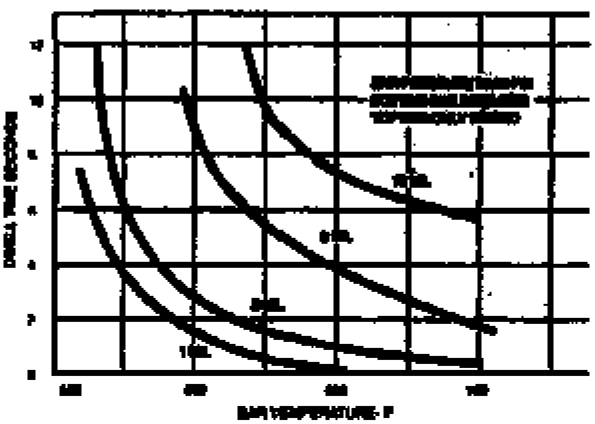


Figure 5. Temperature-Time Relationship for Obtaining Fusion Heat Seal with Teflon® FEP Film



Effect of Gauge on Heat Seals

Figure 6 indicates the heat seal strength obtainable with the various gauges of Teflon® FEP film. Because a Teflon® FEP film fusion heat seal does not peel, the indicated break strength and elongation is that of the weakest link—the film just adjacent to the sealed area. In general, this is approximately 80% of the tensile strength and ultimate elongation of the virgin film.

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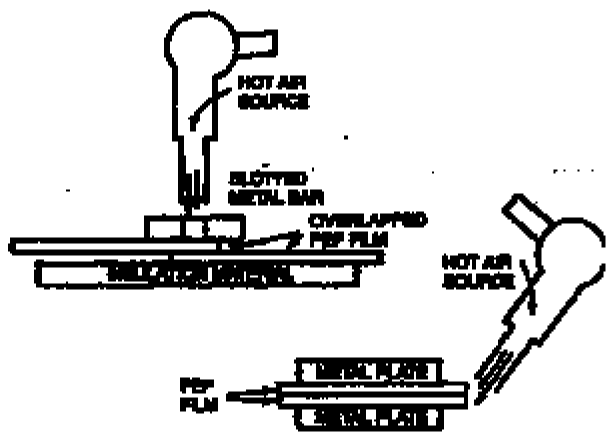
employed to keep the hot air stream directed to only the seal area, while the remainder of the film area is not exposed. A metal guide of complex shape will give a contour seal area.

Illustration B. Hot Air Sealing of Thin Films



Thermoplastic Welding

This information is for experienced operators with a knowledge of thermoplastic welding techniques and a general awareness of available welding tools and equipment.

Publications about welding and fabricating thermoplastic materials may serve as an additional resource.

Safety

Teflon® FEP fluorocarbon resin may undergo some decomposition at welding temperatures. Adequate ventilation must be provided with point-of-work exhaust hoods preferred. Individual fresh air masks may be necessary in some unavoidable enclosed spaces.

Further details regarding safety of Teflon® FEP resin are contained in the bulletin, H-48633, "Guide to the Safe Handling of Fluoropolymer Resins," available from DuPont.

Materials and Equipment

Welding Rods should be extruded virgin Teflon® FEP plastic, normally round, solid, and free of voids with a minimum diameter of ⅛ in and a maximum of 3/16 in.

Electrically Heated Welding Gun with at least a 750-W heating element capable of producing an air temperature of at least 427°C (800°F) when measured at a distance of ¼ in from the installed tip.

Inert Gas Supply and Pressure Regulator to provide 5–6 psig pressure at the tip of the welding tool.

Preparation

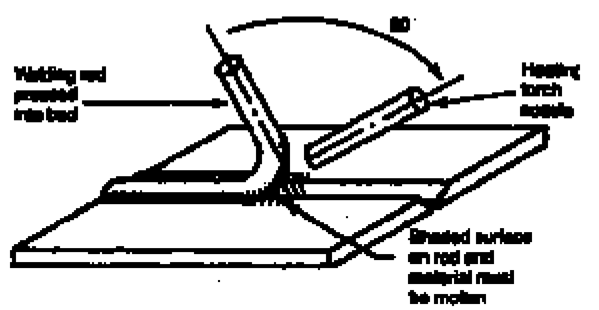
- Cleaning cannot be overemphasized. All surfaces, including welding rods and adjacent plastic for about 1 in beyond the joint, should be cleaned immediately prior to welding with a suitable solvent. Do not use soap or detergents.
- Bevelling of thermoplastic edges is essential to obtain a satisfactory weld. Mechanically guided power tools should be used for straighter edges. Use these bevel angle guidelines for Teflon® FEP sheet:

– Butt Joints (single or double)	60°
– Corners	60°
– Fillets	45°
– Laps	Not required

- The joint must be kept in alignment during welding by mechanical clamping or tack welding with a maximum root gap of 1/16 in.

Welding

1) Start hot gas welder at 343°C (650°F).
2) Preheat starting edge of joint material and rod until both appear shiny and become slightly tacky. Hold welding tip about ¼ in from weld joint/rod intersection.
3) Cut the end of the welding rod at a 45° angle, hold it at a 90° angle to the joint, and move it up and down slightly in the heat until it sticks to the base material. During continuous welding, a slight uniform motion of the torch between the sheet and rod is required (the standard Pendulum Technique used by the industry).
4) Holding the rod at a 45° angle with the base material, apply downward pressure on the rod of about 3 lb force. Avoid tension stretching of the rod. See sketch below.



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Ultrasonic Sealing

Teflon® FEP fluorocarbon film may be ultrasonically sealed. Evaluation of any application for ultrasonic assembly must start with analysis of the part size, shape, and structure to determine ease of matching the ultrasonic tooling for efficient transfer of the sonic vibration without energy losses. Mastersonics* is one manufacturer of equipment that has been effective in ultrasonically sealing Teflon® FEP films.

Heat Bonding

Teflon® FEP Fluorocarbon Film to Various Substrates

Teflon® FEP fluorocarbon film is melt processible. Therefore, it can be heat bonded to many substrates (e.g., metals, glass cloth, and other high-temperature materials) without using adhesives. In this way, the unique properties of Teflon® FEP film expand the functionality of the substrate. The substrate material often adds strength and rigidity to the FEP film.

Laminates can be produced in a platen press or on continuous laminating equipment. The general-purpose Type A film or the cementable Type C film may be used. Bonding is accomplished above the melting point of FEP (approximately 271°C [520°F]).

Good bonding to any substrate requires intimate surface contact between the substrate and the FEP film. The molten FEP must flow into the substrate's surface. The substrate must be free from surface contaminants.

Surface Treatment of Metals

Teflon® FEP is quite viscous in the melt, which can impede intimate surface contact with the substrate. Methods of overcoming this are: raising the temperature of the melt to reduce viscosity or increasing laminating pressure to improve flow. However, the surface condition of a metal substrate can greatly influence bonding and dictate temperature and pressure conditions. Sandblasting, chemical etching, or rough grinding increases the effective surface area and "opens up" the surface. On a microscopic scale, a metal's surface is like a mountain range. These surface roughening treatments increase the distance between peaks or widen the valleys. Thus the surface is "open" to the viscous flow of the molten FEP, facilitating intimate contact. The increased surface area also enhances bond strength. These techniques usually remove loose oxides, which, although they may bond to the FEP, have poor bond strength to the metal itself. Many metals are processed using oily lubricants. For this reason, it is wise to degrease the metal surface with solvents. Certain metals (copper in particular) rapidly form oxides at the temperatures recommended for bonding. The use of surface-treated copper is recommended.

Some materials, such as nickel, gold, and aluminum, do not yield strong bonds to Type A FEP film at temperatures under 316°C (600°F). However, Type C FEP film does produce good bonds in that temperature range. Indeed, a few materials will not bond at all to Type A film, but bond well to the Type C surface. It is also possible to bond Type C film to some materials below the melt range of FEP.

Typical platen press conditions and substrate treatments are given in Table 1.

Teflon® FEP Fluorocarbon Dispersion Priming of Metals

Materials such as stainless steel or very thin foils may not respond readily to physical or chemical etching. Excellent bonds can be obtained by priming such surfaces with a thin coating of a fused Teflon® FEP fluorocarbon dispersion. When using the primers, the following procedures are recommended:

1. Spray a very light coating of a mixture of 50% TFE Primer—#850-line and 50% FEP Dispersion #120** on the clean metal surface.
2. Fuse the coating in a forced draft oven at 371°C (700°F) for 5–10 min depending upon the mass of metal involved.
3. Laminate Teflon® FEP fluorocarbon film to the primed surface at 288°C (550°F).

*Mastersonics, Granger, IN
**Available from the DuPont Company

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Teflon® FEP Fluorocarbon Film as an Adhesive

Teflon® FEP fluorocarbon film is thought of usually as a release or antistick material. It is thought of occasionally as an inert thermoplastic from which various parts and shapes of pure Teflon® can be formed. Rarely is it thought of as an adhesive—yet its performance in all three of these areas is equally outstanding. It may be surprising to know that, when melted, Teflon® film actually becomes an excellent adhesive for bonding many materials—metals and nonmetallics as well.

Few adhesives can match the broad capabilities of Teflon® film. Its excellent resistance to both chemicals and high temperatures makes possible bonded structures suitable for service in applications where ordinary adhesives may not be equal to the task. Teflon® film is a flexible adhesive that permits laminated structures to be post-formed. It is the ideal adhesive for Teflon® TFE and produces strong bonds between two surfaces of PTFE or between PTFE and other substrates that can withstand temperatures greater than 332°C (630°F) (above the PTFE melt temperature). Because it is available in film form, on a roll, and in a range of thicknesses from ½–190 mil, Teflon® film is more convenient in handling and storing than many other adhesives.

Adhesive Laminating

Teflon® FEP fluorocarbon film extends the DuPont family of films to those applications requiring high temperature resistance, antisticking surfaces, low coefficient of friction, and resistance to chemical attack. Teflon® FEP film, Type C, has a specially treated surface that permits it to be used with conventional adhesives. Type A film is not as modified, and most adhesives will not adhere to it. However, the Type A film surface may be chemically etched to promote adhesion.

Teflon® FEP film, Type C or etched, can be laminated to many heat-sensitive substrates (elastomers, fabrics, wood, plastics, and papers) using conventional laminating equipment. Irregular shapes can be fabricated using adhesive laminations of Teflon® FEP film and post-forming techniques.

Many materials, by virtue of their adhesive character, may be combined with Teflon® FEP film by casting or molding directly to the etched surface. Included in this category are most epoxy compounds, elastomers, urethane foam, uncured rubber, and some vinyl plastisols.

In most cases, the bond may be enhanced by a pretreatment of the substrate, although in the case of fabrics, wood, and other porous materials, this is unnecessary. The specific type of treatment required varies with the substrate used: thus, while metals may be treated with chemical etches or sandblasting, certain plastics may require only a solvent wash to remove surface contamination or plasticizer.

As mentioned above, Teflon® FEP fluorocarbon film, Type C, manufactured by DuPont is modified with a proprietary surface treatment that allows it to be bonded using most commercial adhesives. Prolonged exposure of this specially treated surface to ultraviolet radiation, moisture, or elevated temperature will adversely affect cementability of the film.

Cementability tests have been carried out on unopened archive sample rolls of treated films. The results of these tests suggest that the adverse effect on cementability can be minimized by keeping the film in its original package or otherwise effectively protecting the film from ultraviolet light. For best results, it is advisable to carry out cementability tests on film prior to its use.

Laminating technique varies with the substrate and adhesive system employed. Most adhesive suppliers are familiar with the condition employed when bonding Teflon® film to various substrates and will have specific recommendations. When contacting adhesive suppliers for specific recommendations for a specific end-use application, it is suggested that the following information be supplied in the initial inquiry:

Process Limitations

- Maximum laminating temperature available.
- Maximum laminating pressure.
- Maximum time, heat, and pressure that can be applied to the laminate (drying tunnel, roll storage).
- Speed of laminator (if continuous process).
- Whether aqueous or organic solvent systems are preferred.
- Type of substrate.
- Type of adhesive applicator (reverse roll, gravure, flexographic).

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Pressure Forming

Pressure forming involves heating the clamped film with a contact platen mounted over the mold, then evacuating the mold cavity and simultaneously applying air pressure of 20–100 psi or greater to the upper side of the film.

Good conformity and detail are achieved with 1- to 20-mil Teflon® FEP fluorocarbon film in such pressure forming equipment. Optimum platen temperatures range from 246°C (475°F) for 1-mil film to 254°C (490°F) for 5-, 10-, and 20-mil films. Above 257°C (495°F) the film tends to stick to the heater platen. At these temperatures, pressure requirements vary from 60–120 psi depending upon the thickness of the film.

Molds heated to 93–177°C (200–350°F) are required for pressure forming 10- and 20-mil Teflon® FEP film. With 1-, 2-, and 5-mil films, the use of heated molds widens the forming temperature range from ±2.7 to 5.5°C (±5 to 10°F).

As shown in Table 3, a heating time of 10 sec is adequate for 1- to 20-mil film, although shorter heating time can be used with thinner films. The dwell time after forming is not critical, provided it is long enough to cool the film so that it can be removed from the mold without distortion.

Table 3
Optimum Conditions for Pressure Forming

Film Gauge, mil	Temp., °C (°F)	Heat Time, sec	Dwell Time, sec	Pressure, psi	Remarks
1	246 (475)	10	6	60	
2	252 (485)	10	6	60	
5	254 (490)	10	6	60	
10	254 (490)	10	7	60	Holes
20	254 (490)	10	6	100	

Note: The mold for the first set of data is a group of nine 3-in square pouches, 1 in deep. It represents an area increase of about 190% in each pouch. This mold has no heating.

Film Gauge, mil	Heat Temp., °C (°F)	Mold Temp., °C (°F)	Heat Time, sec	Dwell Time, sec	Pressure, psi
5	254 (490)	121 (250)	10	6	60
10	254 (490)	121 (250)	10	6	80
20	254 (490)	149 (300)	10	8	100

Note: The need for a heated mold is proved by the use of a disk shaped mold 4½ in diameter and 1 in deep heated with strap heater. Area increase is 67%.

Summary of Important Points

Thermoformable?

Yes—Teflon® FEP is a true thermoplastic material that is readily formable.

Problems?

The major problem is when someone has difficulty in thermoforming FEP film, most of the time sufficient heat is not available (or if it's available, it's not made available long enough) to bring the film up to forming temperature.

What does it take?

It takes 3–3.5 kW/ft² watt density of radiant heat.

Teflon® FEP film is very transparent to infrared energy and doesn't readily absorb the energy from radiant heaters. Ceramic heating elements have been successful in adequately heating Teflon® FEP film for thermoforming.

The temperature of the heaters is usually above 649°C (1200°F) just to effectively heat the film to 260–288°C (500–550°F).

What does the FEP film do?

If there is sufficient heat intensity, the FEP film first wrinkles, buckles upward (against gravity, thermoexpansion, and relieving of stresses) and then tends to straighten out and finally free downward and continues to sag.

The FEP film will sag considerably and become crystal clear at the point when it should be formed, which is easily seen in 5-mil and above.

Minor wrinkles may occur at the first part of the heating cycle, but should even themselves out during sag.

One test of sufficient heat availability is that if heat is left on the FEP film, it will continue to sag indefinitely until it breaks from thinning out or touches something beneath it.

If it sags to a point and continued heating doesn't cause it to sag further, heat intensity is marginal.

Deep Draws

In deep draws, take advantage of the sag of the film. For instance, if you are forming a dome or cylinder, either form into a female mold or up over a male mold. Forming down over a male mold is more difficult (but not impossible) because you must turn the sag of the film inside-out.

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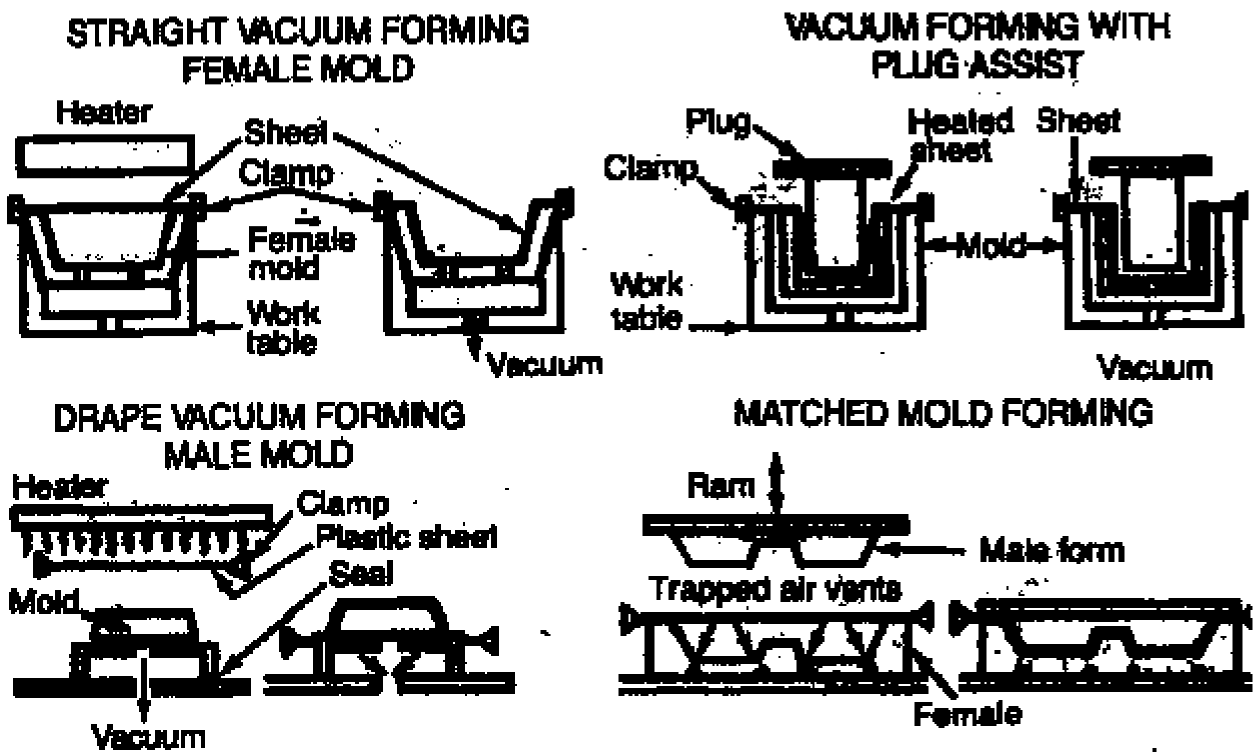
Most Commonly Used Forming Techniques



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Caution: Do not use in medical applications involving permanent implantation in the human body. For other medical applications, see "DuPont Medical Caution Statement," H-50102.

TI 0010678

DuPont Films

[illegible] 240879 Printed in U.S.A.
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Reorder No.: H-[illegible]-1

DuPont Films

High Performance Films

Teflon® PFA

fluorocarbon film

Description

Teflon® PFA film is a transparent, thermoplastic film that can be heat sealed, thermoformed, vacuum formed, heat bonded, welded, metallized, laminated (combined with dozens of other materials), and used as an excellent hot-melt adhesive. This wide variety of fabrication possibilities combines with the following important properties to offer a unique balance of capabilities not available in any other plastic film.

Chemical Compatibility

Teflon® PFA film is chemically inert and solvent resistant to virtually all chemicals, except molten alkali metals, gaseous fluorine, and certain complex halogenated compounds, such as chlorine trifluoride at elevated temperatures and pressures.

- Teflon® is the most inert of all plastics.
- Low permeability to liquids, gases, moisture, and organic vapors

Electrical Reliability

- Superior reliability and retention of properties over large areas of film
- High dielectric strength, over 260 kV/mm for 0.025-mm film (6500 V/mil for 1-mil film)
- No electric tracking, nonwettable, and noncharring
- Very low power factor and dielectric constant, only slight change over wide ranges of temperature and frequency

Wide Thermal Range

- Continuous service temperature: –240 to 260°C (–400 to 500°F)
- Melting range: 300 to 310°C (572 to 590°F)
- Heat sealable

Mechanical Toughness

- Superior antistick and low frictional properties
- High resistance to impact and tearing
- Useful physical properties at cryogenic temperatures

Long Time Weatherability*

- Inert to outdoor exposure
- High transmittance of ultraviolet and all but far infrared

Reliability

- PFA film contains no plasticizers or other foreign materials.
- Conventional equipment and techniques can be used for processing; basic composition and properties will not be influenced.
- Rigid quality control by DuPont ensures uniform gauge, void-free film.

*[illegible]

TI 0010678

Table 2
Summary of Properties of Teflon® PFA Film

	Property	Test Method	Typical Value*	
			SI Units	English Units
Mechanical	Tensile Strength at Break	ASTM D-882	21 N/mm²	3000 psi
	Elongation at Break	ASTM D-882	300%	
	Yield Point	ASTM D-882	12 MPa	1700 psi
	Elastic Modulus	ASTM D-882	480 MPa	70,000 psi
	Impact Resistance	DuPont pneumatic impact tester	6.2×10^4	14 in-lb/mil
	Folding Endurance (MIT)	ASTM D-2176	100,000 cycles	
	Tear Strength—Initial (Graves)	ASTM D-1004	4.90 N	500 g
	Tear Strength—Propagating (Elmendorf)	ASTM D-1922	0.74 N	75 g
Thermal	Melt Point	ASTM D-3418 (DTA)	302–310°C	576–590°F
	Thermal Conductivity	Cenco-Fitch	0.195 W/(m·K)	1.35 Btu·in/(h·ft²·°F)
	Specific Heat	—	1172 J/(kg·K)	0.28 Btu/(lb·°F)
	Dimensional Stability	30 min at 150°C (302°F)	MD = 1% shrinkage TD = 1% shrinkage	
	Oxygen Index	ASTM D-2863	95%	
Electrical	Dielectric Strength, short-time, in air at 23°C (73°F), 6.35 mm (1/4 in) diameter electrode, 0.79 mm (1/32 in) radius, 60 Hz, 500 V/s rate of rise; 0.025 mm (1 mil) film	ASTM D-149 Method A	260 kV/mm	6500 V/mil
	Dielectric Constant, 25°C (77°F), 100 Hz to 1 MHz	ASTM D-150	2.0	
	Dissipation Factor, 25°C (77°F), 100 Hz to 1 MHz	ASTM D-150	0.0002–0.0007	
	Volume Resistivity, −40 to 250°C (−40 to 482°F)	ASTM D-257	$>1 \times 10^{17}$ ohm-cm	
Chemical	Moisture Absorption	—	<0.03%	
	Permeability, Gas:	ASTM D-1434	cm³/(m²·24 h·atm)**	
	Carbon Dioxide		14×10^3	
	Nitrogen		2.0×10^3	
	Oxygen		6.7×10^3	
	Permeability, Vapor:	ASTM E-96	g/(m²·d)	g/(100 in²·24 h)
	Water		2	0.13
	Teflon® is chemically inert and solvent resistant to virtually all chemicals, except molten alkali metals, gaseous fluorine, and certain complex halogenated compounds, such as chlorine trifluoride at elevated temperatures and pressures.			
Misc.	Density	ASTM D-1505	2150 kg/m³	134 lb/ft³
	Coefficient of Friction Kinetic (Film-to-Steel)	ASTM D-1894	0.1–0.3	
	Refractive Index	ASTM D-542	1.350	
	Solar Transmission	ASTM E-424	96%	

*For 0.050-mm (2-mil) film at 25°C (77°F), unless otherwise specified
**To convert to cm³/(100 in²·24 h·atm), multiply by 0.0645

TI 0010878

DuPont Films

High Performance Films

Teflon® FEP

fluorocarbon film

Teflon® as Film

Teflon® FEP fluorocarbon film offers the outstanding properties of Teflon® in a convenient, easy-to-use form. It can be heat-sealed, thermoformed, welded, metallized, and laminated to many other materials or serve as a hot melt adhesive.

This combination of unique properties and easy-to-use form offers design and fabrication opportunities for a wide variety of end uses.

Teflon® Is Unique Among Plastics

- Most chemically inert of all plastics
- Withstands both high- and low-temperature extremes
- Superior antistick/low friction properties
- Outstanding weather resistance
- Excellent optical characteristics
- Superior electrical properties
- Free of plasticizers or additives
- Excellent processibility with conventional thermoplastic methods

Teflon® FEP Film Is Offered

- In thicknesses from 12.5–4750 µm (0.5–190 mil)
- In custom slit widths up to 1.2–1.6 m (46–63 in) depending on thickness
- In various size rolls wound on 7.6 cm or 15.2 cm (3 in or 6 in) cores

Teflon® film affords the engineer/designer a wide range of opportunities to take advantage of these properties with minimal and convenient fabrication techniques.

The ability of Teflon® FEP film to be easily cut, thermoformed, heat sealed, and welded permits ready application as diaphragms, gaskets, protective linings, or thermoformed pouches or containers, wherever high temperature and/or chemical resistance is required.

The excellent optical properties and resistance to weathering and ultraviolet degradation have led to the use of Teflon® FEP film in such varied applications as environmental growth chambers, solar energy collectors, and radome windows.

Its superior dielectic properties have been used in flexible, flat cable insulation, printed circuits, and electronic components for computers and aircraft.

The nonstick properties of Teflon® FEP have found use in conveyor belts, process roll covers, and as mold release films.

Special grades of Teflon® FEP film offer specific properties such as cementability or high stress crack resistance under extreme environmental conditions.

A complete listing of FEP film grades and their availability in different thicknesses is given in Table 1.

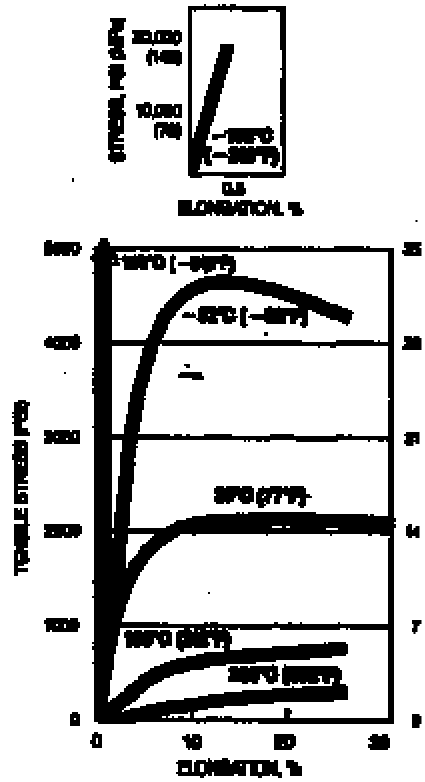
In addition to FEP, DuPont offers films of Teflon® PFA, for use at temperatures up to 260°C (500°F), and Tefzel® fluoropolymer for increased toughness and resistance to tear propagation.

Teflon® FEP film offers unique properties in a convenient form requiring minimal fabrication. Consider it for your next project.

For additional information, call (800) 237-4357.

TI 0010880

Figure 3. Tensile Stress vs. Elongation of Teflon® FEP Film



Residual Shrinkage

Stresses set up in the film during manufacturing or converting can cause shrinkage in unrestrained film when exposed to high temperatures.

Exposure of film to an elevated temperature, and the attendant shrinkage, will relieve this stress, and no further shrinkage will occur at lower temperatures.

Thermal Expansion

After residual shrinkage has been removed, Teflon® FEP film will expand and contract according to its normal coefficient of thermal expansion (see Figures 4 and 5). Note that this coefficient increases with temperature.

Figure 4. Shrinkage of Teflon® FEP 100A Film vs. Temperature

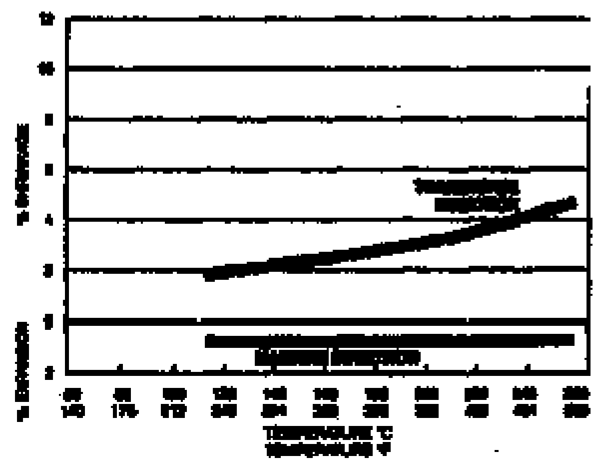


Table 2
Typical Mechanical Properties of Teflon® FEP Film*

Property	ASTM Method	SI Units	English Units
Tensile strength (at break)	D-882-81	21 MPa	3000 psi
Elongation at break	D-882-81	300%	300%
Elastic modulus	D-882-81	480 MPa	70 000 psi
Yield point	D-882-81	12 MPa	1700 psi
Stress to produce 5% strain	D-882-81	12 MPa	1700 psi
Folding endurance (MIT)	D-2176-69	10,000 cycles	10,000 cycles
Initial tear strength (Graves)	D-1004-66	5.3 N	1.2 lbf
Propagating tear strength (Elmendorf)	D-1922-67	2.5 N	250 g
Bursting strength**	D-774-67 (Mullen)	76 kPa	11 psi
Density	D-1505-68	2150 kg/m³	134 lb/ft³
Coefficient of friction kinetic (film to steel)	D-1894-61	0.3	0.3

*200 gauge unless otherwise noted
**100 gauge film

Table 3
Typical Thermal Properties of Teflon® FEP Film*

Property	ASTM Method	SI Units	English Units
Melt point	D-3418 (DTA)	260–280°C	500–536°F
Maximum continuous service temperature		205°C	400°F
Zero strength*** temperature	***	255°C	490°F
Specific heat		1172 J/kg·K	0.28 Btu/lb·°F
Coefficient of thermal conductivity		0.195 W/m·K	1.35 $\frac{Btu \cdot in}{h \cdot ft^2 \cdot °F}$
Coefficient of linear thermal expansion	D-696-79	$9.4 \times 10^{-5} \frac{mm}{mm \cdot °C}$	$5.4 \times 10^{-5} \frac{in}{in \cdot °F}$
Flammability classification	ANSI/UL-94	VTM-0	VTM-0
Oxygen index	D-2863-77	95%	95%
Dimensional stability MD	30 min at 150°C (302°F)	0.7% expansion	0.7% expansion
Dimensional stability TD		2.2% shrinkage	2.2% shrinkage

*200 gauge unless otherwise noted
**100 gauge film
***Temperature at which film supports a load of 0.14 MPa (20 psi) for 5 sec

TI 0010882

Dissipation Factor

The consistently low value of the dissipation factor over a broad range of temperature and frequency makes Teflon® fluorocarbon film ideal in applications where electrical losses must be minimized (see Figure 9).

At a constant temperature, this dissipation factor of Teflon® films varies as noted in Figure 18. Absolute values remain low in comparison with many other dielectric materials.

Figure 9. Dissipation Factor vs. Temperature of Teflon® FEP Film

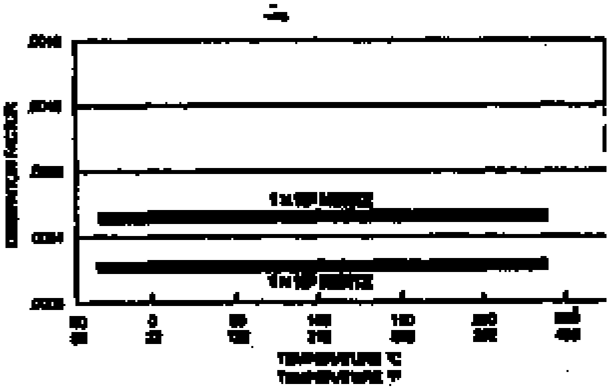
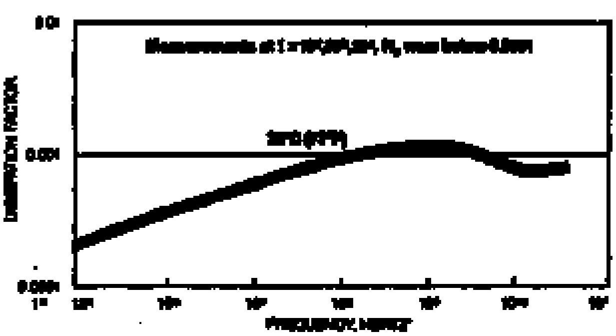


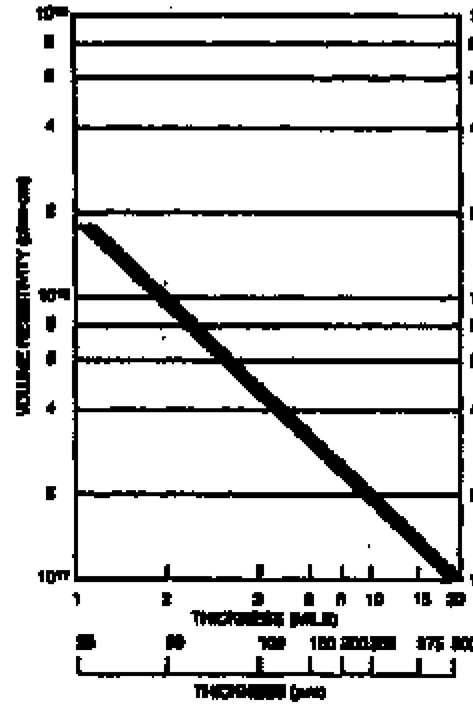
Figure 10. Dissipation Factor vs. Frequency of Teflon® FEP Film



Volume Resistivity

Volume resistivity of Teflon® fluorocarbon film decreases slightly as the film thickness increases (see Figure 11).

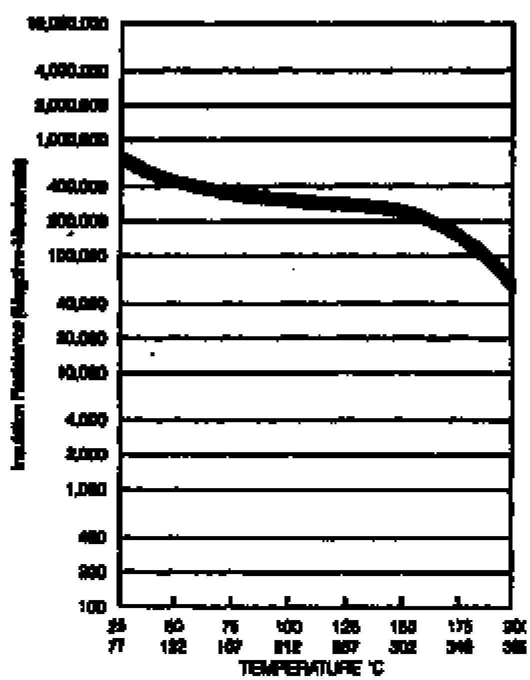
Figure 11. Volume Resistivity vs. Thickness (at 175°C [347°F])



Insulation Resistance

Even at 200°C (392°F), the insulation resistance of Teflon® film (65,000 megohm-microfarad) is higher than most conventional dielectric materials at room temperature (see Figure 12).

Figure 12. Insulation Resistance vs. Temperature (125 µm/0.5 mil TEFLON FEP film)



TI 0010884

DD/NHTSA No. 3
00134

Physical Properties

Absorption

Almost all plastics absorb small quantities of certain materials with which they come in contact. Submicroscopic voids between polymer molecules provide space for the material absorbed without chemical reaction. This phenomenon is usually marked by a slight weight increase and sometimes by discoloration.

Teflon® FEP fluorocarbon films have unusually low absorption compared with other thermoplastics. They absorb practically no common acids or bases at temperatures as high as 200°C (392°F) and exposures of up to one year. Even the absorption of solvents is extremely small. Weight increases are generally less than 1% when exposed at elevated temperatures for long periods. In general, aqueous solutions are absorbed very little by Teflon® FEP film. *Moisture absorption is typically less than 0.01% at ambient temperature and pressure.*

Permeability

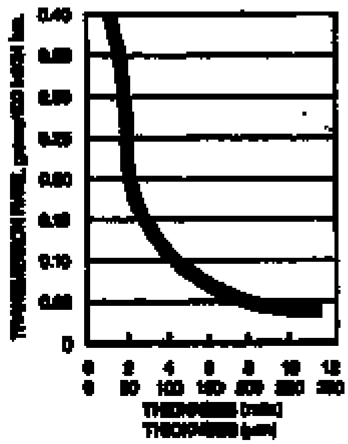
Many gases and vapors permeate Teflon® films at a much lower rate than for other thermoplastics (see Figure 13). In general, permeation increases with temperature, pressure, and surface contact area and decreases with increased film thickness. Table 6 lists rates at which various gases are transmitted through Teflon® FEP fluorocarbon film, while Table 7 lists rates of vapor permeability for some representative substances. Note that the pressure for each material is its vapor pressure at the indicated temperature.

Table 6
Typical Gas Permeability Rates of Teflon® FEP Fluorocarbon Film, 25 µm (1 mil) Thickness
(Test Method: ASTM D-1434 at 25°C [77°F])

Gas	Permeability Rate* cm³/(m²·24 h·atm)
Carbon Dioxide	25.9 × 10³
Hydrogen	34.1 × 10³
Nitrogen	5.0 × 10³
Oxygen	11.6 × 10³

*To convert to cm³/(100 in²·24 h·atm), multiply by 0.0645.

Figure 12. Water Vapor Transmission Rate of Teflon® FEP Film at 40°C (104°F) per ASTM E-96 (Modified)



Notes: Values are averages only and not for specification purposes. To convert the permeation values for 100 in² to those for 1 m², multiply by 15.5.

Table 7
Typical Vapors Transmission Rates of Teflon® FEP Fluorocarbon Film, 25 µm (1 mil) Thickness
(Test Method: Modified ASTM E-96)

Vapor	Temperature °C	Temperature °F	Vapor Transmission Rate SI Units (g/m²·d)	Vapor Transmission Rate English Units (g/100 in²·d)
Acetic Acid	35	95	6.3	0.41
Acetone	35	95	14.7	0.95
Benzene	35	95	9.9	0.64
Carbon Tetrachloride	35	95	4.8	0.31
Ethyl Acetate	35	95	11.7	0.76
Ethyl Alcohol	35	95	10.7	0.69
Freon® F-12	23	73	372.0	24.0
Hexane	35	95	8.7	0.56
Hydrochloric Acid	25	77	<0.2	<0.01
Nitric Acid (Red Fuming)	25	77	160.0	10.6
Sodium Hydroxide, 50%	25	77	<0.2	<0.01
Sulfuric Acid, 98%	25	77	2×10^{-4}	1×10^{-5}
Water	39.5	103	7.0	0.40

TI D010888

USDA Acceptance

Clear Teflon® FEP fluorocarbon film is acceptable as a component of materials for use in slaughtering, processing, transporting, or storage areas in direct contact with meat or poultry food product prepared under federal inspection.

Mildew (Fungus) Resistance

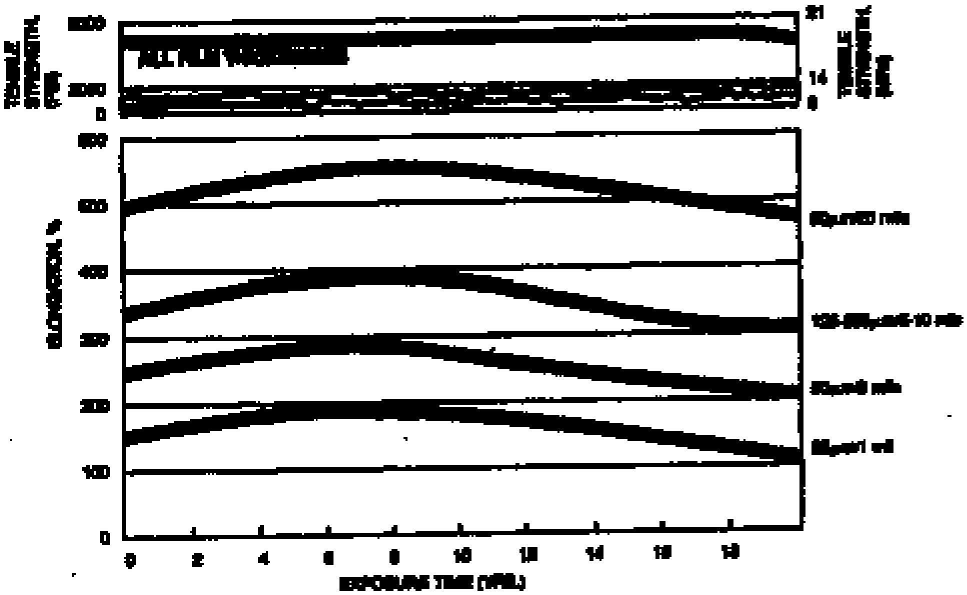
Teflon® FEP has been shown to be completely resistant to mildew growth by testing both in humidity chamber exposure inoculated with a mixed spore suspension and a soil burial test for three months.

Weatherability

In contrast to most other clear thermoplastic films, Teflon® film remains essentially unchanged after 20 years of outdoor exposure (see Figure 17). There is no evidence of discoloration, ultraviolet degradation, or strength loss. This outstanding performance is due to the structure of the polymer molecule and is not the result of chemical additives.

Types C and C-20 Teflon® film are not recommended for outdoor applications because ultraviolet radiation may adversely affect the treated surface.

Figure 17. The Effects of Florida Weathering on Teflon® FEP Film



Safety and Handling

Unheated Teflon® fluorocarbon is essentially inert. Animal tests indicate that Teflon® is nonirritating and nonsensitizing to the skin. Dust generated by cutting, grinding, or machining the unheated film should be avoided, as with any other nuisance dusts that are regulated by OSHA at 15 mg/m³ in air (29 CFR 1910:1000).

Care should be taken to avoid contamination of smoking tobacco or cigarettes with fluorocarbon resins.

Teflon® film can be processed and used at elevated temperatures without hazard if proper ventilation is used. Ventilation should be provided at processing temperatures of 275°C (525°F) or above.

Additional details on safety in handling and use are available in bulletin H-48633, "Guide to the Safe Handling of Fluoropolymer Resins," available from DuPont.

Other related literature available from DuPont:

Bulletin	Title
E-80413-1	Teflon® PFA Film—Specification Bulletin (T62-3)
H-55003-1	Teflon® FEP Film—Specification Bulletin (T62-1)
E-55008-1	Teflon® FEP Film—Properties Bulletin

TI 0010888

DD/NHTSA No. 3
00136

DuPont Films

High Performance Films

Teflon® FEP

fluorocarbon film

Teflon® as Film

Teflon® FEP fluorocarbon film offers the outstanding properties of Teflon® in a convenient, easy-to-use form. It can be heat-sealed, thermoformed, welded, metallized, and laminated to many other materials or serve as a hot melt adhesive.

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Teflon® Is Unique Among Plastics

- Most chemically inert of all plastics
- Withstands both high- and low-temperature extremes
- Superior antistick/low friction properties
- Outstanding weather resistance
- Excellent optical characteristics
- Superior electrical properties
- Free of plasticizers or additives
- Excellent processibility with conventional thermoplastic methods

Teflon® FEP Film Is Offered

- In thicknesses from 12.5–4750 μm (0.5–190 mil)
- In custom slit widths up to 1.2–1.6 m (46–63 in) depending on thickness
- In various size rolls wound on 7.6 cm or 15.2 cm (3 in or 6 in) cores

Teflon® film affords the engineer/designer a wide range of opportunities to take advantage of these properties with minimal and convenient fabrication techniques.

The ability of Teflon® FEP film to be easily cut, thermoformed, heat sealed, and welded permits ready application as diaphragms, gaskets, protective linings, or thermoformed pouches or containers, wherever high temperature and/or chemical resistance is required.

The excellent optical properties and resistance to weathering and ultraviolet degradation have led to the use of Teflon® FEP film in such varied applications as environmental growth chambers, solar energy collectors, and radome windows.

Its superior dielectric properties have been used in flexible, flat cable insulation, printed circuits, and electronic components for computers and aircraft.

The nonstick properties of Teflon® FEP have found use in conveyor belts, process roll covers, and as mold release films.

Special grades of Teflon® FEP film offer specific properties such as cementability or high stress crack resistance under extreme environmental conditions.

A complete listing of FEP film grades and their availability in different thicknesses is given in Table 1.

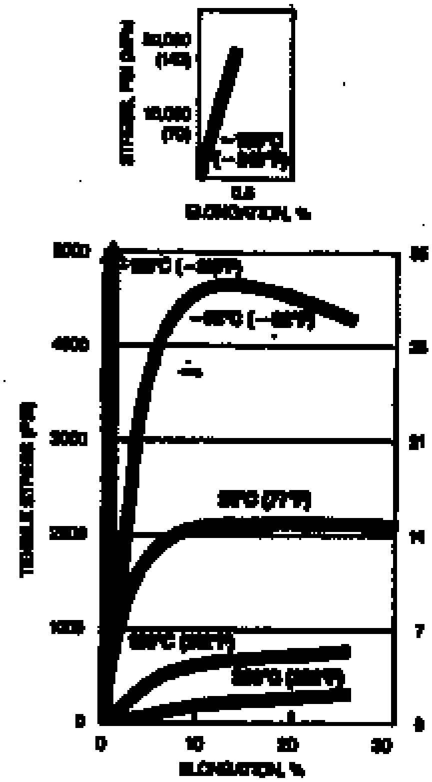
In addition to FEP, DuPont offers films of Teflon® PFA, for use at temperatures up to 260°C (500°F), and Tefzel® fluoropolymer for increased toughness and resistance to tear propagation.

Teflon® FEP film offers unique properties in a convenient form requiring minimal fabrication. Consider it for your next project.

For additional information, call (800) 237-4357.

TI 0010890

Figure 3. Tensile Stress vs. Elongation of Teflon® FEP Film



Residual Shrinkage

Stresses set up in the film during manufacturing or converting can cause shrinkage in unrestrained film when exposed to high temperatures.

Exposure of film to an elevated temperature, and the attendant shrinkage, will relieve this stress, and no further shrinkage will occur at lower temperatures.

Thermal Expansion

After residual shrinkage has been removed, Teflon® FEP film will expand and contract according to its normal coefficient of thermal expansion (see Figures 4 and 5). Note that this coefficient increases with temperature.

Figure 4. Shrinkage of Teflon® FEP 100A Film vs. Temperature

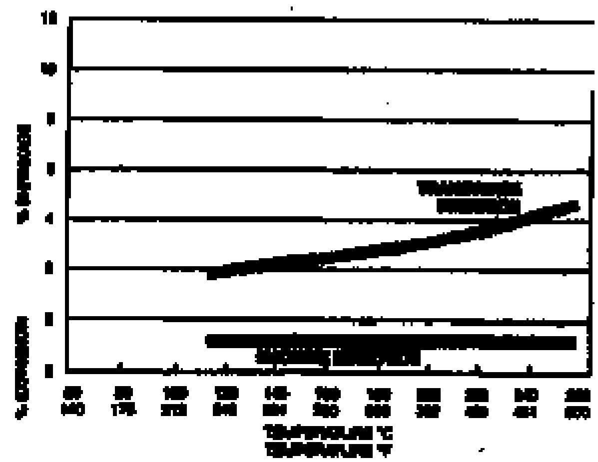


Table 2
Typical Mechanical Properties of Teflon® FEP Film*

Property	ASTM Method	SI Units	English Units
Tensile strength (at break)	D-882-81	21 MPa	3000 psi
Elongation at break	D-882-81	300%	300%
Elastic modulus	D-882-81	480 MPa	70 000 psi
Yield point	D-882-81	12 MPa	1700 psi
Stress to produce 5% strain	D-882-81	12 MPa	1700 psi
Folding endurance (MIT)	D-2176-69	10,000 cycles	10,000 cycles
Initial tear strength (Graves)	D-1004-66	5.3 N	1.2 lbf
Propagating tear strength (Elmendorf)	D-1922-67	2.5 N	250 g
Bursting strength**	D-774-67 (Mullen)	76 kPa	11 psi
Density	D-1505-68	2150 kg/m³	134 lb/ft³
Coefficient of friction kinetic (film to steel)	D-1894-81	0.3	0.3

*200 gauge unless otherwise noted
**100 gauge film

Table 3
Typical Thermal Properties of Teflon® FEP Film*

Property	ASTM Method	SI Units	English Units
Melt point	D-3418 (DTA)	260–280°C	500–536°F
Maximum continuous service temperature		205°C	400°F
Zero strength** temperature	***	255°C	490°F
Specific heat		1172 J/kg·K	0.28 Btu/lb·°F
Coefficient of thermal conductivity		0.195 W/m·K	1.35 $\frac{Btu\cdot in}{h\cdot ft^2\cdot °F}$
Coefficient of linear thermal expansion	D-696-79	$9.4 \times 10^{-5} \frac{mm}{mm\cdot °C}$	$5.4 \times 10^{-5} \frac{in}{in\cdot °F}$
Flammability classification	ANSI/UL-94	VTM-0	VTM-0
Oxygen index	D-2863-77	95%	95%
Dimensional stability MD	30 min at 150°C (302°F)	0.7% expansion	0.7% expansion
Dimensional stability TD		2.2% shrinkage	2.2% shrinkage

*200 gauge unless otherwise noted
**100 gauge film
***Temperature at which film supports a load of 0.14 MPa (20 psi) for 5 sec

TI 0010692

DD/NHTSA No. 3
00138

Dissipation Factor

The consistently low value of the dissipation factor over a broad range of temperature and frequency makes Teflon® fluorocarbon film ideal in applications where electrical losses must be minimized (see Figure 9).

At a constant temperature, the dissipation factor of Teflon® films varies as noted in Figure 10. Absolute values remain low in comparison with many other dielectric materials.

Figure 9. Dissipation Factor vs. Temperature of Teflon® FEP Film

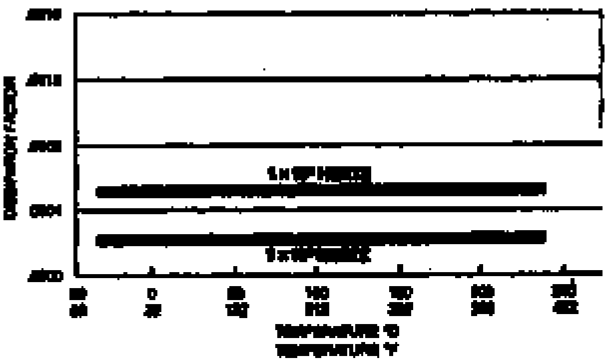
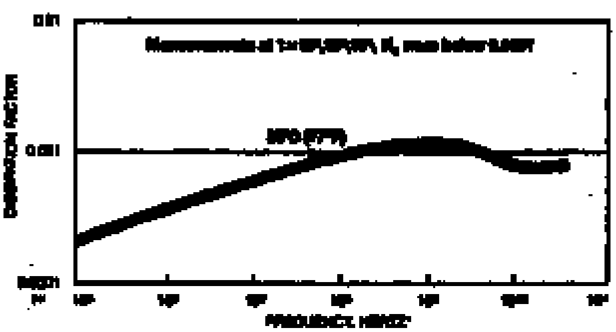


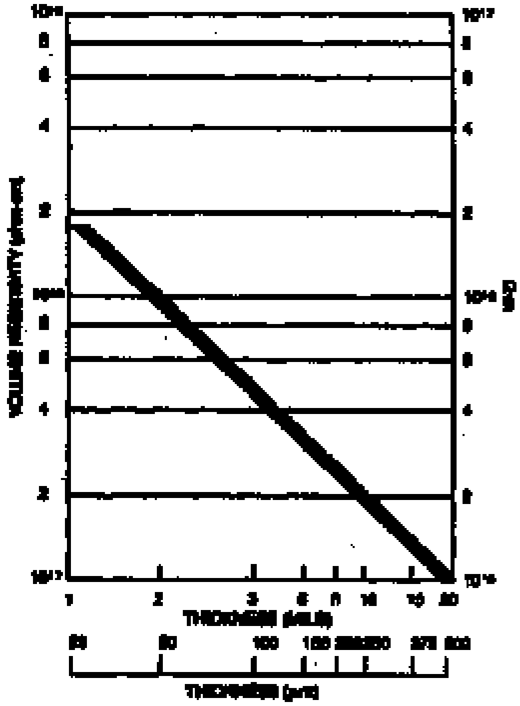
Figure 10. Dissipation Factor vs. Frequency of Teflon® FEP Film



Volume Resistivity

Volume resistivity of Teflon® fluorocarbon film decreases slightly as the film thickness increases (see Figure 11).

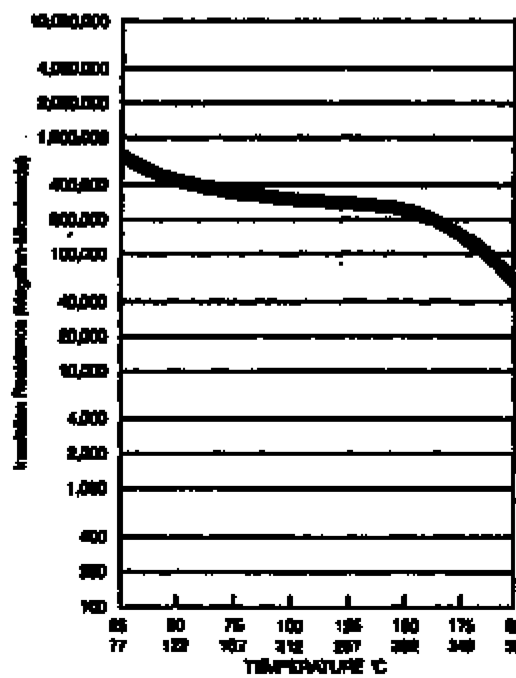
Figure 11. Volume Resistivity vs. Thickness (at 175°C (347°F))



Insulation Resistance

Even at 200°C (392°F), the insulation resistance of Teflon® film (65,000 megohm-microfarad) is higher than most conventional dielectric materials at room temperature (see Figure 12).

Figure 12. Insulation Resistance vs. Temperature (125 µm/0.5 mil TEFLON FEP film)



Physical Properties

Absorption

Almost all plastics absorb small quantities of certain materials with which they come in contact. Sub① microscopic voids between polymer molecules provide space for the material absorbed without chemical reaction. This phenomenon is usually marked by a slight weight increase and sometimes by discoloration.

Teflon® FEP fluorocarbon films have unusually low absorption compared with other thermoplastics. They absorb practically no common acids or bases at temperatures as high as 200°C (392°F) and exposures of up to one year. Even the absorption of solvents is extremely small. Weight increases are generally less than 1% when exposed at elevated temperatures for long periods. In general, aqueous solutions are absorbed very little by Teflon® FEP film. *Moisture absorption is typically less than 0.01% at ambient temperature and pressure.*

Permeability

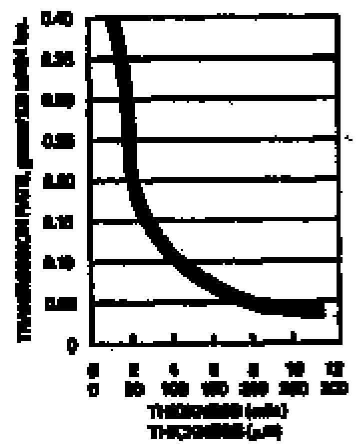
Many gases and vapors permeate Teflon® films at a much lower rate than for other thermoplastics (see Figure 13). In general, permeation increases with temperature, pressure, and surface contact area and decreases with increased film thickness. Table 6 lists rates at which various gases are transmitted through Teflon® FEP fluorocarbon film, while Table 7 lists rates of vapor permeability for some representative substances. Note that the pressure for each material is its vapor pressure at the indicated temperature.

Table 6
Typical Gas Permeability Rates of Teflon® FEP Fluorocarbon Film, 25 µm (1 mil) Thickness
(Test Method: ASTM D-1434 at 25°C [77°F])

Gas	Permeability Rate* $cm^3/(m^2 \cdot 24\ h \cdot atm)$
Carbon Dioxide	25.9×10^3
Hydrogen	34.1×10^3
Nitrogen	5.0×10^3
Oxygen	11.6×10^3

*To convert to $cm^3/(100\ in^2 \cdot 24\ h \cdot atm)$, multiply by 0.0645.

Figure 13. Water Vapor Transmission Rate of Teflon® FEP Film at 40°C (104°F) per ASTM E-96 (Modified)



Notes: Values are averages only and not for specification purposes. To convert the permeation values for 100 in² to those for 1 m², multiply by 15.5.

Table 7
Typical Vapors Transmission Rates of Teflon® FEP Fluorocarbon Film, 25 µm (1 mil) Thickness
(Test Method: Modified ASTM E-96)

Vapor	Temperature °C	Temperature °F	Vapor Transmission Rate SI Units $(g/m^2 \cdot d)$	Vapor Transmission Rate English Units $(g/100\ in^2 \cdot d)$
Acetic Acid	35	95	6.3	0.41
Acetone	35	95	14.7	0.95
Benzene	35	95	9.9	0.64
Carbon Tetrachloride	35	95	4.8	0.31
Ethyl Acetate	35	95	11.7	0.76
Ethyl Alcohol	35	95	10.7	0.69
Freon® F-12	23	73	372.0	24.0
Hexane	35	95	8.7	0.56
Hydrochloric Acid	25	77	<0.2	<0.01
Nitric Acid (Red Fuming)	25	77	160.0	10.5
Sodium Hydroxide, 50%	25	77	<0.2	<0.01
Sulfuric Acid, 98%	25	77	2×10^{-4}	1×10^{-5}
Water	39.5	103	7.0	0.40

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USDA Acceptance

Clear Teflon® FEP fluorocarbon film is acceptable as a component of materials for use in slaughtering, processing, transporting, or storage areas in direct contact with meat or poultry food product prepared under federal inspection.

Mildew (Fungus) Resistance

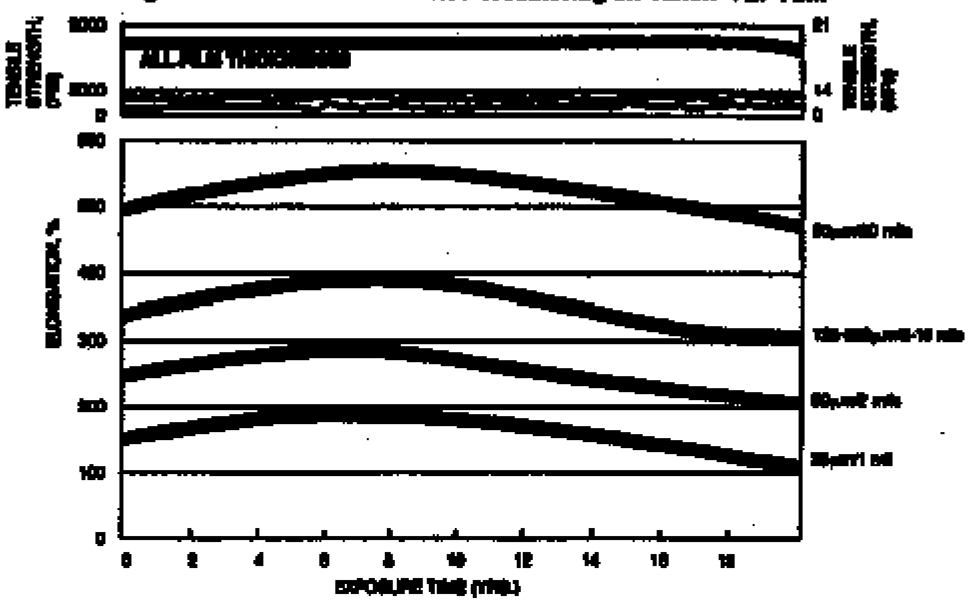
Teflon® FEP has been shown to be completely resistant to mildew growth by testing both in humidity chamber exposure inoculated with a mixed spore suspension and a soil burial test for three months.

Weatherability

In contrast to most other clear thermoplastic films, Teflon® film remains essentially unchanged after 20 years of outdoor exposure (see Figure 17). There is no evidence of discoloration, ultraviolet degradation, or strength loss. This outstanding performance is due to the structure of the polymer molecule and is not the result of chemical additives.

Types C and C-20 Teflon® film are not recommended for outdoor applications because ultraviolet radiation may adversely affect the treated surface.

Figure 17. The Effects of Florida Weathering on Teflon® FEP Film



Safety and Handling

Unheated Teflon® fluorocarbon is essentially inert. Animal tests indicate that Teflon® is nonirritating and nonsensitizing to the skin. Dust generated by cutting, grinding, or machining the unheated film should be avoided, as with any other nuisance dusts that are regulated by OSHA at 15 mg/m³ in air (29 CFR 1910:1000).

Care should be taken to avoid contamination of smoking tobacco or cigarettes with fluorocarbon resins.

Teflon® film can be processed and used at elevated temperatures without hazard if proper ventilation is used. Ventilation should be provided at processing temperatures of 275°C (525°F) or above.

Additional details on safety in handling and use are available in bulletin H-48633, "Guide to the Safe Handling of Fluoropolymer Resins," available from DuPont.

Other related literature available from DuPont:

Bulletin	Title
H-80413-1	Teflon® PFA Film—Specification Bulletin (T62-3)
H-55003-1	Teflon® FEP Film—Specification Bulletin (T62-1)
H-55008-1	Teflon® FEP Film—Properties Bulletin

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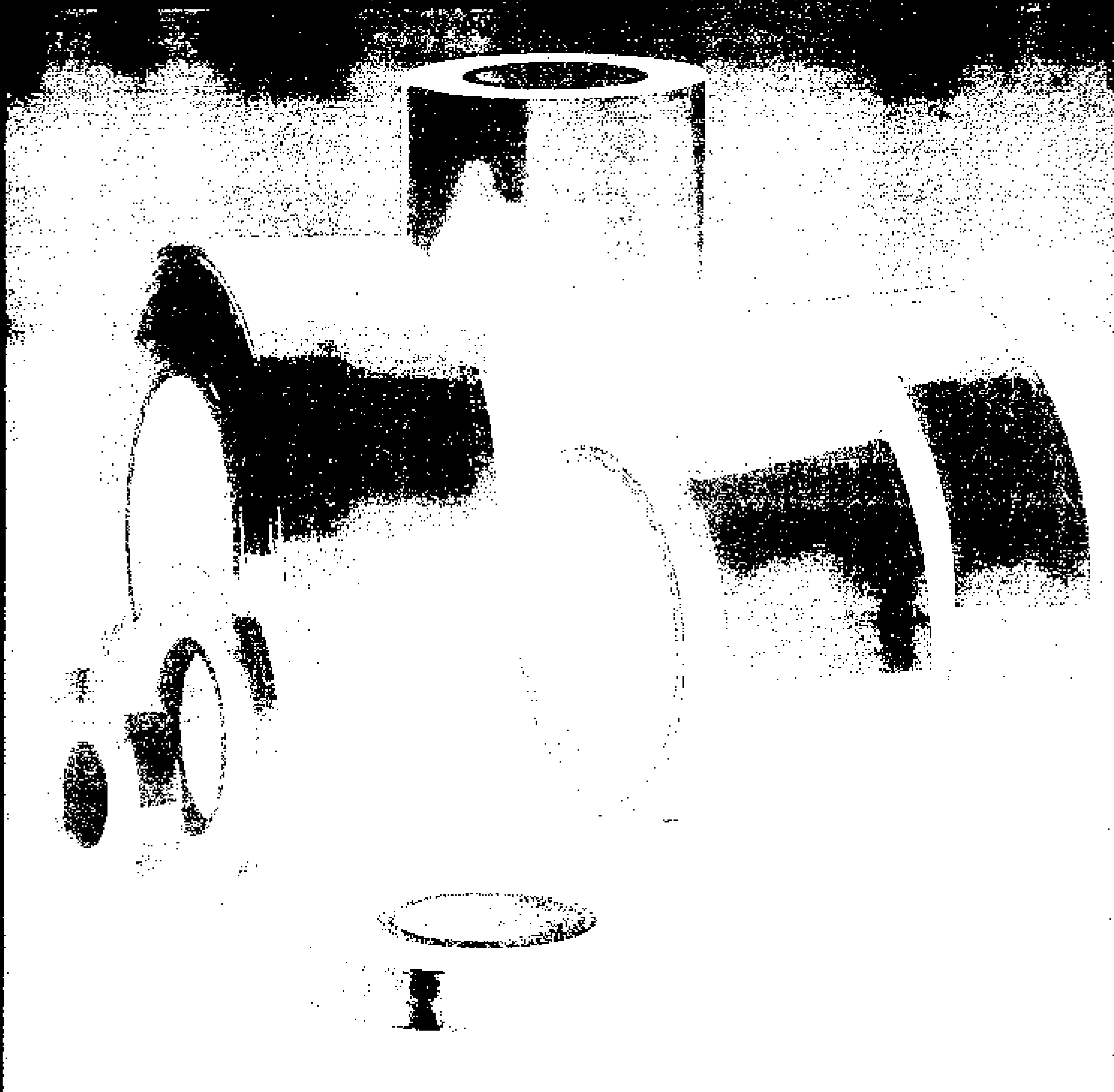
SUMMARY OF PROPERTIES



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Kapton®
POLYIMIDE FILM

GENERAL INFORMATION

KAPTON* polyimide film possesses a unique combination of properties previously unavailable among polymeric film materials. 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 has proved to be especially useful in applications involving high operating temperatures.

KAPTON is synthesized by a polycondensation reaction between an aromatic dianhydride and an aromatic diamine. There is no known organic solvent for the film and it is infusible and flame resistant. The outstanding properties of KAPTON permit it to be used at both high and low temperature extremes where other organic materials would not be functional.

Adhesives are available for bonding KAPTON to itself, to metals, to papers of various types and to other films.

Applications for KAPTON polyimide film include 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, transformers and capacitor insulation, magnetic and pressure sensitive tapes and tubing. Many of these applications are based on the excellent electrical properties of KAPTON, such as dielectric strength and dissipation factor, which remain nearly constant over a wide range of temperature and frequency. Other applications make use of the film's radiation resistance or chemical resistance at elevated temperatures. It is this combination of useful properties at extremes in temperatures that makes KAPTON a unique industrial material.

Du Pont makes three types of KAPTON:

- KAPTON Type H, an all-purpose, all-polyimide film that has been used successfully in applications at temperatures as low as 4K (−269°C) and as high as 673K (400°C). Type H film can be laminated, metallized, punched, formed or adhesive coated. It is available as 0.3, 0.5, 1, 2, 3 and 5 mil film.
- KAPTON TYPE V, an all-purpose, all-polyimide film with all of the properties of Type H, plus superior dimensional stability. Type V is available in 2, 3 and 5 mils.
- KAPTON Type F, a Type H film coated on one or both sides with TEFLON* FEP fluorocarbon resin to impart heat sealability, to provide a moisture barrier and to enhance chemical resistance. It is available in a variety of constructions.

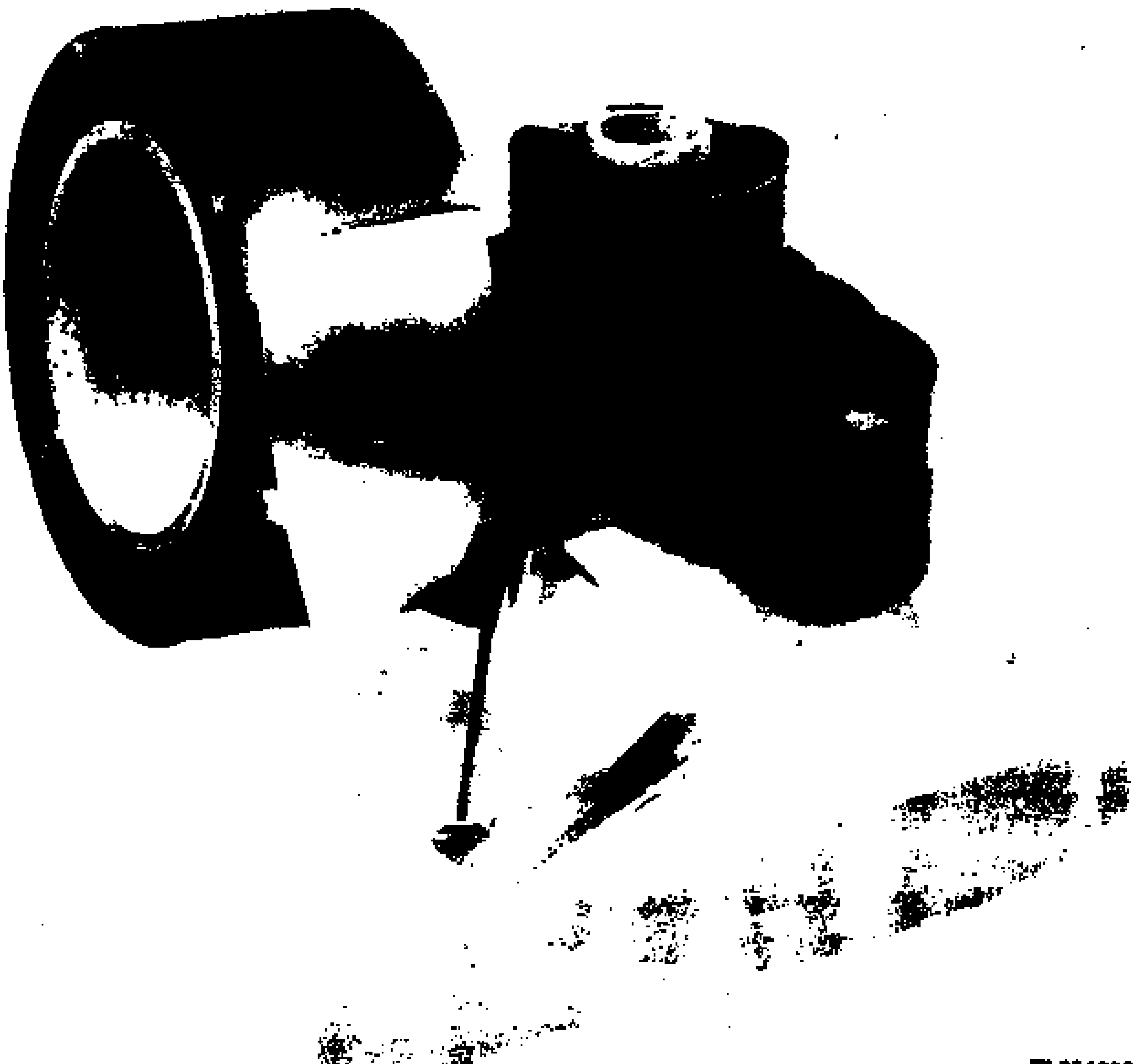
Note: This bulletin provides a summary of typical properties for all three KAPTON polyimide films Type H, Type V and Type F. Additional data should be obtained from your Du Pont Industrial Films Division representative for specification purposes.

*Reg. U.S. Pat. Off.

In the KAPTON® Type F order code of 3 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 TEFLON® FEP fluorocarbon resin in mils. The symbol 9 is used to represent 13 μm (½ mil) and 6 to represent 2.5 μm (¹/₁₀ mil). Example: 120F616 is a 120 gauge structure consisting of a 25 μm (1-mil) base film with a 2.5 μm (¹/₁₀ mil) coating of TEFLON on each side. Illustrated are 3 examples of the many types available.

ORDER CODE	NOMINAL THICKNESS		"TEFLON" FEP		"KAPTON" TYPE H		"TEFLON" FEP	
	μm	mils	μm	mils	μm	mils	μm	mils
120F616	30	1.2	2.5	0.1	25	1	2.5	0.1
150F019	38	1.5	0	0	25	1	13	½
250F029	64	2.5	0	0	51	2	13	½

ORDER CODE	STANDARD WIDTHS		AREA FACTOR	
	mm	inches	m²/Kg	FT²/LB.
120F616	3.18-914	1/8-36	21.3	104
150F019	3.18-914	1/8-36	15.8	77
250F029	3.18-914	1/8-36	11.1	49



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In U.S.A.
Du Pont Company
Electronics Department
High Performance Films Division
Wilmington, DE 19898
(800) 527-2601

In Canada
Du Pont Canada Inc.
P.O. Box 2200 Streetsville Postal Station
Mississauga, Ontario
L5M 2H3
(416) 821-3300

In Europe
Du Pont de Nemours International S.A.
Electronics Department
50-52 Route des Acacias
CH-1211 Geneva 24, Switzerland
(022) 37 81 11

In Japan
Du Pont-Toray Co., Ltd.
5-6, Nihonbashi-Honcho 1-chome
Chuo-ku, Tokyo 103 Japan
03 245 5061

In Brazil
Du Pont do Brasil S/A
Caixa Postal, 26 — Alphaville
06400 Barueri/Sao Paulo, Brazil

In South East Asia
Du Pont Asia Pacific (Ltd.)
1122 New World Office Building (East Wing)
Salisbury Road, Kowloon
Hong Kong, BCC
03 734 5377

Worldwide (Except Europe
Du Pont Company
International Customer Services
Concord Plaza-Reed Bldg.
Wilmington, DE 19898
(302) 772-5120

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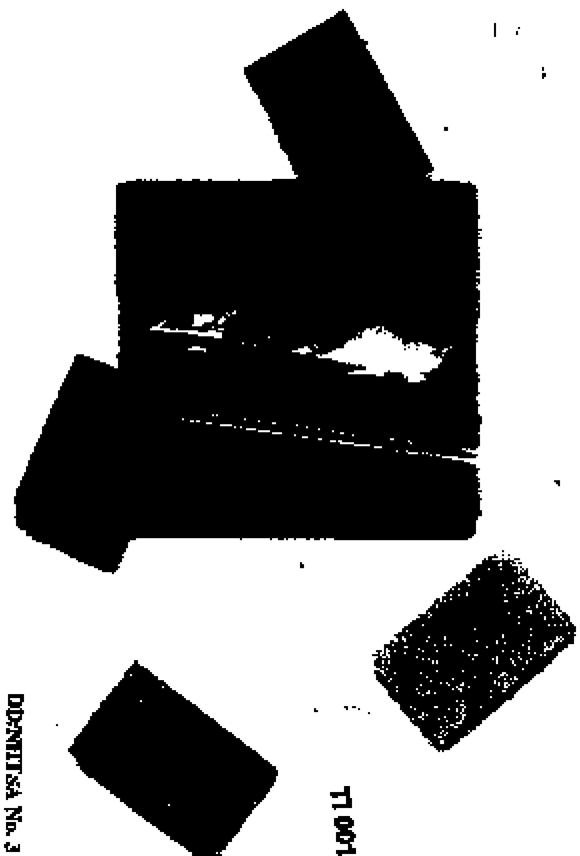
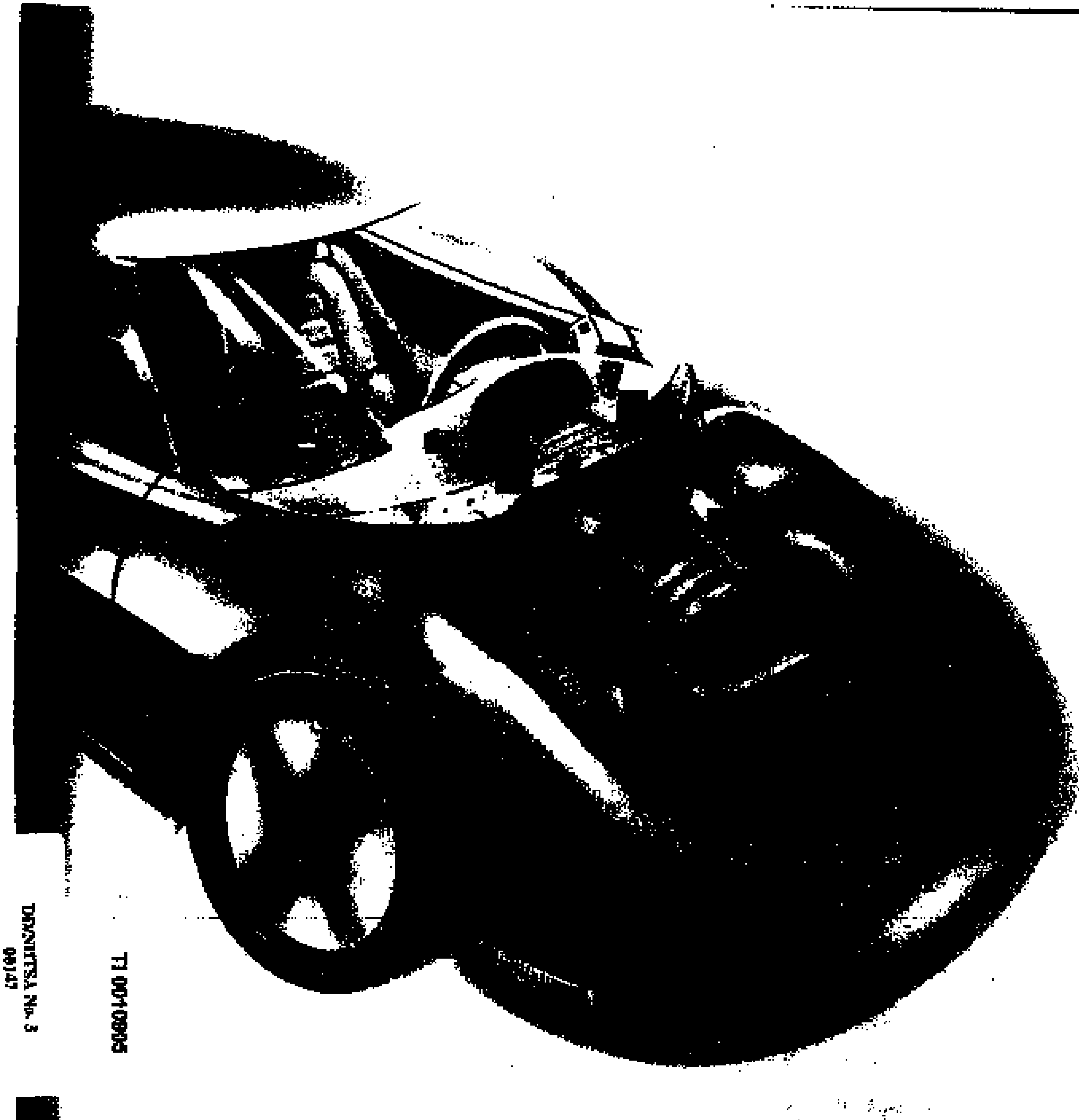
DuPont KAPTON®



The thermal, physical, chemical resistance and electrical properties of KAPTON are exceptional. And, the benefits don't stop there. KAPTON can be easily fabricated by a wide variety of techniques, including die cutting, punching and thermoforming. It offers excellent adhesive bondability as well.

And, KAPTON is backed by a team of DuPont experts who are ready to provide technical support to designers, fabricators and original equipment manufacturers. In addition, the DuPont KAPTON Marketing Development Group offers a unique opportunity to form partnerships in selling products to the automotive industry.

We hope that this brochure has helped you discover how KAPTON can accelerate your design ideas for cars of the future. For more information or to talk to a DuPont Representative, please call 1-800-237-4357.

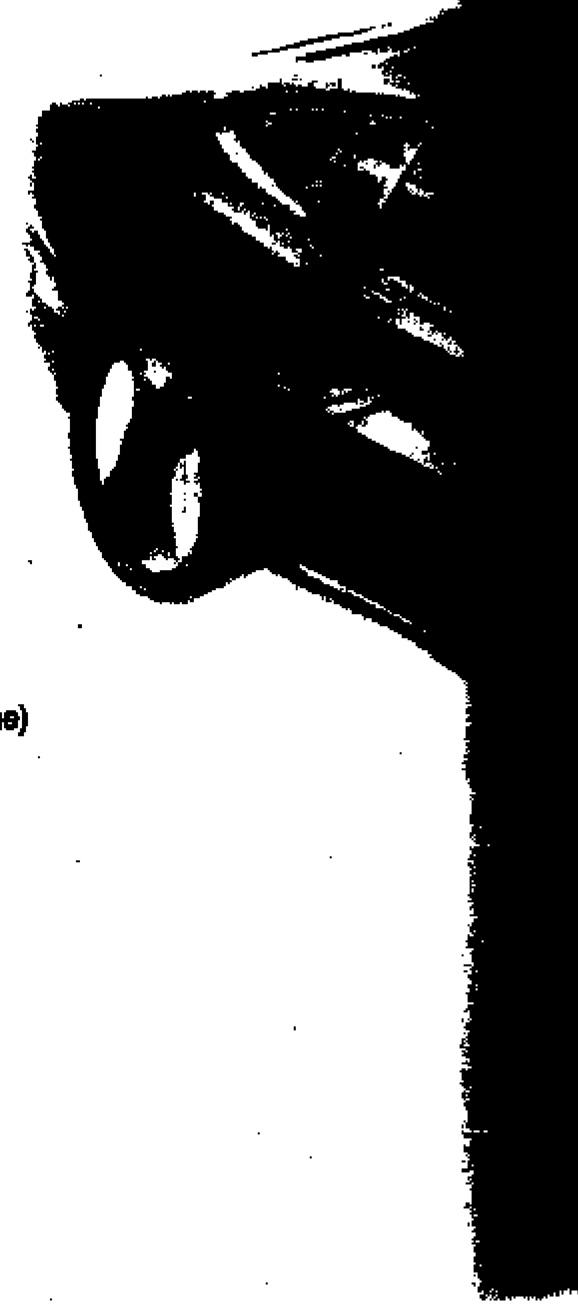


- Spark Plug Boot
- Speaker Parts
  - cones
  - domes
  - spiders
  - surrounds
  - voice coils
- Switches
  - air conditioning system (pressure, punched)
  - button for under-the-hood thermostat (punched)
  - transmission pressure
  - vacuum electrical

rent and Potential

of **KAPTON®**

- Alternator Heat Sink Insulator Pads
- Diaphragms
  - air bag
  - air conditioning system
  - fuel pressure regulator
  - oil pressure switch
  - power steering switch
  - pressure switch in brake systems (punched)
- Disposable Pin Carrier for PCB Interconnections
- Flexible Circuit for Dashboard
- Fuel Pulsation Dampener
- Fuse Plane
- Gasket (under the hood, punched)
- Miniature Pressure Transducer
- Radiator Plug
- Seals for Air Conditioning System
- Sensors
  - accelerator pedal
  - air conditioning system (pressure)
  - automatic windshield wipers (membrane)
  - brake pedal
  - brake systems (pressure)
  - clutch slave cylinder
  - door buzzer
  - EGR
  - memory seat
  - shock height
  - temperature
  - throttle position
  - transmission



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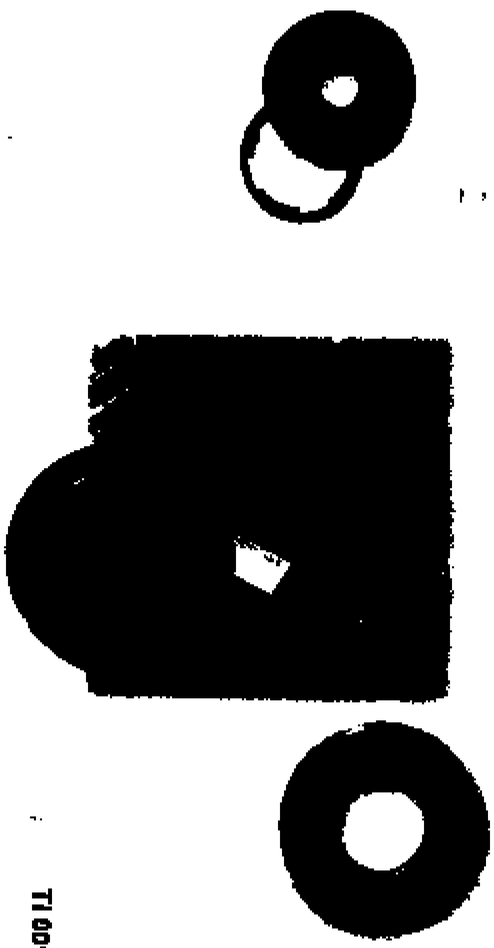
Typical

of KAPTON®

Thermal Properties	
Useful Temperature Range, °C (°F)	-269 to 400 (-452 to 752)
UL®-94 Rating	V-O
UL Thermal Index (100,000 hours)	240°C (464°F)
Melting Point	None
Physical Properties	
Ultimate Tensile Strength at 23°C (73°F), MPa (psi)	231 (33,500)
Yield Point at 3% at 23°C (73°F), MPa (psi)	69 (10,000)
Stress to Produce 5% Elongation at 23°C (73°F), MPa (psi)	90 (13,000)
Ultimate Elongation at 23°C (73°F), %	72
Tensile Modulus at 23°C (73°F), GPa (psi)	2.5 (370,000)
Impact Strength at 23°C (73°F), N•cm (ft•lb)	78 (0.58)
Folding Endurance at 23°C (73°F) (MIT), cycles	285,000
Electrical Properties	
Dielectric Strength, kV/mm (V/mil)	300 (7,700)
Dielectric Constant at 1 kHz	3.4
Chemical Resistance	
	Most organic chemicals, solvents, fuels, lubricants

*For information on the various grades and types of KAPTON, and their specific properties, please contact DuPont (see addresses and phone numbers on the back cover).



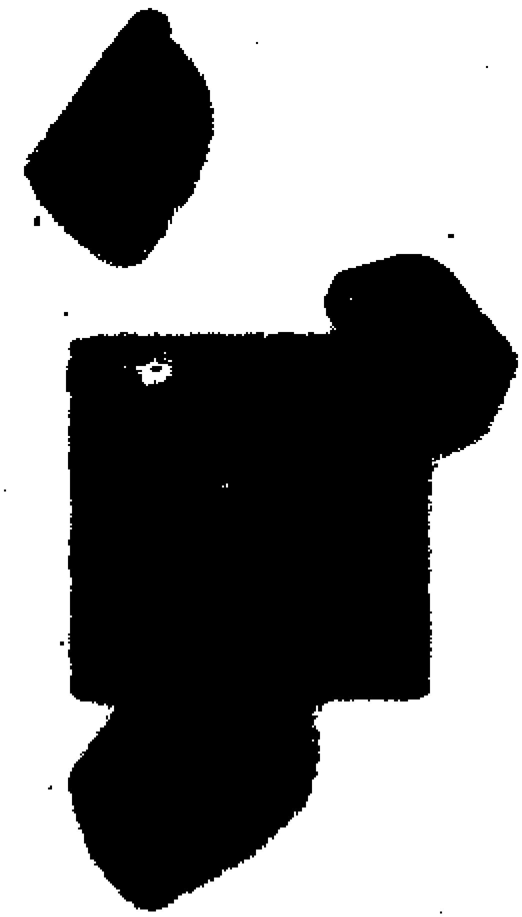
KAPTON® is used in fuel pulsation dampeners, fuse planes, wiring harne
replacements, power steering switches, EGR sensors, ABS components
and a host of other automotive applications. In addition to outstanding
chemical resistance, KAPTON features a UL®-94 V-O rating for flammabi

It Provides Excellent Electrical Performance KAPTON play
a key role in insulating and providing static drain of electromagnetic and
radio frequency interference (EMI/RFI) due to its high dielectric strength
(7,700 volts/mil) and high-temperature resistance. Certain KAPTON films
have unique, combined properties, such as greatly enhanced thermal
conductivity with heat resistance. These combinations can be critical in aut
motive parts where both properties must play a role in performance, such a
the characteristics needed in temperature sensors for instrumentation.

of 240°C (464°F) and can operate at temperatures ranging from -269°C to 400°C (-452°F to 752°F).

Even If It's Flexed a Million Times Although thin and lightweight, KAPTON is amazingly flexible and resilient. It can withstand flexing without developing cracks or tears, which are typical problems encountered with rubber and other common materials. KAPTON enables diaphragms and other parts that work "in movement" under high pressure to remain flexible and functional, while performing for millions of cycles.

And Exposed to Almost Any Solution KAPTON resists most organic chemicals, solvents, lubricants and fuels. In fact, its unmatched resistance to fuels, fluids and other harsh chemicals is the reason



Time and time again, KAPTON® stands up to the harshest conditions – temperature extremes, mechanical stress and contact with organic solvents, to name just a few – while performing better than ordinary materials. That's why more and more automotive engineers and parts designers are specifying KAPTON for diaphragms, insulators, gaskets and parts that must withstand harsh operating environments, such as those found under the hood.

KAPTON Can Take the Heat Because today's and tomorrow's engines will run at increasingly elevated temperatures, high-temperature stability is a critical concern for any under-the-hood part. But temperature extremes are no problem for KAPTON, which carries a UL® Thermal Index automotive, aerospace and electronics industries. These engineers have seen first-hand that KAPTON can take brutal punishment and keep on performing like few other materials.

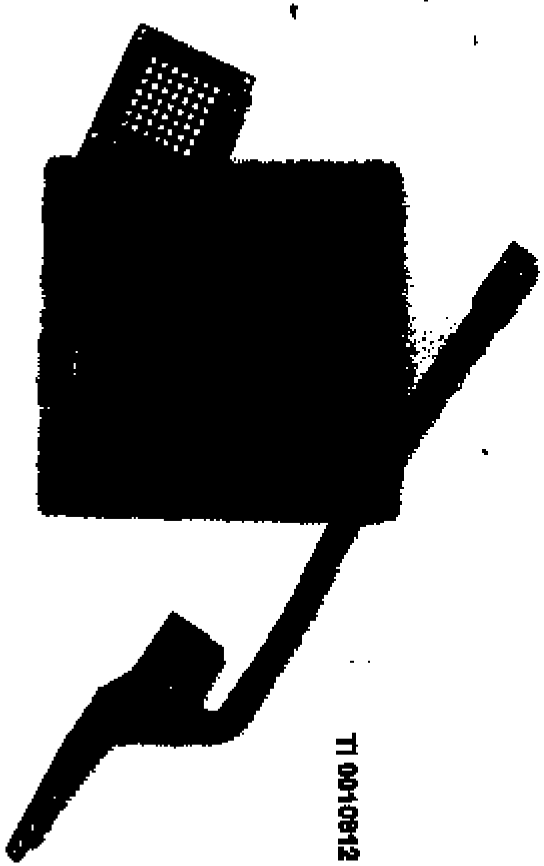
For example, automotive engineers have used KAPTON in a newly designed throttle position sensor that helps maximize fuel efficiency.

Aerospace engineers have sent KAPTON to the moon as a radiation shield on the Lunar Excursion Module and as the multilayer insulation blankets that protect cargo and crew from the intense heat of lift-off and reentry.

And, electrical engineers have come to rely on KAPTON as insulating and shielding material for a broad range of applications – from microwave and satellite communications systems to electronic medical diagnostic equipment and computer components.

n Up Your

with DuPont KAPTON®



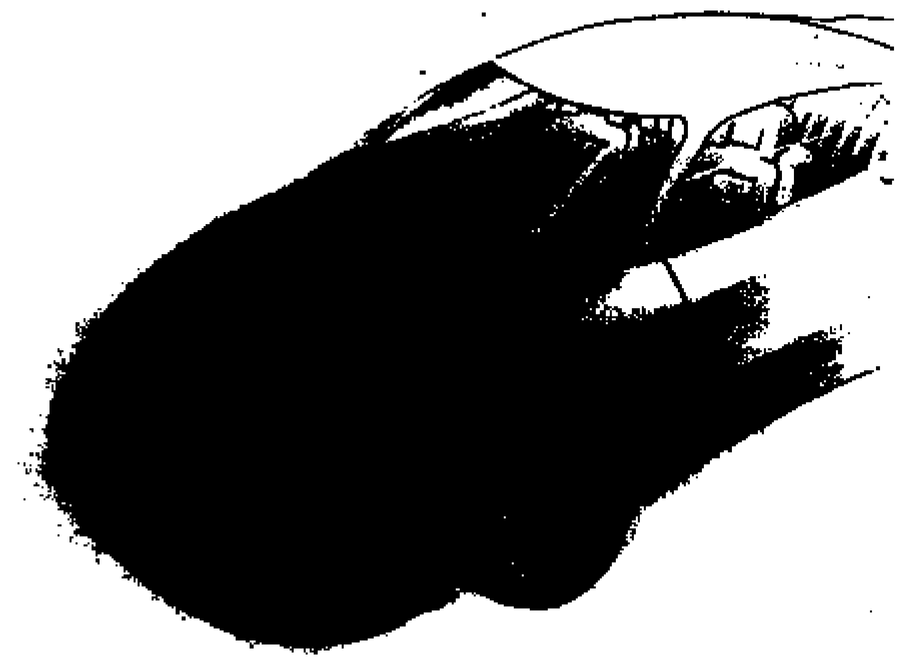
When you take a look into the future of the automotive industry, what do you see? Engines that will run hotter than ever before? Extended factory warranties? Stricter safety and emissions requirements? More and more challenges?

Meeting these challenges will be a tough bill to fill. Ordinary materials, such as silicone, metals, rubbers and plastics, may stall your innovative designs. They simply don't offer high-temperature stability, flexibility, durability, chemical resistance and space and weight savings. KAPTON polyimide film can help you meet whatever challenges you're likely to face in the future by offering all these benefits and more.

Known for its outstanding thermal, mechanical and electrical properties, KAPTON is an advanced material used by engineers in the

How to

with **DuPont KAPTON®**



KAPTON
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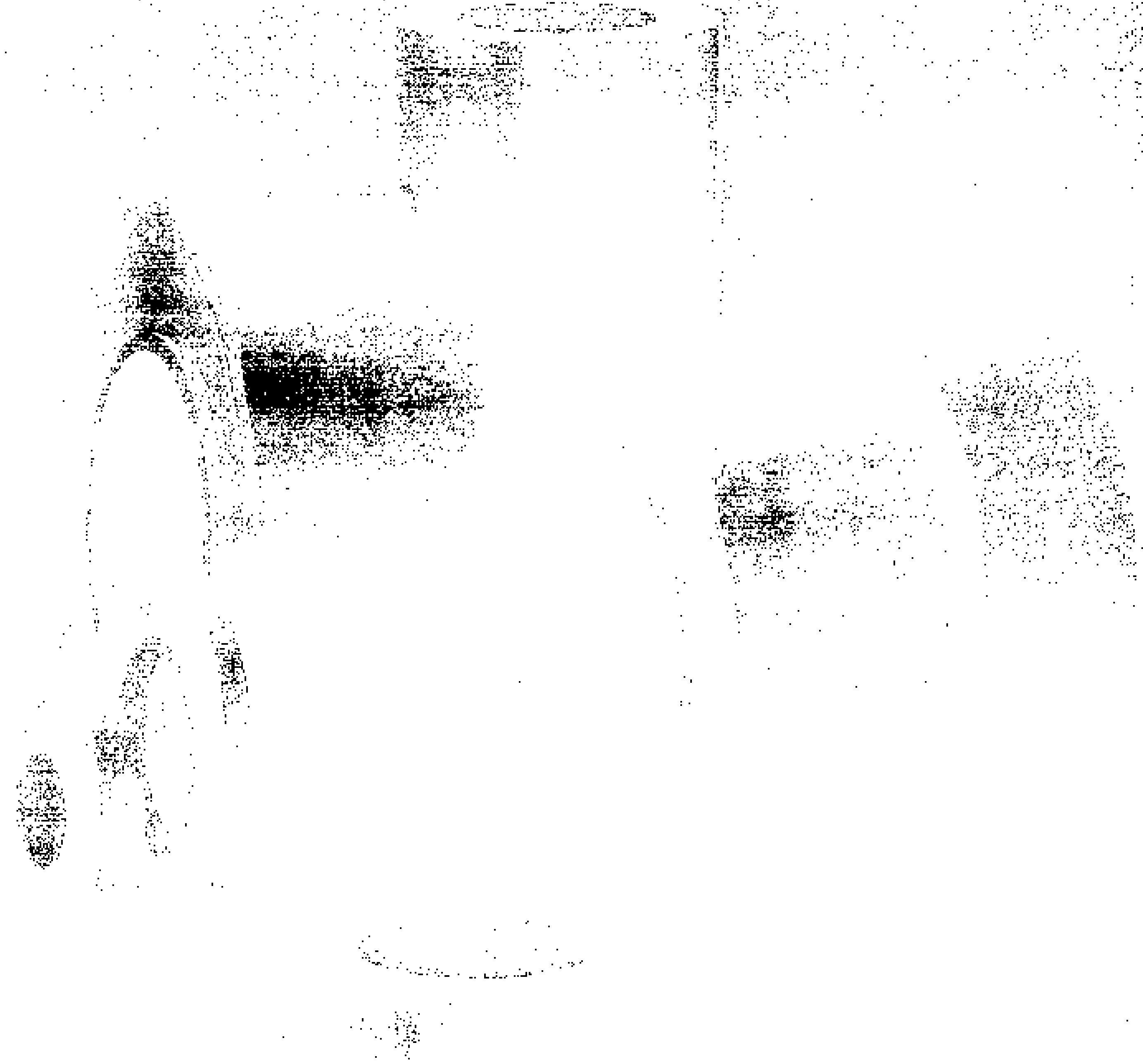
Kapton

POLYIMIDE FILM



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Kapton®

GENERAL INFORMATION

[illegible] polyimide film possesses a [illegible] of properties previously unavailable among [illegible] materials. The [illegible] of KAPTON to [illegible] its excellent physical, electrical and mechanical [illegible] over a wide temperature range [illegible] new design and application areas to plastic film. KAPTON has proved to be [illegible] in [illegible] involving high operating temperatures.

[illegible] synthesized by a [illegible] between an aromatic dianhydride and an [illegible]. There [illegible] film and it is infusible and flame resistant. The [illegible] properties of KAPTON permit it to be used at both high and low temperature extremes where [illegible] materials would not be functional.

[illegible] are available for bonding KAPTON to itself, to metals, to papers of various types and to other films. [illegible] for KAPTON polyimide film include a variety of electrical and electronic insulation applications [illegible] tapes, formed coil insulation, [illegible] flexible printed circuits, motor slot liners, [illegible] transformers and capacitor [illegible], magnetic and pressure sensitive tapes and tubing. [illegible] applications are based on [illegible] electrical properties of KAPTON, such as dielectric [illegible] and dissipation factor, which [illegible] over a wide range of temperature and [illegible]. Other applications make use of [illegible] resistance or chemical resistance at elevated [illegible]. It is this combination of [illegible] extremes in temperatures that makes KAPTON [illegible] material.

[illegible] three types of KAPTON:

- KAPTON Type H, all-purpose, [illegible] film that has been used successfully in applications at temperatures as low as 4K (−269°C) [illegible] (400°C). Type H film can be laminated, metallized, [illegible], formed or adhesive coated. It is available in 0.3, 0.5, 1, 2, 3 and 5 mil film.
- KAPTON TYPE V, an all-purpose, [illegible] film with all of the properties of Type H, plus superior dimensional stability. Type V is available in [illegible] and 5 mils.
- KAPTON Type F, a Type H film coated on one or both sides with TEFLON* FEP fluorocarbon resin to impart heat sealability, to provide a moisture barrier and to enhance chemical resistance. It is available in a variety of constructions.

Note: This bulletin provides a summary of typical properties for all three KAPTON polyimide films Type H, Type V and Type F. Additional data should be obtained from your Du Pont Industrial Films Division representative for specification purposes.

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TI 0010815

PHYSICAL & THERMAL PROPERTIES

KAPTON® Type H Film

25 μm (1 mil)

PHYSICAL PROPERTIES

PHYSICAL PROPERTIES	TYPICAL VALUES 77K (−196°C)	296K (23°C)	473K (200°C)	TEST METHOD
Ultimate Tensile (MD) Strength, MPa (psi)	241 (35,000)	172 (25,000)	117 (17,000)	ASTM D-882-81
Yield Point (MD) at 3%, MPa (psi)		69 (10,000)	41 (6,000)	ASTM D-882-81
Stress to Produce (MD) 5% Elongation, MPa (psi)		90 (13,000)	59 (8,500)	ASTM D-882-81 ASTM D-882-81
Ultimate Elongation (MD)%	2	75	90	ASTM D-882-81
Tensile Modulus, GPa (MD) (psi)	3.5 (510,000)	3.0 (430,000)	1.86 (260,000)	ASTM D-882-81
Impact Strength, J/mm (kg-cm)		23 (6)		Du Pont Pneumatic Impact Test
Folding Endurance MIT		10,000 cycles		ASTM D-2176-69
Tear Strength—Propagating (Elmendorf), g		8		ASTM D-1922-67
Tear Strength—Initial (Graves), g (g/mil)		510 (510)		ASTM D-1004-66
Density, g/cm³		1.42		ASTM D-1505-68
Coefficient of Friction Kinetic (Film-to-Film)		.42		ASTM D-1894-78
Refractive Index (Becke Line)		1.78		Encyclopedic Dictionary of Physics, Vol. 1
Poisson's Ratio		.34		Ave. 3 Samples Elongated at 5%, 7%, 10%

MD—Machine Direction

THERMAL PROPERTIES

THERMAL PROPERTIES	TYPICAL VALUES	TEST CONDITION	TEST METHOD
Melting Point	NONE		ASTM E-794-8
Zero Strength Temperature	1088K (815°C)	.14 MPa (20 psi) load for 5 seconds	Du Pont Hot Bar Test
Coefficient of Linear Expansion	$2.0x10^{-5}$ m/m/K ($2.0x10^{-5}$ in/in/°C)	259 to 311K (−14°C to 38°C)	ASTM D-696-44
Coefficient of Thermal Conductivity, W/m·K $\left(\frac{(cal)(cm)}{(cm^2)(sec)(°C)}\right)$	0.155 ($3.72x10^{-4}$) 0.163 ($3.89x10^{-4}$) 0.178 ($4.26x10^{-4}$) 0.189 ($4.51x10^{-4}$)	296K (23°C) 348K (75°C) 473K (200°C) 573K (300°C)	Model TC-1000 Twin Heatmaster Comparative Tester
Specific Heat	1.09 (.261)	J/g·K (cal/g/°C)	Differential Calorimetry
Flammability	94 VTM-0		UL-94 (1-24-80)
Shrinkage	(See chart on Page 7)		IPC Method 2-2-2-A
Heat Sealability	Not Heat Sealable		
Limiting Oxygen Index	100H-38		ASTM D-2863-77
Smoke Generation	100H – DM = less than 1	NBS Smoke Chamber	NFPA-258 procedures
Glass Transition Temperature (Tg)	A second order transition occurs in KAPTON between 633K (360°C) and 683K (410°C). This is assumed to be the glass transition temperature. Different measurement techniques produce different results within the above temperature range.		

KAPTON® Type V Film

PROPERTY	TYPICAL VALUES Film Gauge				TEST METHOD
	25 μm (1 mil)	50 μm (2 mil)	75 μm (3 mil)	125 μm (5 mil)	
Tensile Strength MPa (psi) @ 296K (23°C). Machine Direction (MD) and Transverse Direction (TD).	172 (25,000)	172 (25,000)	172 (25,000)	172 (25,000)	ASTM D-882, Method A using an Instron Tensile Tester (specimen size: 25 × 127 mm (1" × 5"), jaw separation: 50 mm (2"), jaw speed: 50 mm (2"/min.) Average of 5 specimens based on original measured thickness.
Elongation, % MD and TD	75	70	70	70	Same method as above
Shrinkage, % MD and TD Typical after 60 min. @ 473K (200°C).	0.10	.02	.02	.02	Average of 3 measurements in each direction before and after exposure to 473K (200°C) for 60 min. Film must be allowed to come to equilibrium with equivalent room conditions before and after exposure.

KAPTON® Type F Film

PROPERTY	TYPICAL VALUES Film Type*		
	120F616	150F019	250F029
Ultimate Tensile Strength (MD), MPa (psi)			
296K (23°C)	165 (24,000)	117 (17,000)	172 (25,000)
473K (200°C)	110 (16,000)	76 (11,000)	110 (16,000)
Yield Point at 3% (MD), MPa (psi)			
296K (23°C)	62 (9,000)	50 (7,300)	69 (10,000)
473K (200°C)	38 (5,500)	28 (4,000)	55 (8,000)
Stress at 5% Elongation (MD), MPa (psi)			
296K (23°C)	86 (12,500)	62 (9,000)	
473K (200°C)	52 (7,500)	38 (5,500)	
Ultimate Elongation (MD)			
296K (23°C)%	85	75	90
473K (200°C)%	95	85	
Tensile Modulus, MD GPa (psi)			
296K (23°C)	2.86 (415,000)	2.21 (320,000)	
473K (200°C)	1.48 (215,000)	1.19 (173,000)	
Impact Strength at 296K (23°C)			
J-m (Kg-cm/μm)	70 (7)	70 (7)	
J-m/μ (Kg-cm/mil)	2.3 (6.0)	1.8 (4.8)	
Tear Strength—Propagating (Elmendorf)			
g		28	
g/μm (g/mil)	0.39 (10)	0.53 (13.5)	0.47 (12)
Tear Strength—Initial (Graves)			
g		650	
g/μm (g/mil)	19 (750)	17 (435)	
Weight % Polyimide	80	57	73
Weight % FEP	20	43	27
Density			
Kg/m³x10⁻³	1.53	1.67	1.57

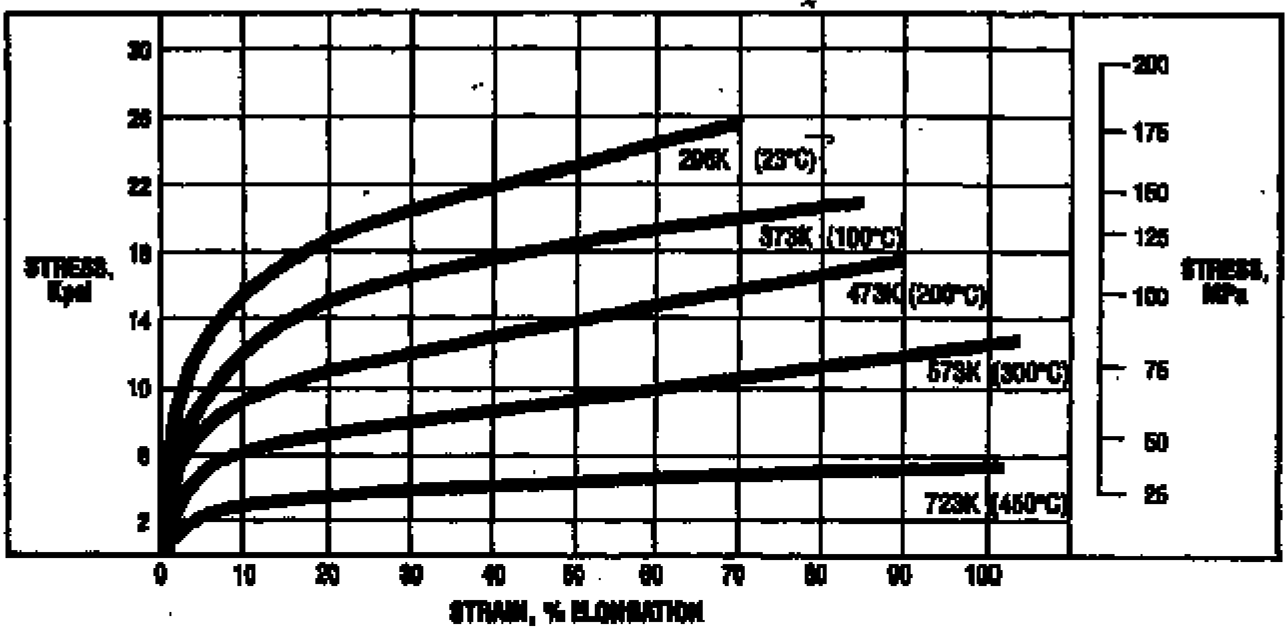
*Since a number of combinations of polyimide film and fluorocarbon coating add up to the same total gauge, it is necessary to distinguish among them. A three digit system is used in which the middle digit represents the nominal thickness of the base KAPTON film in mils. The first and third digits represent the nominal thickness of the coating of TEFLON FEP fluorocarbon resin in mils. The symbol 9 is used to represent 13 μm (½mil), and 6 to represent 2.5 μm (1/10 mil). Example: 120F616 is a 120-gauge structure consisting of a 25 μm (1-mil) base film with a 2.5 μm (1-10 mil) coating of TEFLON on each side. See page 22 for construction explanation.

TI 0010616

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 below. Such properties as tensile strength and modulus have an inverse relation with temperature, while elongation peaks to a maximum value at about 573K (300°C). Other factors such as humidity, film thickness, and Instron elongation rate were found to have only a negligible effect on the shape of the 296K (23°C) curve.

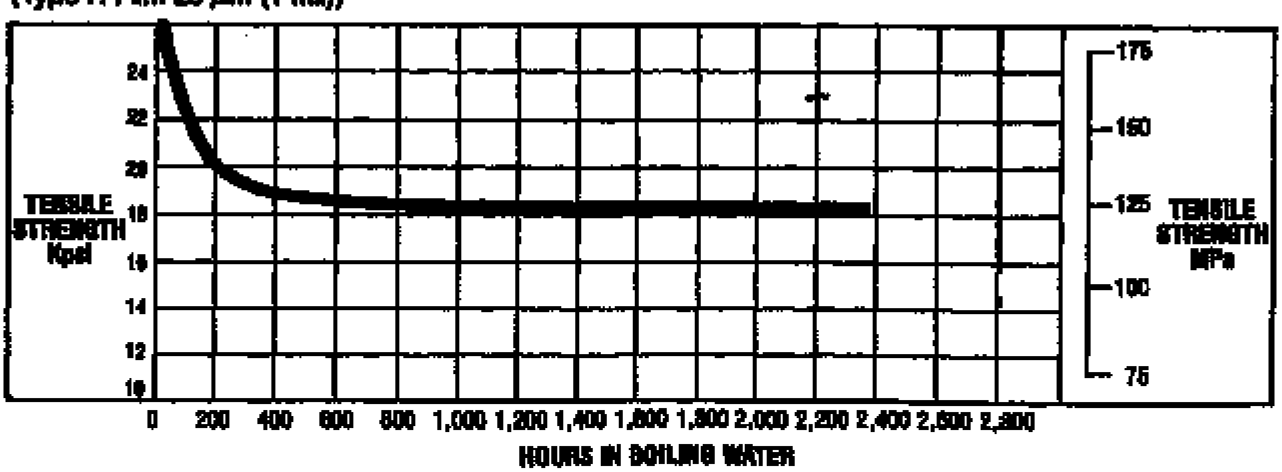
TENSILE STRESS STRAIN CURVES
(Type H Film 25 μm (1 mil))



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 below, will reduce the level of film properties, sufficient tensile and elongation remain to insure good mechanical performance. A decrease in the temperature and the water concentration will reduce the rate of KAPTON property reduction while higher temperatures and pressures will increase it.

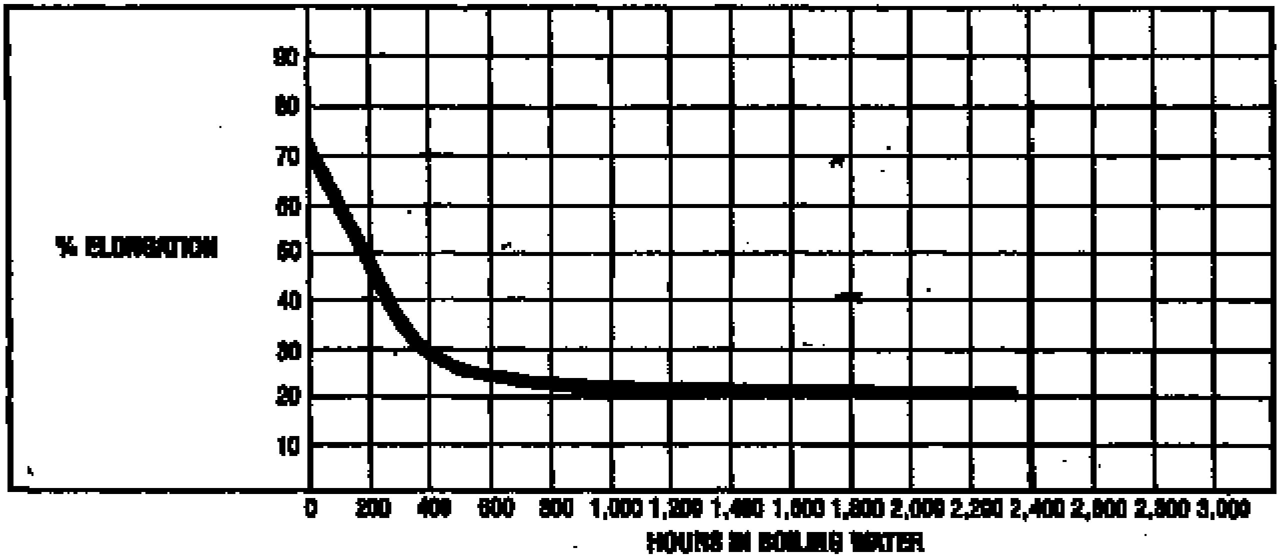
TENSILE STRENGTH AFTER EXPOSURE TO 373K (100°C) WATER
(Type H Film 25 μm (1 mil))



TI 0010918

DD/NHTSA No. 3
00161

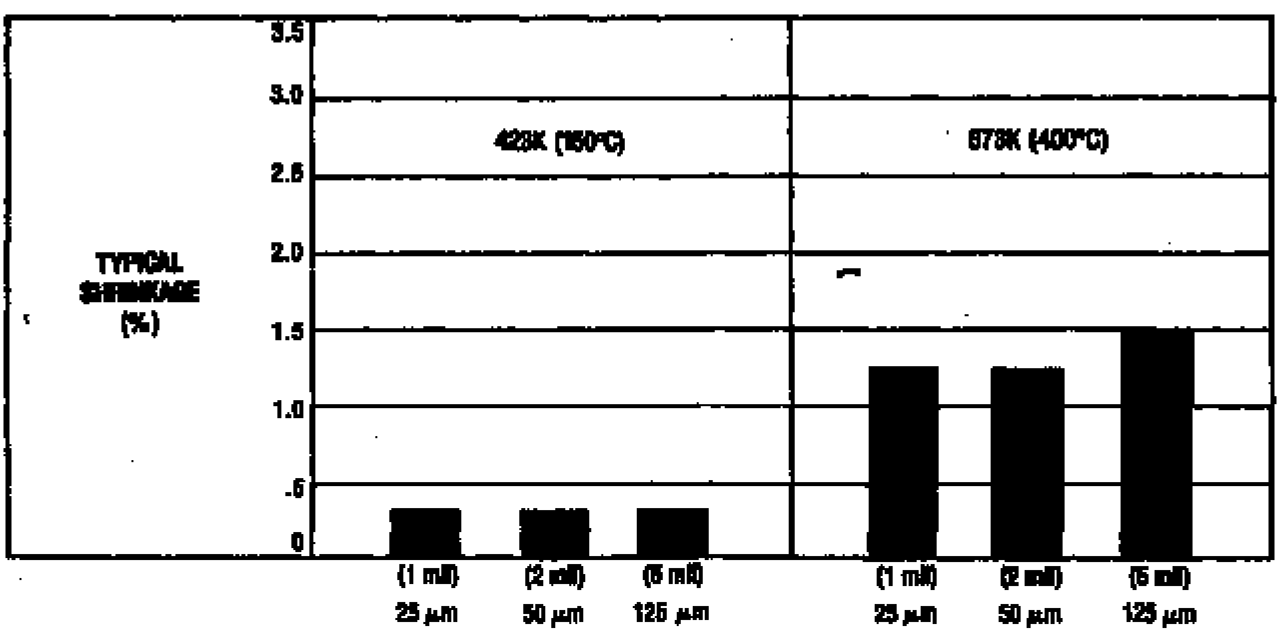
ULTIMATE ELONGATION AFTER EXPOSURE IN 373K (100°C) WATER
(Type H Film 25 μm (1 mil))



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 graphs below. Once the film has been exposed, the normal values for thermal expansion listed on Page 6 can be expected.

RESIDUAL SHRINKAGE VS. EXPOSURE TEMPERATURE AND GAUGE
(Type H Film)



TI 0010920

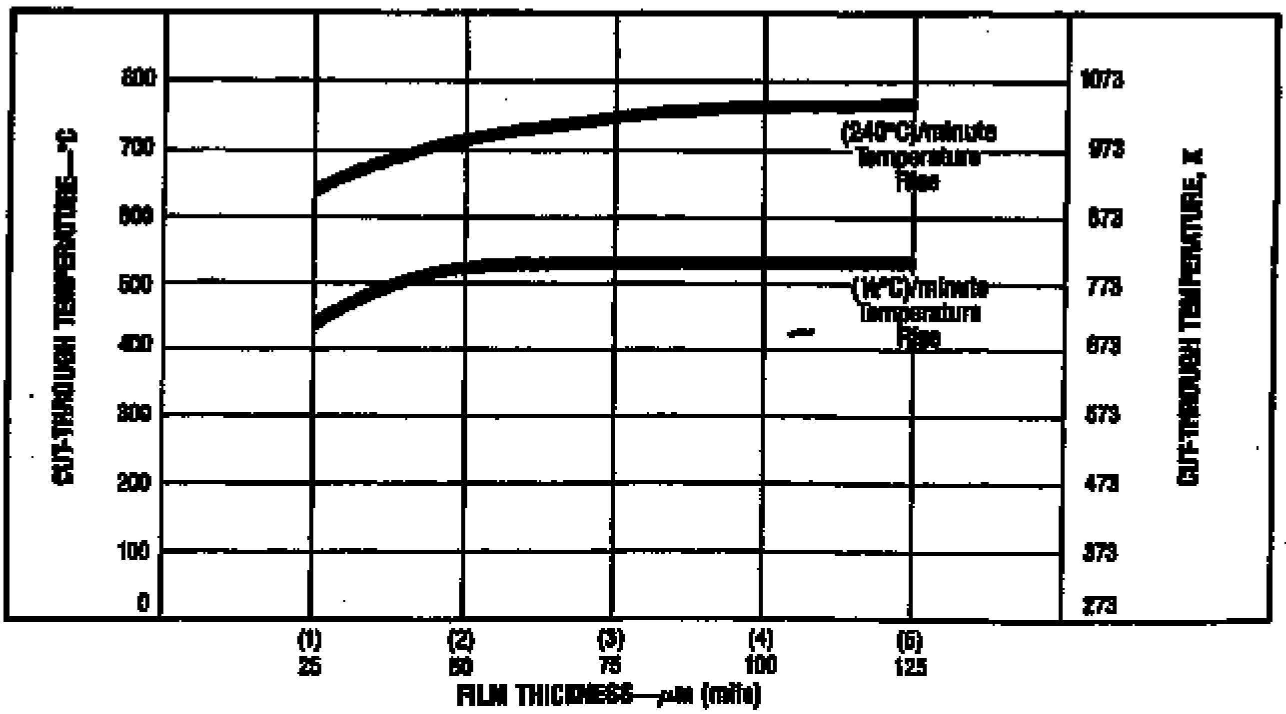
THERMAL COEFFICIENT OF EXPANSION
(Type H Film 25 μm (1 mil)) Thermally Exposed

Temperature Range	α m/m·K x 10^{-5}
296-373K (23-100°C)	1.80
373-473K (100-200°C)	3.10
473-573K (200-300°C)	4.85
573-673K (300-400°C)	7.75
296-673K (23-400°C)	4.65

CUT-THROUGH AND COLD FLOW

Most organic films exhibit a tendency to flow or thin out under high compressive stresses, especially at elevated temperatures. KAPTON® polyimide film possesses an extremely high resistance to such stresses. Test procedures described in ASTM D-876-61 have been adapted to flat films to provide the data below. Stresses range from an infinitely high point load to 83 MPa (12,000 psi) at cut-through for a 25 μm (1 mil) film.

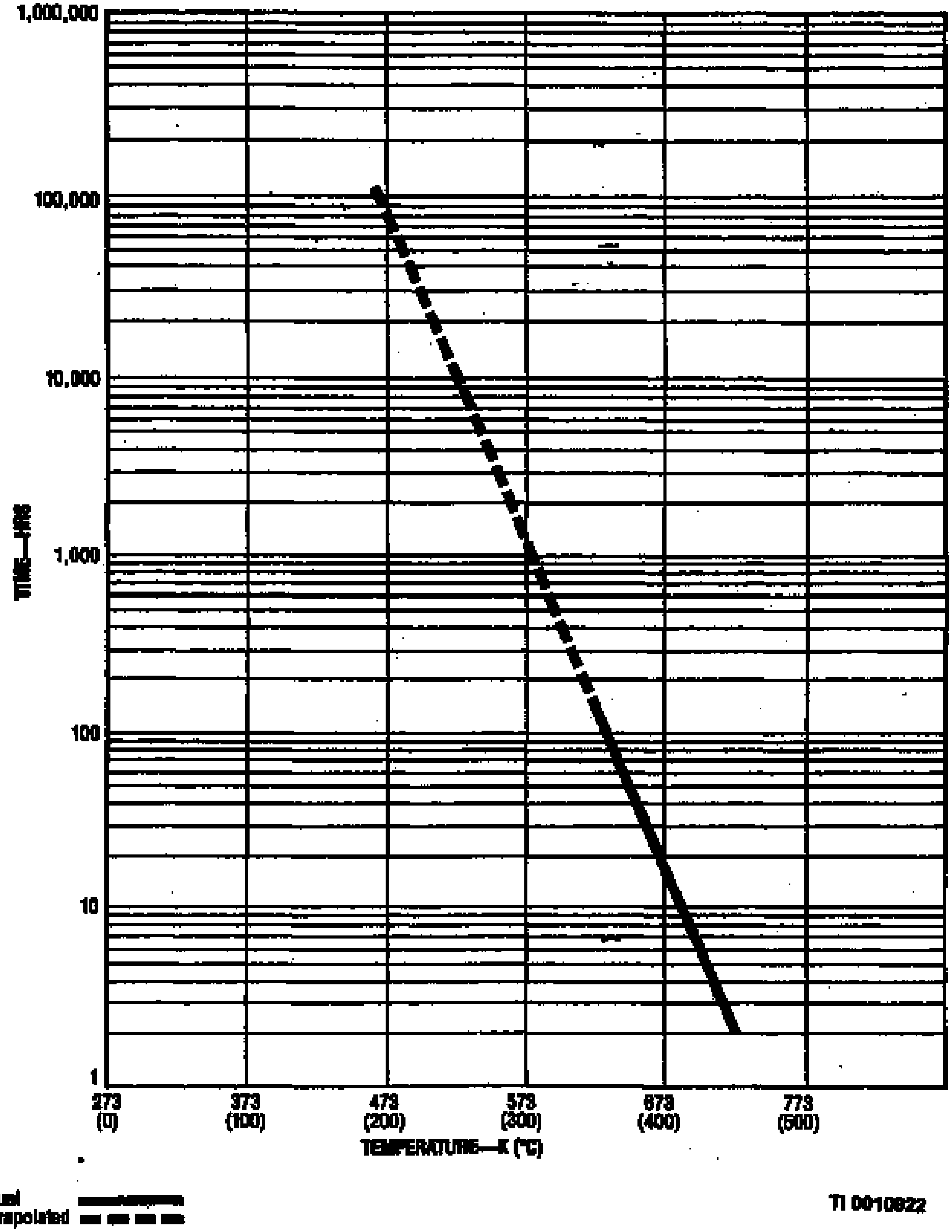
CUT-THROUGH TEMPERATURE VS. RATE OF TEMPERATURE RISE AND GAUGE
(Type H Film)



TI 0010921

RESISTANCE TO CUT-THROUGH VS. TEMPERATURE

(Type H Film—25 μm (1 mil))



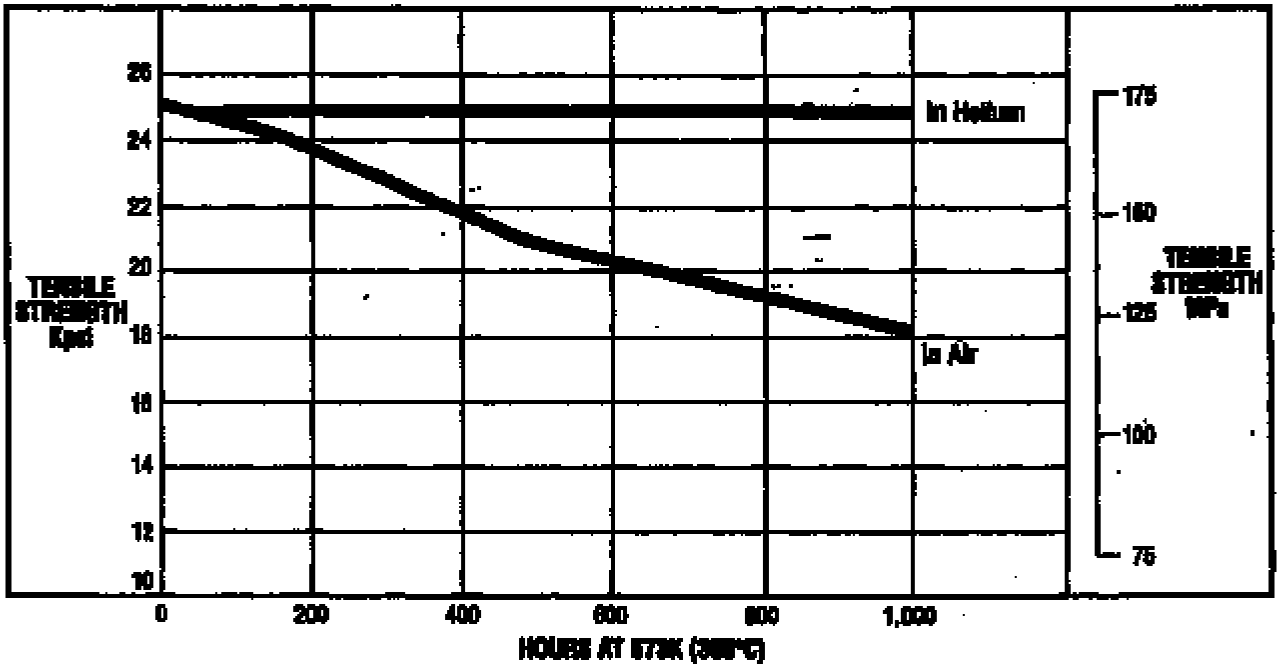
TI 0010822

DD/NHTSA No. 3
06164

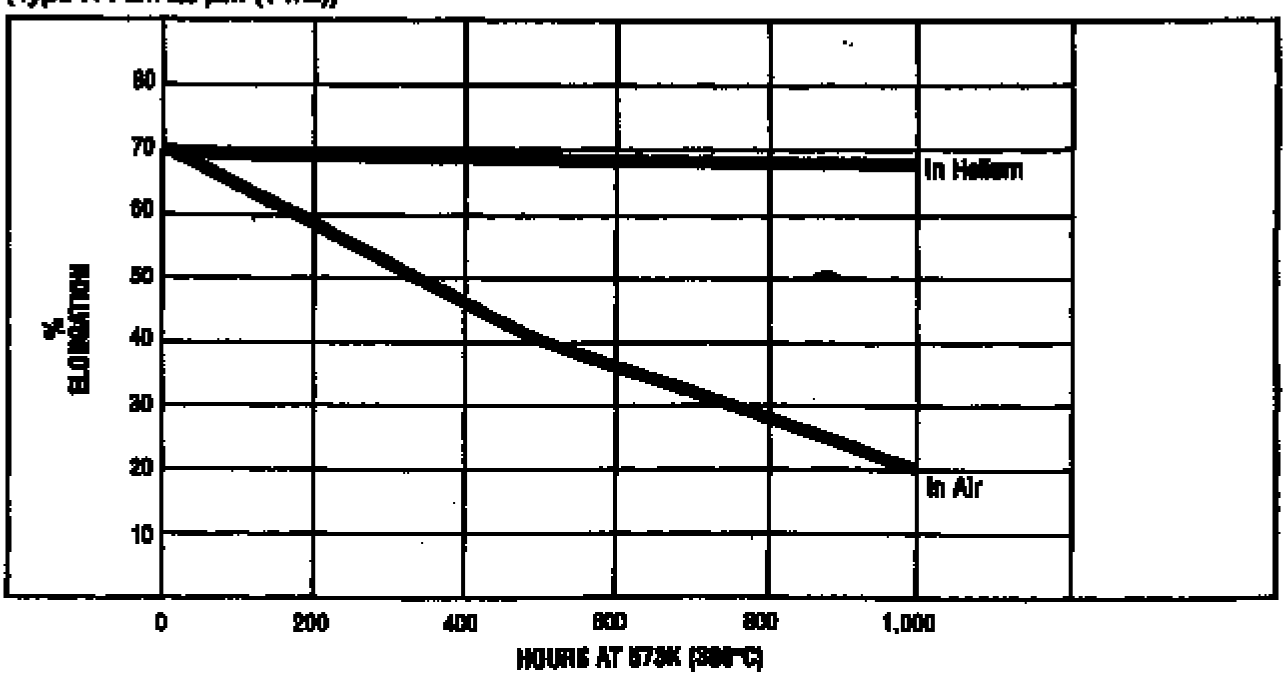
THERMAL AGING

KAPTON® polyimide film is subject to oxidative degradation. Therefore its useful life is a function of both temperature and oxygen concentration in the test environment. The effect of these factors is shown below.

TENSILE STRENGTH VS. AGING AT 575K (300°C)
(Type H Film 25 μm (1 mil))



ULTIMATE ELONGATION VS. AGING AT 575K (300°C)
(Type H Film 25 μm (1 mil))



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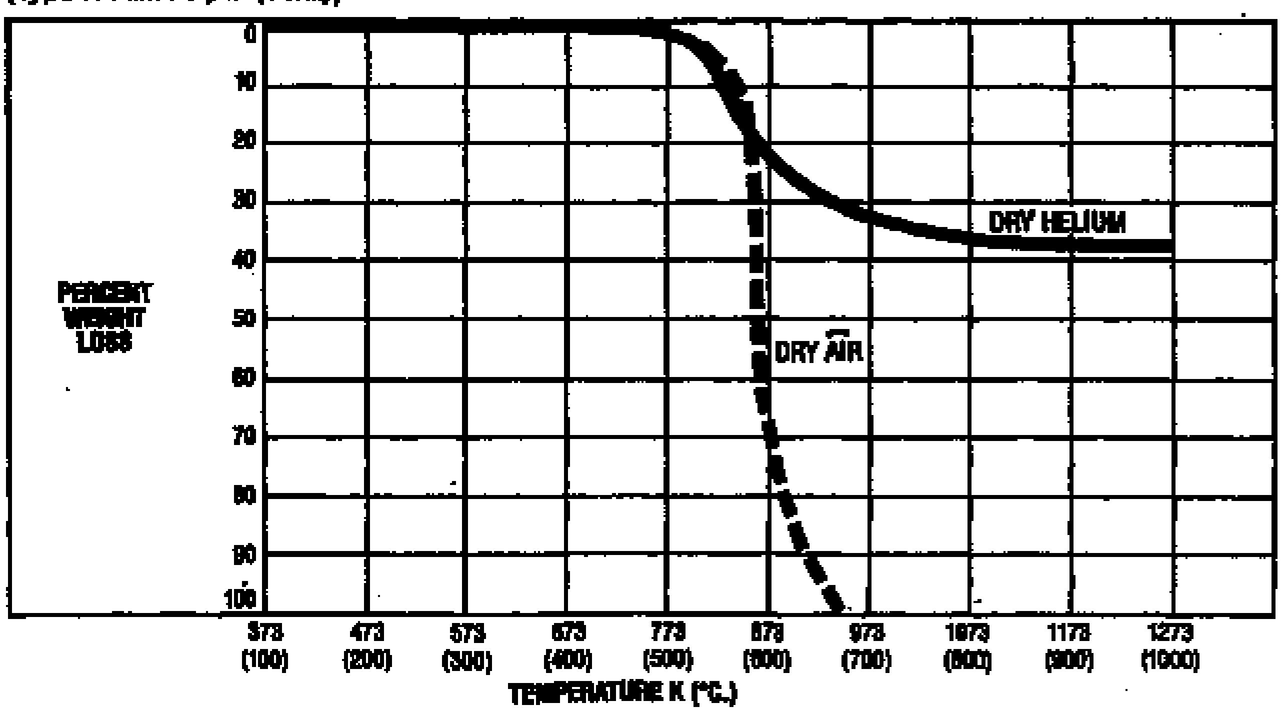
DD/NHTSA No. 3
00165

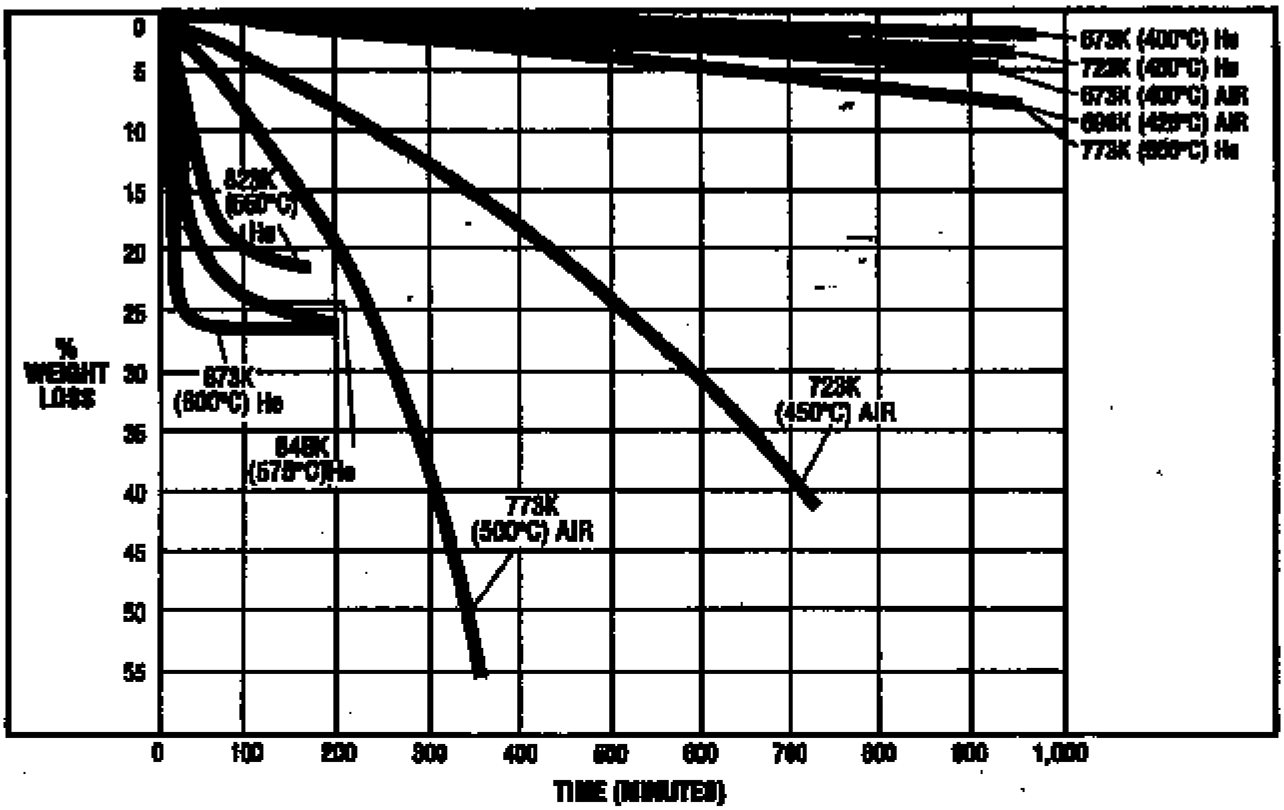
TIME REQUIRED FOR REDUCTION IN ULTIMATE ELONGATION FROM 70% to 1%
(Type H Film 25 μm (1 mil))

Temperature		Environment: Air	Environment: Helium
723K	(450°C)	2 hours	22 hours
698K	(425°C)	6 hours	3½ days
673K	(400°C)	12 hours	2 weeks
648K	(375°C)	2 days	2 months
623K	(350°C)	6 days	1 year
573K	(300°C)	3 months	—
548K	(275°C)	1 year	—
523K	(250°C)	8 years	—

WEIGHT LOSS AT (3°C)/MINUTE TEMPERATURE RISE
(Type H Film 25 μm (1 mil))



ISOTHERMAL WEIGHT LOSS
(Type H Film 25 µm (1 mil))



ELECTRICAL PROPERTIE

KAPTON® Type H Film

TYPICAL ELECTRICAL PROPERTIES

PROPERTY	TYPICAL VALUE	TEST CONDITION	TEST METHOD
Dielectric Strength		60 hertz ¼" electrodes	ASTM D-149-81
25 µm (1 mil)	276 v/µm (7,000 v/mil)		
50 µm (2 mil)	213 v/µm (5,400 v/mil)		
75 µm (3 mil)	161 v/µm (4,600 v/mil)		
125 µm (5 mil)	142 v/µm (3,600 v/mil)		
Dielectric Constant		1 kilohertz	ASTM D-150-81
25 µm (1 mil)	3.5		
50 µm (2 mil)	3.6		
75 µm (3 mil)	3.7		
125 µm (5 mil)	3.7		
Dissipation Factor		1 kilohertz	ASTM D-150-81
25 µm (1 mil)	.0025		
50 µm (2 mil)	.0025		
75 µm (3 mil)	.0025		
125 µm (5 mil)	.0027		
Volume Resistivity		125 volts	ASTM D-257-78
25 µm (1 mil)	$1 \times 10^{[illegible]}$ ohm-m		
50 µm (2 mil)	$8 \times 10^{[illegible]}$ ohm-m		
75 µm (3 mil)	$5 \times 10^{[illegible]}$ ohm-m		
125 µm (5 mil)	$1 \times 10^{[illegible]}$ ohm-m		

KAPTON® Type V Film

TYPICAL ELECTRICAL PROPERTIES

PROPERTY	TYPICAL VALUE	TEST CONDITION	TEST METHOD
Dielectric Strength		60 hertz ¼" electrodes	ASTM D-149-81
50 µm (2 mil)	213 v/µm (5,400 v/mil)		
75 µm (3 mil)	161 v/µm (4,600 v/mil)		
125 µm (5 mil)	142 v/µm (3,600 v/mil)		
Dielectric Constant		1 kilohertz	ASTM D-150-81
50 µm (2 mil)	3.6		
75 µm (3 mil)	3.7		
125 µm (5 mil)	3.7		
Dissipation Factor		1 kilohertz	ASTM D-150-81
50 µm (2 mil)	.0025		
75 µm (3 mil)	.0025		
125 µm (5 mil)	.0027		
Volume Resistivity		125 volts	ASTM D-257-78
50 µm (2 mil)	$8 \times 10^{[illegible]}$ ohm-m		
75 µm (3 mil)	$5 \times 10^{[illegible]}$ ohm-m		
125 µm (5 mil)	$1 \times 10^{[illegible]}$ ohm-m		

KAPTON® Type F Film

TYPICAL ELECTRICAL PROPERTIES

PROPERTY	120F616	150F019	250F029
Dielectric Strength			
Total volts	7,500	6,300	
volts/µm	267	165	157
(volts/mil)	(6,800)	(4,200)	(4,000)
Dielectric Constant	2.8	3.0	
Dissipation Factor	.0022	.0014	
Volume Resistivity			
ohm-m @ 296K (23°C)	1.5 x 10^{14}	$10^{[illegible]}$	7 x $10^{[illegible]}$
(ohm-cm.)	(1.5 x $10^{[illegible]}$)	($10^{[illegible]}$)	(7 x $10^{[illegible]}$)
ohm-m @ 473K (200°C)	5 x $10^{[illegible]}$	10^{14}	
(ohm-cm.)	(5 x 10^{14})	($10^{[illegible]}$)	

EFFECT OF HUMIDITY

(Type H Film 25 µm (1 mil))

Because the water content of KAPTON® polyimide film can affect its electrical properties, electrical measurements were made on 1 mil film after exposure to environments of varying relative humidities at 296K (23°C).

The results of these measurements are given below.

RELATIVE HUMIDITY VS. ELECTRICAL PROPERTIES OF KAPTON

% RELATIVE HUMIDITY	AC DIELECTRIC STRENGTH V/µm	(V/mil)	DIELECTRIC CONSTANT	DISSIPATION FACTOR
0	307	(7,800)	3.0	.0018
30	287	(7,300)	3.3	.0021
50	276	(7,000)	3.5	.0025
80	256	(6,500)	3.7	.0037
100	244	(6,200)	3.8—	.0047

For calculations involving absolute water content, 50% RH in our study is equal to 1.3% water in the film and 100% RH is equal to 2.8% water, the maximum adsorption possible regardless of the driving force.

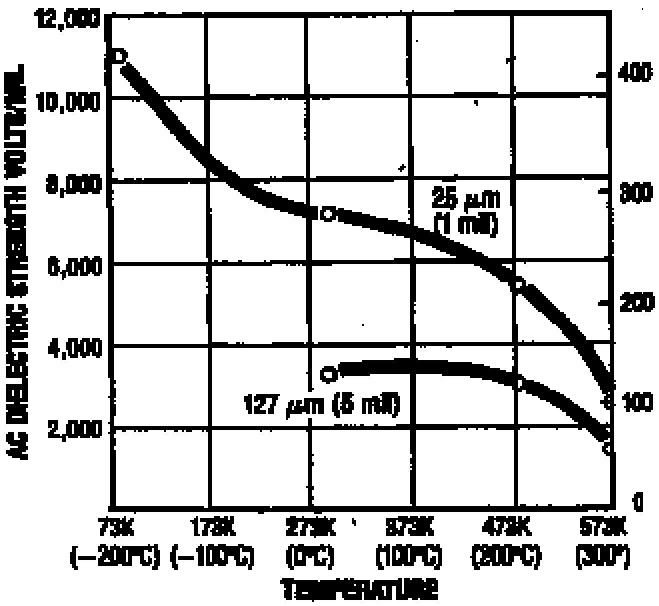
TI 0010928

EFFECT OF TEMPERATURE

As the graphs below indicate, extreme changes in temperature have relatively little affect on the excellent room temperature electrical properties of KAPTON.

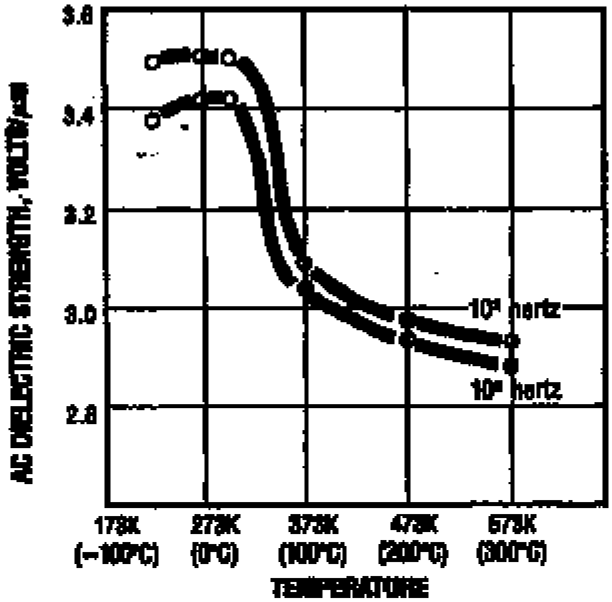
AC DIELECTRIC STRENGTH VS. TEMPERATURE

(Type H Film)



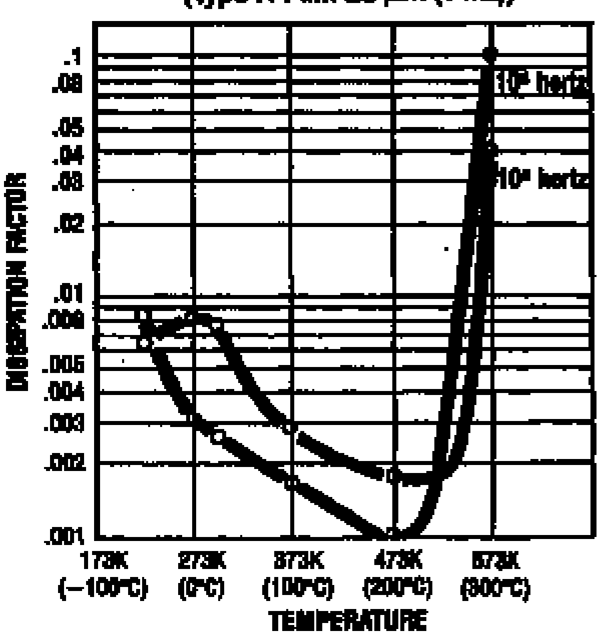
DIELECTRIC CONSTANT VS. TEMPERATURE

(Type H Film—25 μm (1 mil))



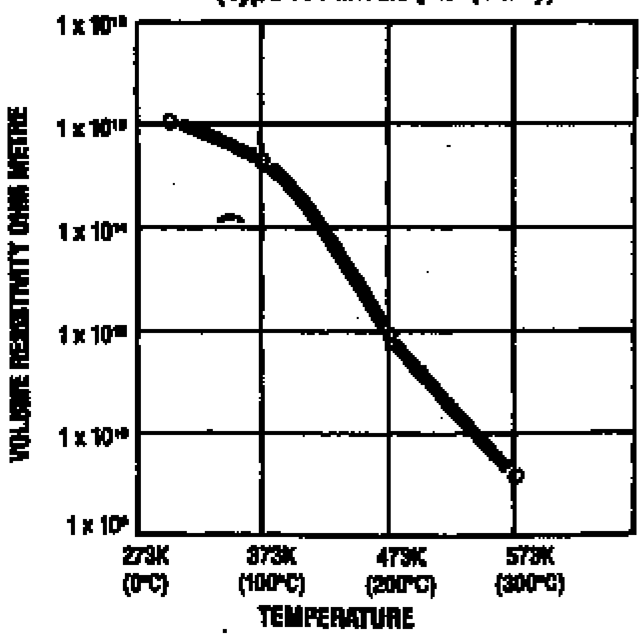
DISSIPATION FACTOR VS. TEMPERATURE

(Type H Film 25 μm (1 mil))



VOLUME RESISTIVITY VS. TEMPERATURE

(Type H Film 25 μm (1 mil))

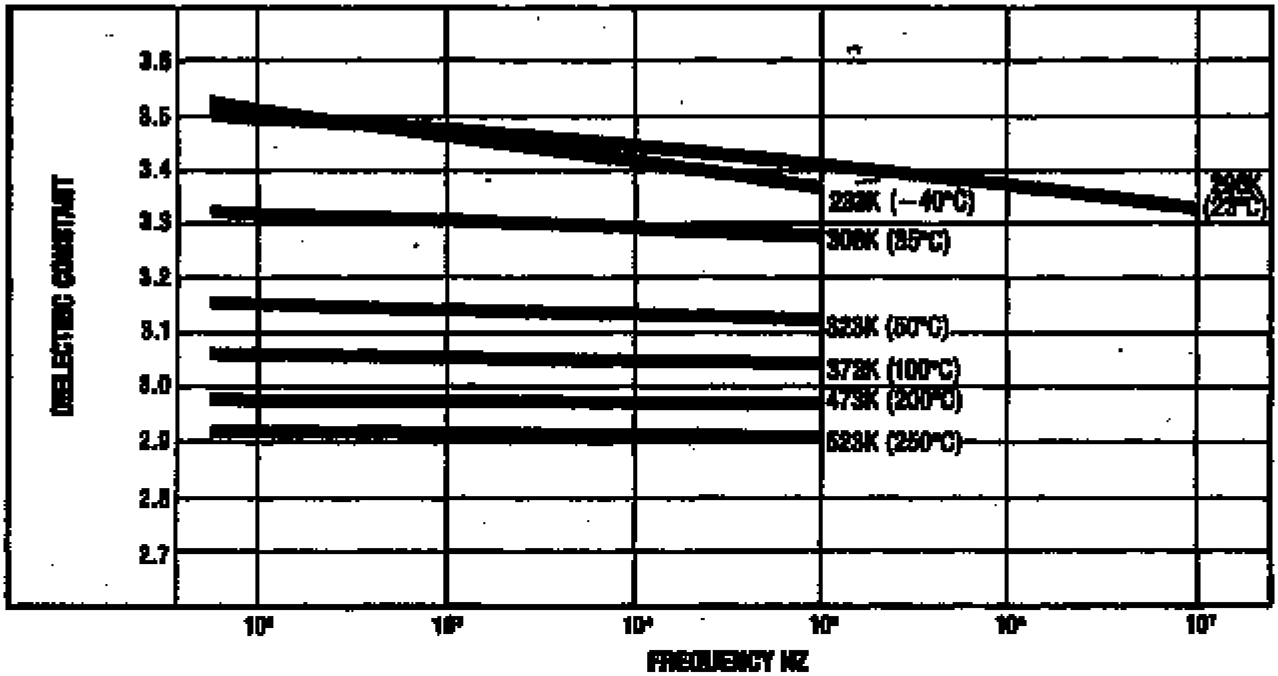


EFFECT OF FREQUENCY

The effects of frequency on the value of the dielectric constant and dissipation factor at various isotherms are shown below.

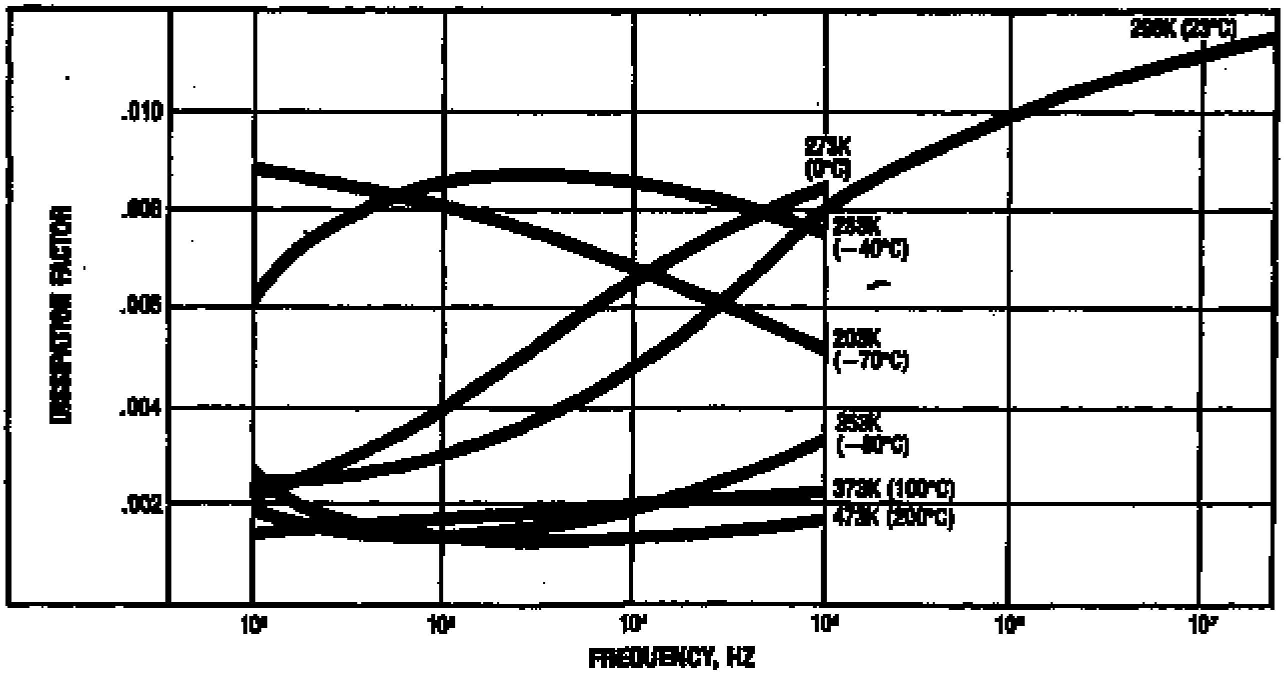
DIELECTRIC CONSTANT VS. FREQUENCY

(Type H Film 25 μm (1 mil))



DISSIPATION FACTOR VS. FREQUENCY

(Type H Film 25 μm (1 mil))

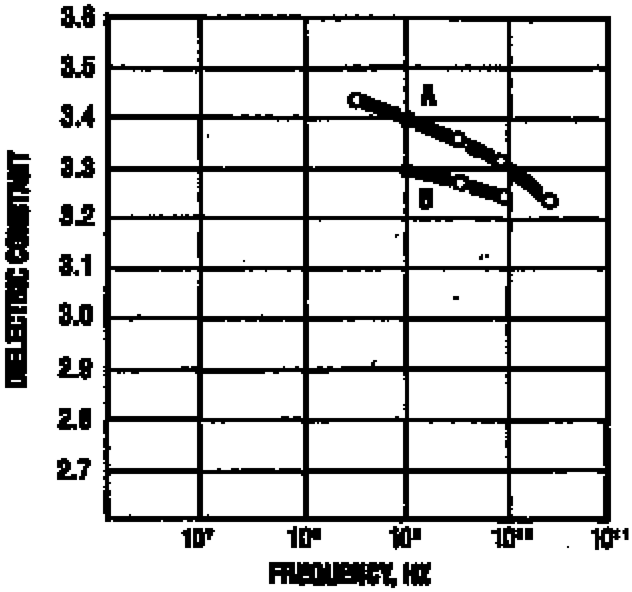


TI 0010830

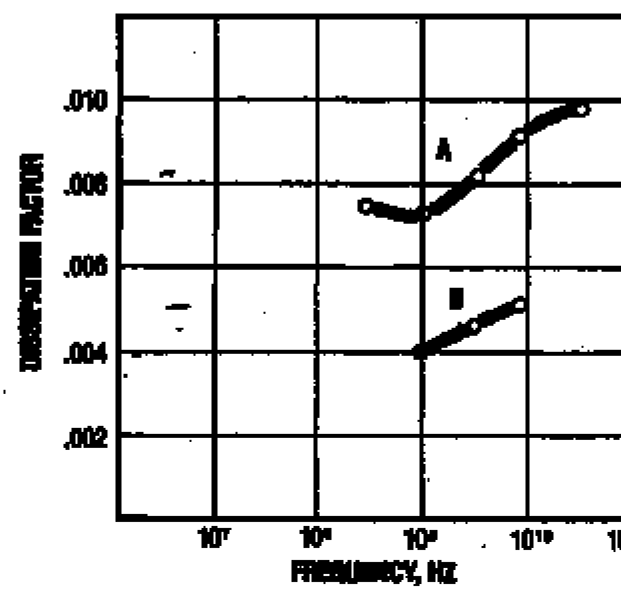
DD/NHTSA No. 3
00172

DIELECTRIC PROPERTIES IN GIGAHERTZ FREQUENCY RANGE

(Type H Film, 125μm (5 mil))*



(Type H Film, 125μm (5 mil))*



*Technical Report AFML-TR-72-39—Curve A is 500H KAPTON as received and measured at 23°C 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 for 48 hours.

TRACKING RESISTANCE

A 125 μm (5 mil) KAPTON® polyimide film, Type H, has a tracking resistance of 183 seconds as measured by ASTM D-495-61. The failure was due to true tracking rather than erosion, etc.

CORONA LIFE

Like all organic materials, KAPTON is attacked by corona and will ultimately fail dielectrically when exposed continuously to corona. At moderate levels of corona exposure, devices insulated with KAPTON have survived up to 3,000 hours, giving reasonable assurance that brief exposures to corona will not significantly affect the life of a properly designed insulation system based on KAPTON.

Corona inception voltage and corona intensity are functions of many parameters, including insulation thickness, air gap thickness, and device shape. Consult with a Du Pont technical representative on the suitability of KAPTON for specific applications where corona may be present.

TI 0010831

DD/NHTSA No. 3
00173

CHEMICAL PROPERTIES

KAPTON® Type H Film

25 μm (1 mil)

CHEMICAL PROPERTIES

PROPERTY	TYPICAL VALUES (~25 μm (1 mil)) % Tensile Retained	% Elongation Retained	% Modulus Retained	TEST CONDITION/METHOD
RESISTANCE TO:				Days Immersed at Room Temperature
Benzene	100	82	100	365
Toluene	99	91	97	365
Methanol	100	73	140	365
Acetone	67	62	160	365
10% Sodium Hydroxide		Degrades		5
Glacial Acetic Acid	85	62	102	36 days @ 383K (110°C)
p-Cresol	100	77	102	22 days @ 473K (200°C)
Transformer Oil	100	100	100	180 days @ 423K (150°C)
Water pH = 1	65	30	100	14 days @ 373K (100°C)
pH = 4.2	65	30	100	14 days @ 373K (100°C)
pH = 7.0	65	20	100	168 days @ 373K (100°C)
pH = 8.9	65	20	100	14 days @ 373K (100°C)
pH = 10.0	60	10	100	4 days @ 373K (100°C)
RADIATION RESISTANCE				
Gamma (Savannah River)		Still Flexible (180° Bend)		Exposure: 4.16 x 10^7 Gy
Electron (Van de Graaff)		Retains 50% of Original Elongation		Exposure: 6 x 10^7 Gy
Neutron plus Gamma (Brookhaven)		Darkened but tough		Exposure: 10^6 Gy
FUNGUS RESISTANCE		Inert		Soil Burial
MOISTURE ABSORPTION		1.3% Type H		50% Relative Humidity at 296K (23°C)
		2.9% Type H & V		Immersion for 24 hours at 296K (23°C)
HYGROSCOPIC COEFFICIENT OF EXPANSION		2.2 x 10^{-5} m/m/% Relative Humidity		296K (72°F) 20%-80% Relative Humidity
PERMEABILITY Gas		ml/m²·MPa·day (cc/(100 in²) (24 hrs.) (atm/mil))		
Carbon Dioxide		6.9 (45)		ASTM D-1434-63 @ 296K (23°C)
Hydrogen		38 (250)		
Nitrogen		0.9 (6)		
Oxygen		3.8 (25)		
Helium		63 (415)		
Water Vapor		g/m²·day 54 g/(100 in²) (24 hrs.)/mil 5.4		ASTM E-96-63T

TI 0010933

DD/NHTSA No. 3
08175

KAPTON® Type V Film

CHEMICAL PROPERTIES

Typical chemical properties for Type V film are similar to Type H.

KAPTON® Type F Film

CHEMICAL PROPERTIES

PROPERTY	120F616	150F019	400F022
Moisture Absorption @ 296K (23°C), 50% R.H. 98% R.H.	 1.3% 2.5%	 .8% 1.7%	 .4% 1.2%
Water Vapor Permeability g/m²·d (gm./(100 in²) (24 hrs.) g/m²·d·µm (g./(100 in²)(24 hrs./mil)	 13.7 (0.89) 0.44 (1.07)	 8.8 (0.57) 0.35 (0.85)	 3.6 (0.23) 0.14 (0.92)

TI 0010934

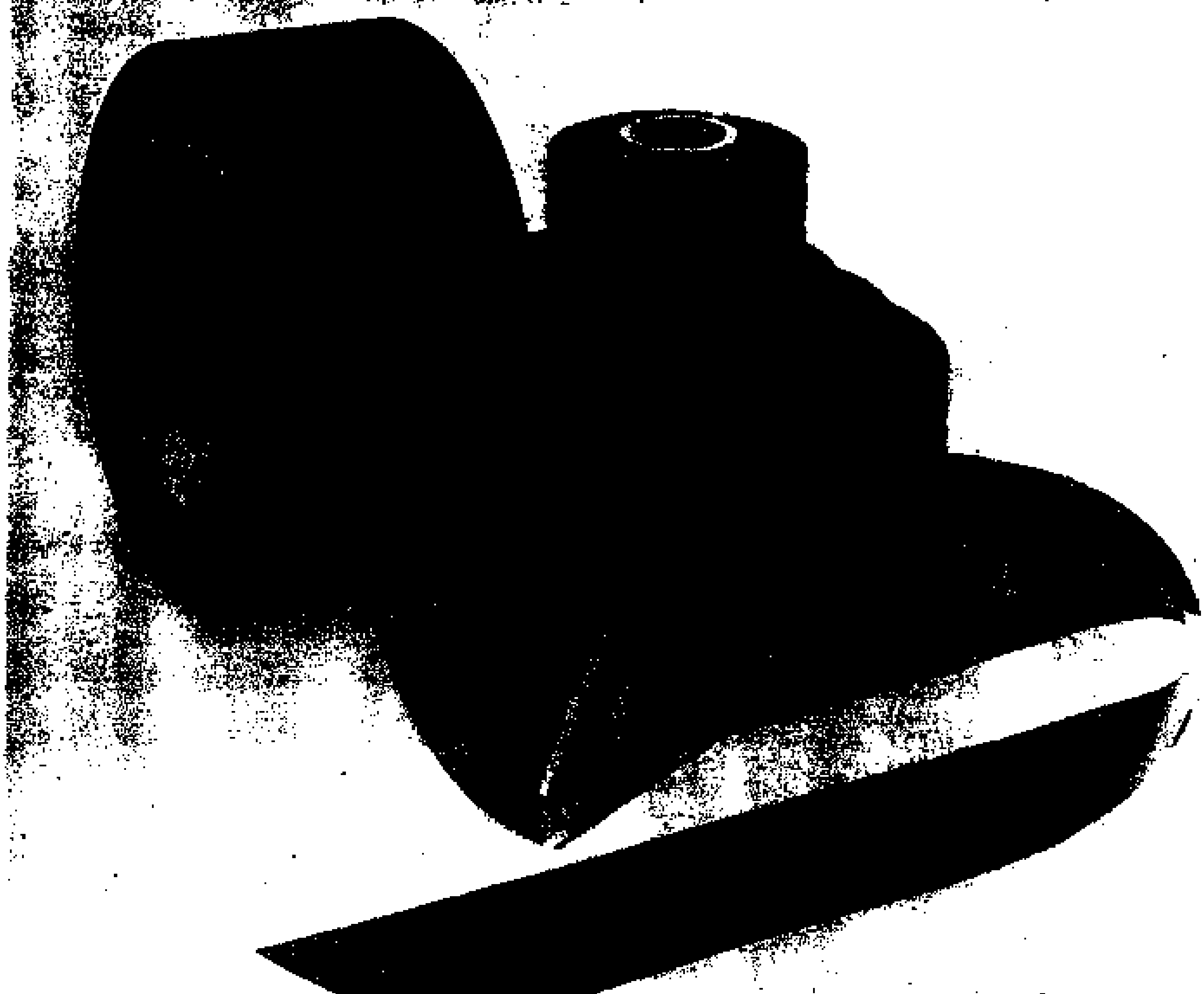
DD/NHTSA No. 3
00176

NOMINAL CONSTRUCTION, Type F Film

In the KAPTON® Type F order code of 3 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 TEFLON® FEP fluorocarbon resin in mils. The symbol 9 is used to represent 13 µm (½ mil) and 6 to represent 2.5 µm (1/10 mil). Example: 120F616 is a 120 gauge structure consisting of a 25 µm (1-mil) base film with a 2.5 µm (1/10 mil) coating of TEFLON on each side. Illustrated are 3 examples of the many types available.

ORDER CODE	NOMINAL THICKNESS µm	NOMINAL THICKNESS mils	"TEFLON" FEP µm	"TEFLON" FEP mils	"KAPTON" TYPE H µm	"KAPTON" TYPE H mils	"TEFLON" FEP µm	"TEFLON" FEP mils
120F616	30	1.2	2.5	0.1	25	1	2.5	0.1
150F019	38	1.5	0	0	25	1	13	½
250F029	64	2.5	0	0	51	2	13	½

ORDER CODE	STANDARD WIDTHS mm	STANDARD WIDTHS Inches	AREA FACTOR m²/Kg	AREA FACTOR FT²/LB.
120F616	[illegible]	1/8-36	21.9	104
150F019	[illegible]	1/8-36	15.3	77
250F029	[illegible]	1/8-36	11.1	49



TI 0010935

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DU PONT

TI 0010937

Kapto

POLYIMIDE FILM

TI 0010938

DD/NHTSA No. 3
00181

Kapton®

POLYIMIDE FILM

Summary of Properties

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Kapton®
POLYIMIDE FILM

GENERAL INFORMATION

KAPTON® polyimide film possesses a unique combination of properties previously unavailable among polymeric film materials. 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 has proved to be especially useful in applications involving high operating temperatures.

KAPTON is synthesized by a bipolycondensation reaction between an aromatic dianhydride and an aromatic diamine. There is no known organic solvent for the film and it is infusible and flame resistant. The outstanding properties of KAPTON permit it to be used at both high and low temperature extremes where other organic materials would not be functional.

Adhesives are available for bonding KAPTON to itself, to metals, to papers of various types, and to other films.

Applications for KAPTON polyimide film include 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 electrical properties of KAPTON, such as dielectric strength and dissipation factor, which remain nearly constant over a wide range of temperature and frequency. Other applications make use of the film's radiation resistance or chemical resistance at elevated temperatures. It is this combination of useful properties at extremes in temperatures that makes KAPTON a unique industrial material.

Du Pont makes three types of KAPTON:

- KAPTON Type HN, an all-purpose, all-polyimide film that 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 0.3, 0.5, 0.75, 1, 2, 3, and 5 mil film.
- KAPTON TYPE VN, an all-purpose, all-polyimide film with all of the properties of Type HN, plus superior dimensional stability. Type VN is available in 0.5, 0.75, 1, 2, 3, and 5 mils.
- KAPTON Type FN, a Type HN film coated on one or both sides with TEFLON® FEP fluorocarbon resin to impart heat sealability, to provide a moisture barrier and to enhance chemical resistance. It is available in a variety of constructions.

Note: This bulletin provides a summary of typical properties for all three KAPTON polyimide films: Type HN, Type VN, and Type FN. Additional data should be obtained from your Du Pont representative for specification purposes.

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TI 0010940

DB/NHTSA No. 3
00182

PHYSICAL & THERMAL PROPERTIES

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TI 0010841

DD/NHTSA No. 3
00183

KAPTON® Type 100 HN Film 25 μm (1 mil)

PHYSICAL PROPERTIES

PHYSICAL PROPERTIES	TYPICAL VALUES 23°C (73°F)	TYPICAL VALUES 200°C (392°F)	TEST METHOD
Ultimate Tensile (MD) Strength, MPa (psi)	231 (33,500)	139 (20,000)	ASTM D-882-83, Method A[1]
Yield Point (MD) at 3%, MPa (psi)	69 (10,000)	41 (6,000)	ASTM D-882-81
Stress to Produce (MD) 5% Elongation, MPa (psi)	90 (13,000)	61 (9,000)	ASTM D-882-81
Ultimate Elongation (MD), %	72	83	ASTM D-882-81
Tensile Modulus, GPa (MD) (psi)	2.5 (370,000)	2.0 (290,000)	ASTM D-882-81
Impact Strength, Kg-cm (ft-lb)	6 (.58)		Du Pont Pneumatic Impact Test
Folding Endurance (MIT), cycles	285,000		ASTM D-2176-69 (1982)
Tear Strength (MD) – Propagating (Elmendorf), g	7		ASTM D-1922-67 (1978)
Tear Strength (MD) – Initial (Graves), g	720		ASTM D-1004-66 (1981)
Density, g/cm³	1.42		ASTM D-1505-68 (1979)
Coefficient of Friction – Kinetic (Film-to-Film)	.48		ASTM D-1894-78
Coefficient of Friction – Static (Film-to-Film)	.63		ASTM D-1894-78
Refractive Index (Becke Line)	1.66		ASTM D-542-50 (1977)
Poisson's Ratio	.34		Avg. 3 Samples Elongated at 5%, 7%, 10%
Low Temperature Flex Life	Pass		IPC TM 650, Method 2.6.18

(MD) – Machine Direction

[1] Specimen Size: 25 × 150mm (1" × 6"); Jaw Separation: 100mm (4"); Jaw Speed: 50mm/min (2"/min); Ultimate refers to the tensile strength and elongation measured at break.

THERMAL PROPERTIES

THERMAL PROPERTIES	TYPICAL VALUES	TEST CONDITION	TEST METHOD
Melting Point	NONE		ASTM E-794-81
Thermal Coefficient of Expansion	20 ppm/°C (11 ppm/°F)	−14 to 38°C (7 to 100°F)	ASTM D-696-79
Coefficient of Thermal Conductivity, W/m·K (cal / (cm)(sec)(°C))	0.12 (2.87 × 10⁻⁴)	296°K (23°C)	University of Delaware Physics Department Method
Specific Heat	1.09 (.261)	J/g·K (cal/g·°C)	Differential Calorimetry
Flammability	94V-0		UL-94 (2-8-85)
Shrinkage, %	0.17 1.25	30 min @ 150°C 120 min @ 400°C	IPC TM 650, Method 2.2.4A
Heat Sealability	Not Heat Sealable		
Limiting Oxygen Index, %	37		ASTM D-2863-77
Solder Float	Pass		IPC TM 650, Method 2.4.13A
Smoke Generation	DM = less than 1	NBS Smoke Chamber	NFPA-258
Glass Transition Temperature (Tg)	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.		

KAPTON® Type VN Film

PHYSICAL AND THERMAL PROPERTIES

PROPERTY	TYPICAL VALUES FOR FILM THICKNESS				TEST METHOD
	25 μm (1 mil)	50 μm (2 mil)	75 μm (3 mil)	125 μm (5 mil)	
Ultimate Tensile Strength (MD), MPa Kpsi	231 (33,500)	234 (34,000)	231 (33,500)	231 (33,500)	ASTM D-882-83
Ultimate Elongation (MD), %	72	82	82	82	ASTM D-882-83
Tear Strength (MD) (Initial) Graves, g	729	1566	2581	4765	ASTM D-1004-66 (1981)
Tear Strength (MD) (Propagating) Elmendorf, g	7	21	38	69	ASTM D-1922-67 (1978)
Folding Endurance (MIT), K cycles	285	55	6	5	ASTM D-2176-69 (1982)
Density, g/cm³	1.42	1.42	1.42	1.42	ASTM D-1505-68 (1979)
Flammability	94V-0	94V-0	94V-0	94V-0	UL-94
Shrinkage, %	0.03	0.03	0.03	0.03	IPC TM 650 Method 2.2.4A
Limiting Oxygen Index, %	37	43	46	45	ASTM D-2863-77

KAPTON® Type FN Film

PROPERTIES OF FILM TYPES

PROPERTY	TYPICAL VALUES FOR FILM TYPE*		
	120FN616	150FN019	250FN029
Ultimate Tensile Strength (MD), 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% (MD), MPa (psi) 23°C (73°F) 200°C (392°F)	 61 (9,000) 42 (6,000)	 49 (7,000) 43 (6,000)	 58 (8,500) 35 (5,000)
Stress at 5% Elongation (MD), MPa (psi) 23°C (73°F) 200°C (392°F)	 79 (11,500) 53 (8,000)	 65 (9,500) 62 (9,000)	 76 (11,000) 48 (7,000)
Ultimate Elongation (MD), % 23°C (73°F) 200°C (392°F)	 75 80	 70 75	 85 110
Tensile Modulus, (MD), GPa (psi) 23°C (73°F) 200°C (392°F)	 2.86 (415,000) 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) Kg-cm (ft-lb)	 8 (.58)	 7 (.51)	 16 (1.16)
Tear Strength (MD) – Initial (Graves) g (lbf)	 1,200 (2.6)	 1,175 (2.6)	 1,818 (4.0)
Tear Strength (MD) – Propagating (Elmendorf) g (lbf)	 8 (.02)	 48 (.11)	 58 (.13)
Weight % Polyimide Weight % FEP	80 20	57 43	73 27
Density, g/cm³	1.53	1.67	1.57

*Since 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 TEFLON® FEP fluorocarbon resin in mils. The symbol 9 is used to represent 13 μm (½ mil) and 6 to represent 2.5 μm (1/10 mil). Example: 120FN616 is a 120-gauge structure consisting of a 25 μm (1 mil) base film with a 2.5 μm (1/10 mil) coating of TEFLON on each side. See page 24 for construction explanation.

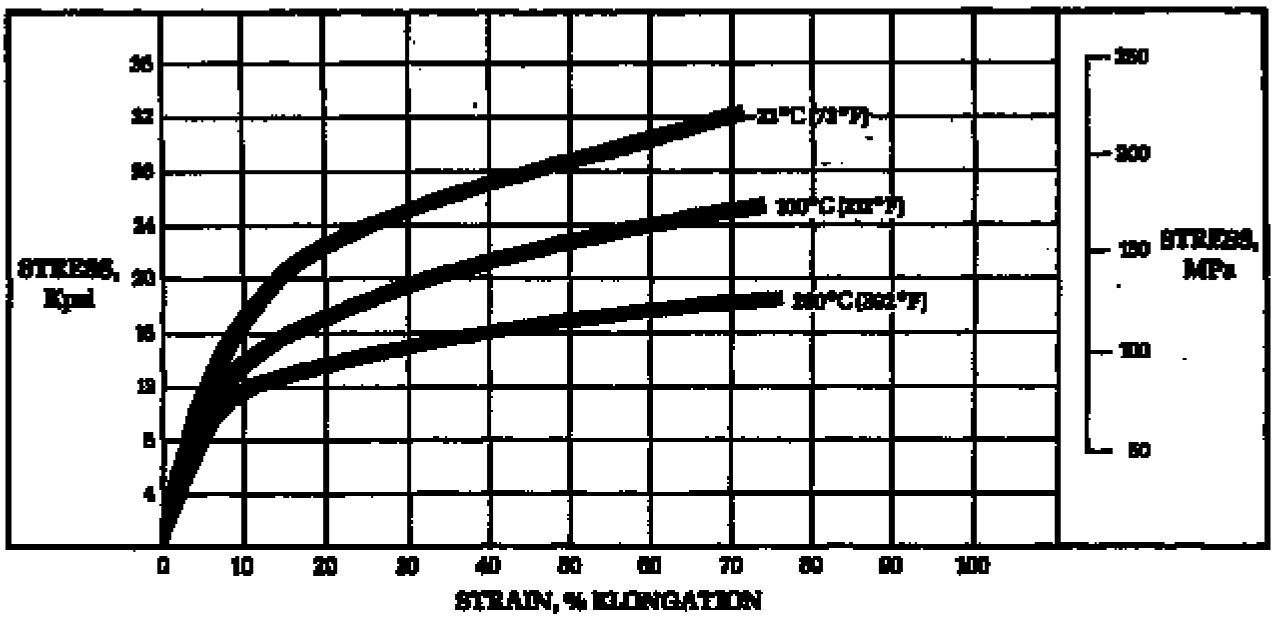
TI 0010943

MECHANICAL PROPERTIES

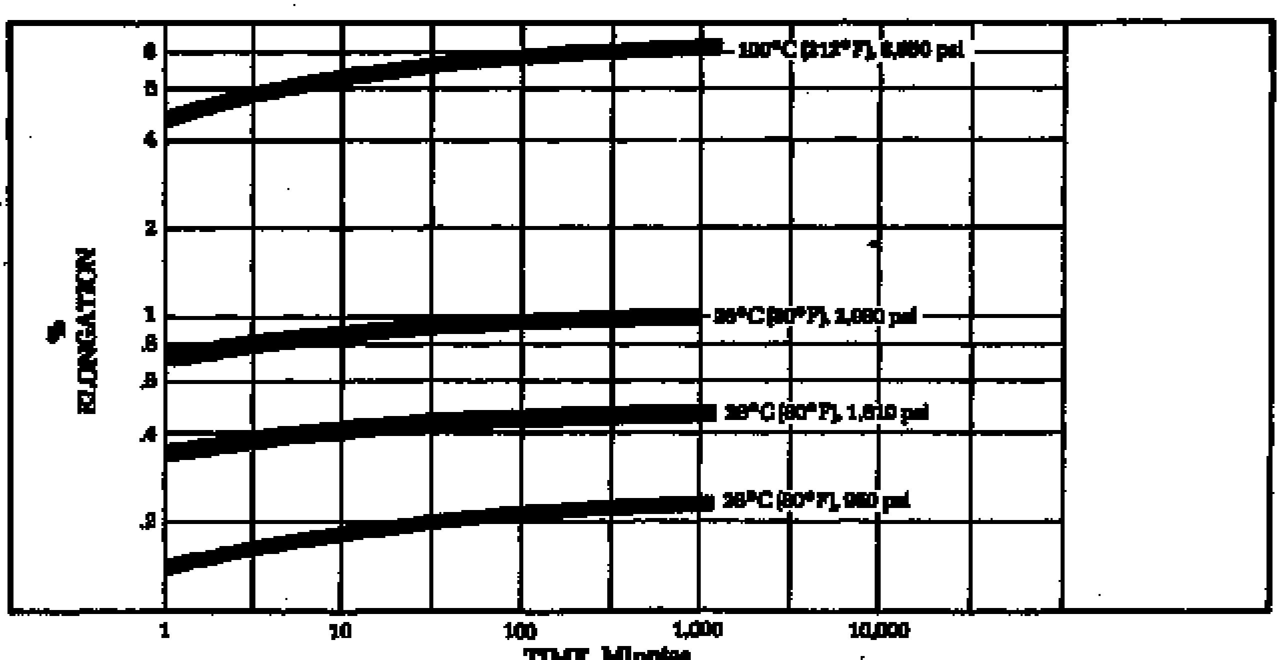
The usual values of tensile strength, tensile modulus, and ultimate elongation at various temperatures can be obtained from the typical stress-strain curves shown below. Such properties as tensile strength and modulus have an inverse relation with temperature, while elongation peaks to a maximum value at about 300°C (570°F). Other factors such as humidity, film thickness, and tensile elongation rate were found to have only a negligible effect on the shape of the 23°C (73°F) curve.

TENSILE STRESS STRAIN CURVES

(Type HN Film, 25 μm (1 mil))



TENSILE CREEP PROPERTIES



TI 0010944

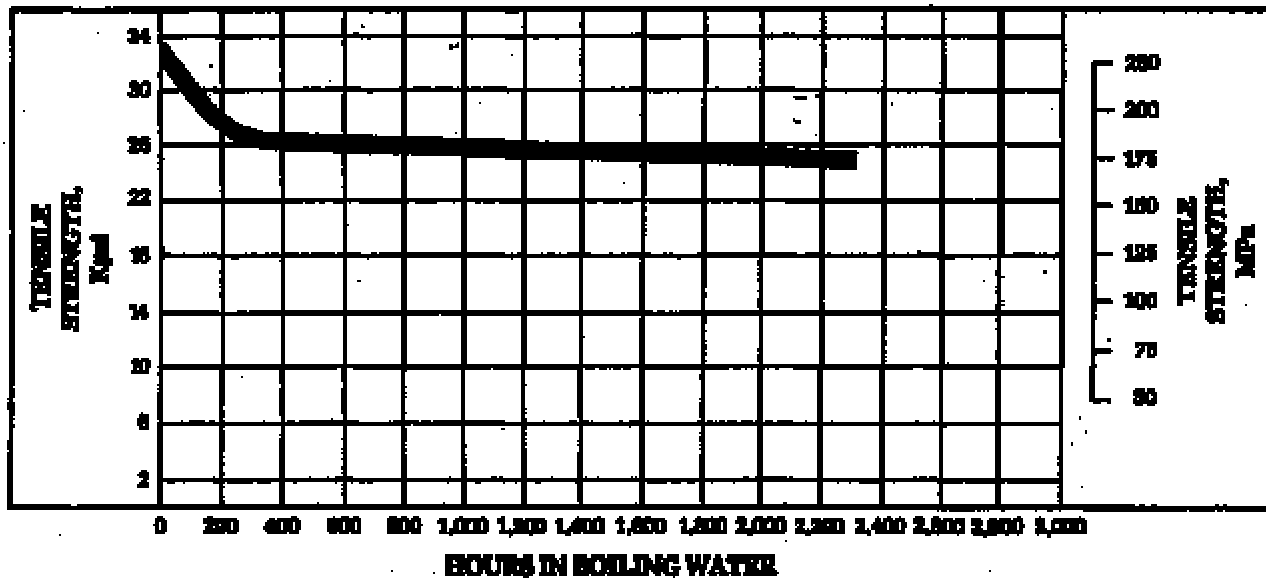
DD/NHTSA No. 3
00186

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 below, will reduce the level of film properties, sufficient tensile and elongation remain to insure good mechanical performance. A decrease in the temperature and the water content will reduce the rate of KAPTON property reduction while higher temperatures and pressures will increase it.

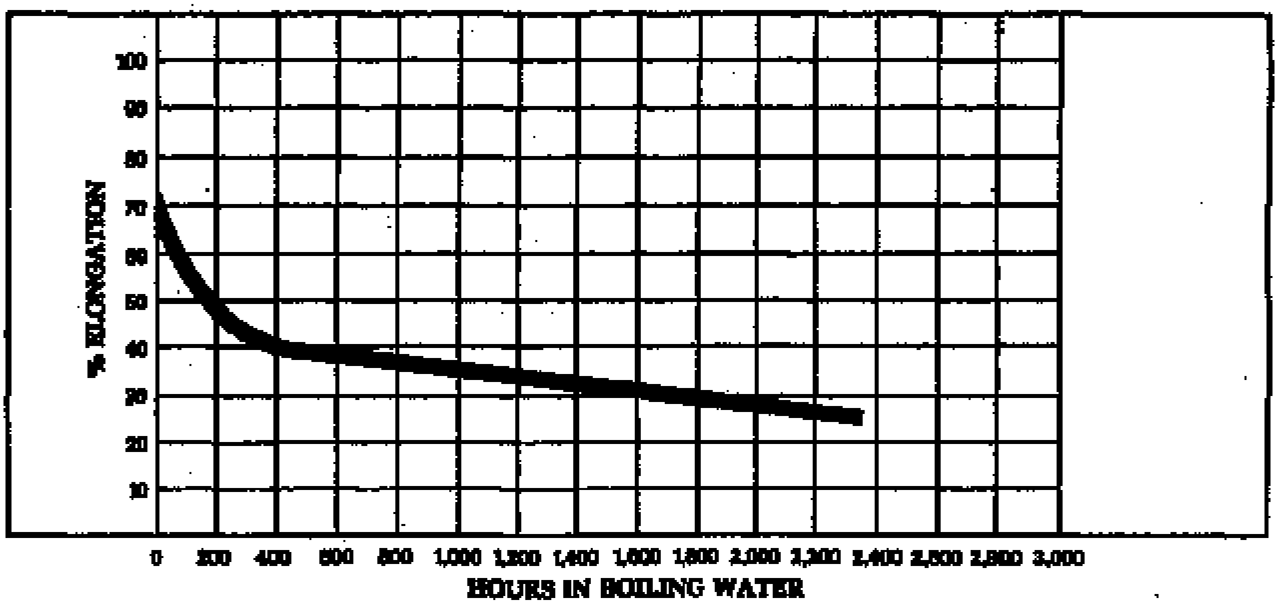
TENSILE STRENGTH AFTER EXPOSURE TO 100°C (212°F) WATER

(Type HN Film, 25 µm (1 mil))



ULTIMATE ELONGATION AFTER EXPOSURE IN 100°C (212°F) WATER

(Type HN Film, 25 µm (1 mil))



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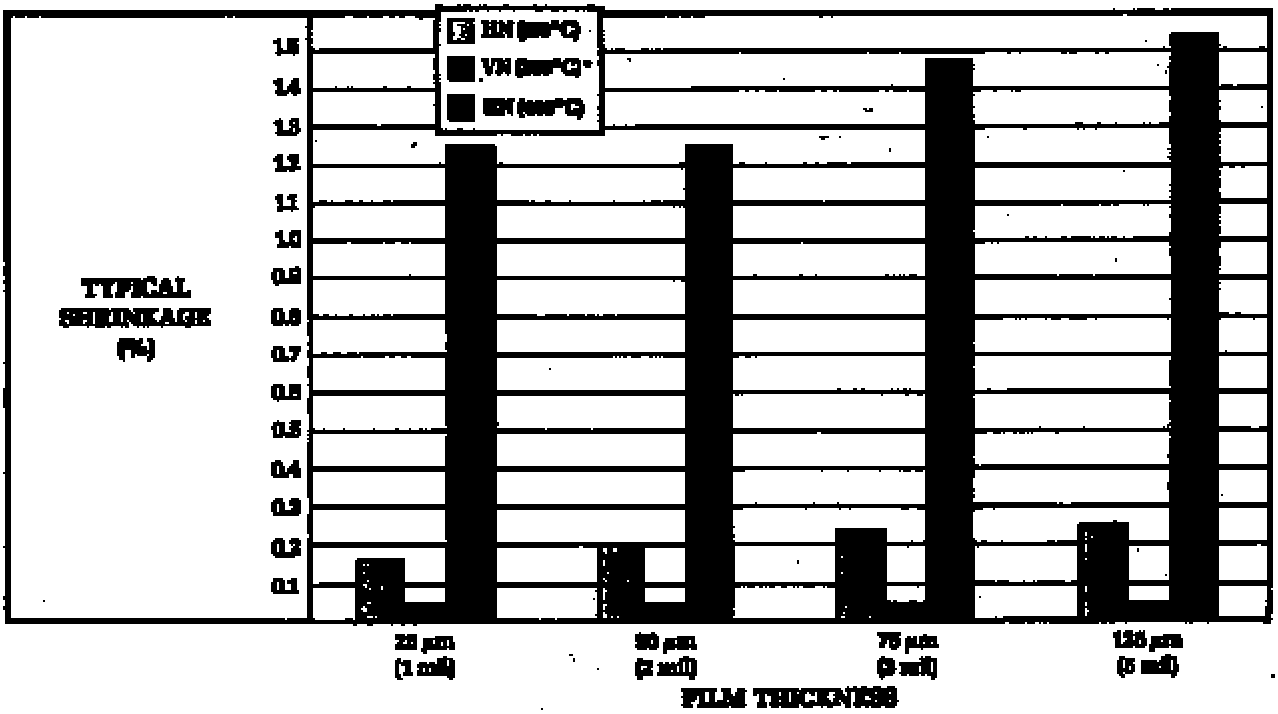
DIMENSIONAL STABILITY

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 graphs below. Once the film has been exposed, the normal values for thermal expansion listed on the bottom of this page can be expected.

RESIDUAL SHRINKAGE VS. EXPOSURE TEMPERATURE AND THICKNESS

(Type HN & VN Film)



*Type VN shrinkage is [illegible] for all thicknesses.

THERMAL COEFFICIENT OF EXPANSION

(Type HN Film, 25 µm (1 mil)) Thermally Exposed

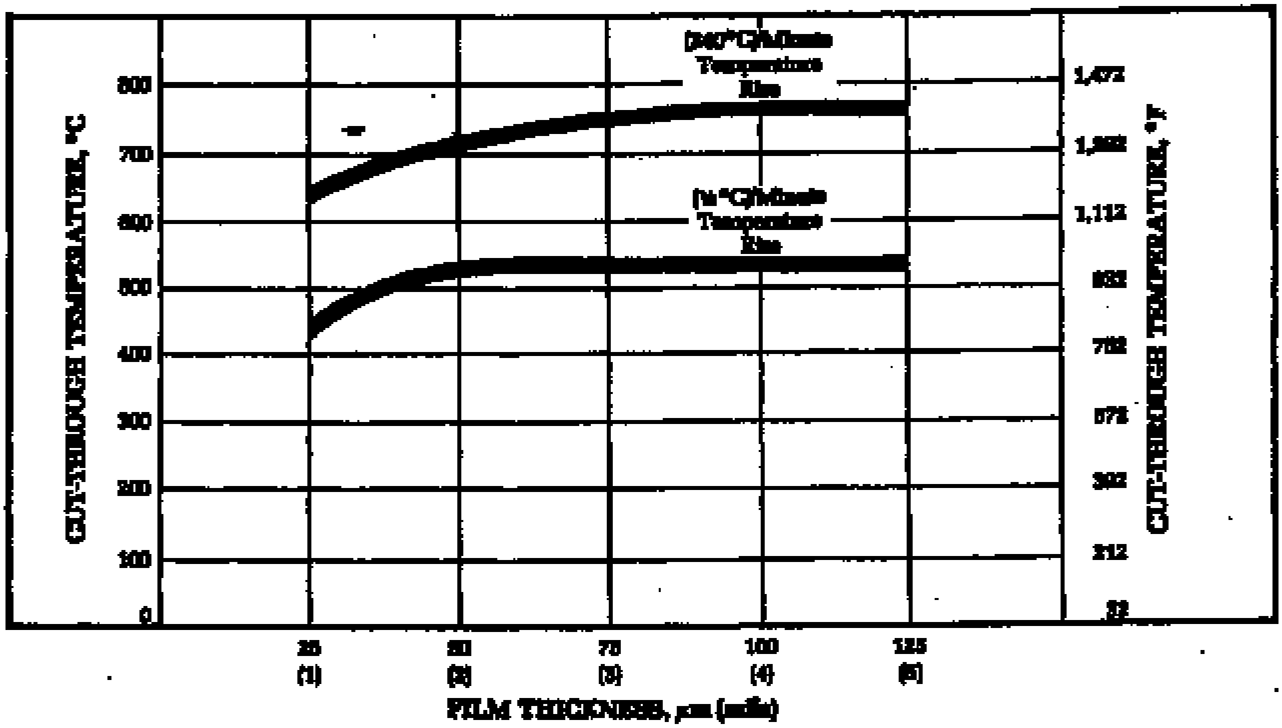
Temperature Range	ppm/°C
23-100°C (73-212°F)	18
100-200°C (212-392°F)	31
200-300°C (392-572°F)	48
300-400°C (572-752°F)	78
23-400°C (73-752°F)	46

TI 0010946

CUT-THROUGH RESISTANCE

Most organic films exhibit a tendency to flow or thin out under high compressive stresses, especially at elevated temperatures. KAPTON® polyimide film possesses an extremely high resistance to such stresses. Test procedures described in ASTM D-876-80 have been adapted to flat films to provide the data below. Stresses range from an infinitely high point load to 83 MPa (12,000 psi) at cut-through for a 25µm (1 mil) film.

CUT-THROUGH TEMPERATURE VS. RATE OF TEMPERATURE RISE AND THICKNESS (Type HN Film)



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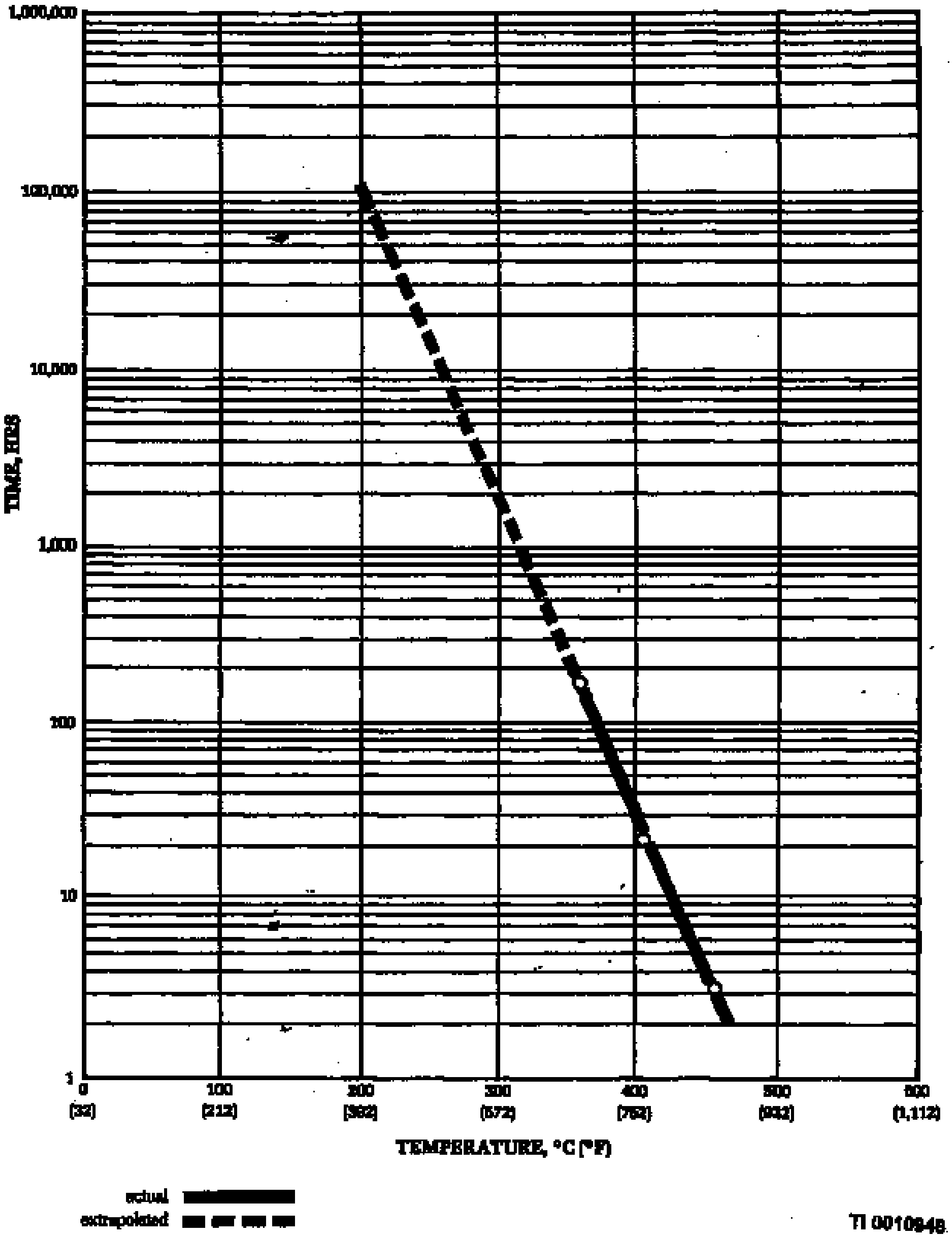
RESISTANCE TO CUT-THROUGH VS. TEMPERATURE

(Type HN Film, 25 μm (1 mil))



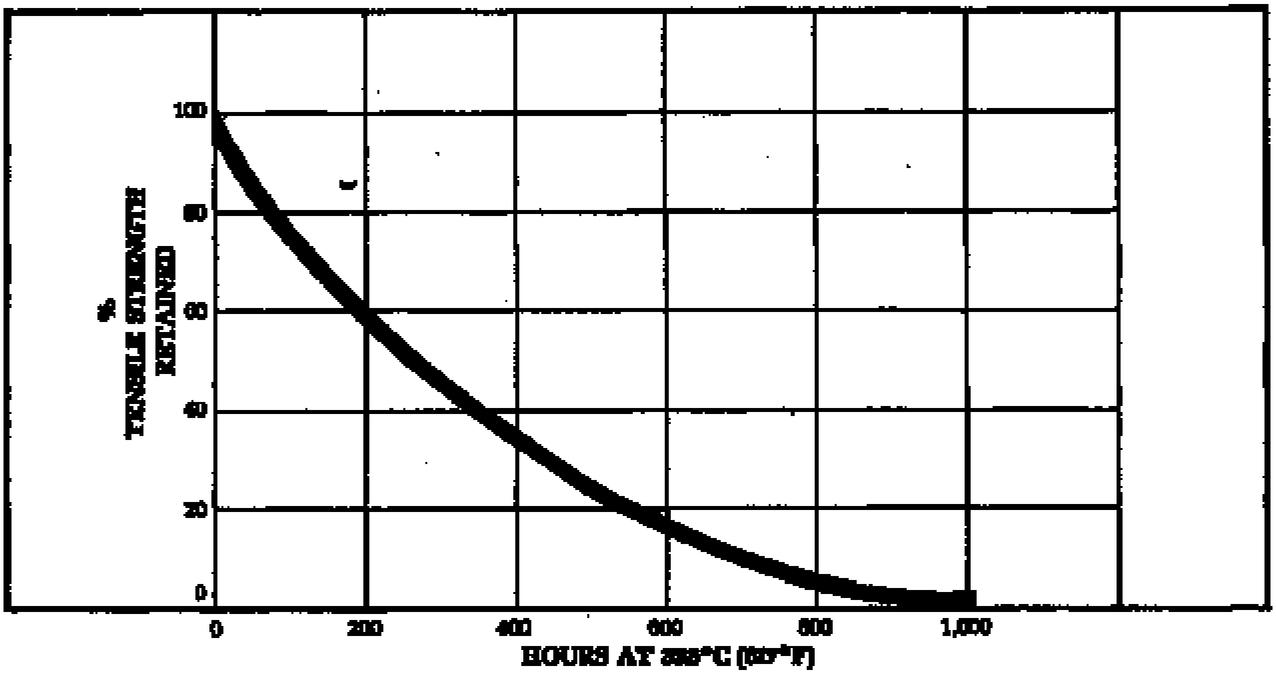
TI 0010948

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 has been determined at various temperatures. At zero time and 325°C, the tensile strength is 234 MPa (34,000 psi) and the elongation is 57 percent. The results are graphed below.

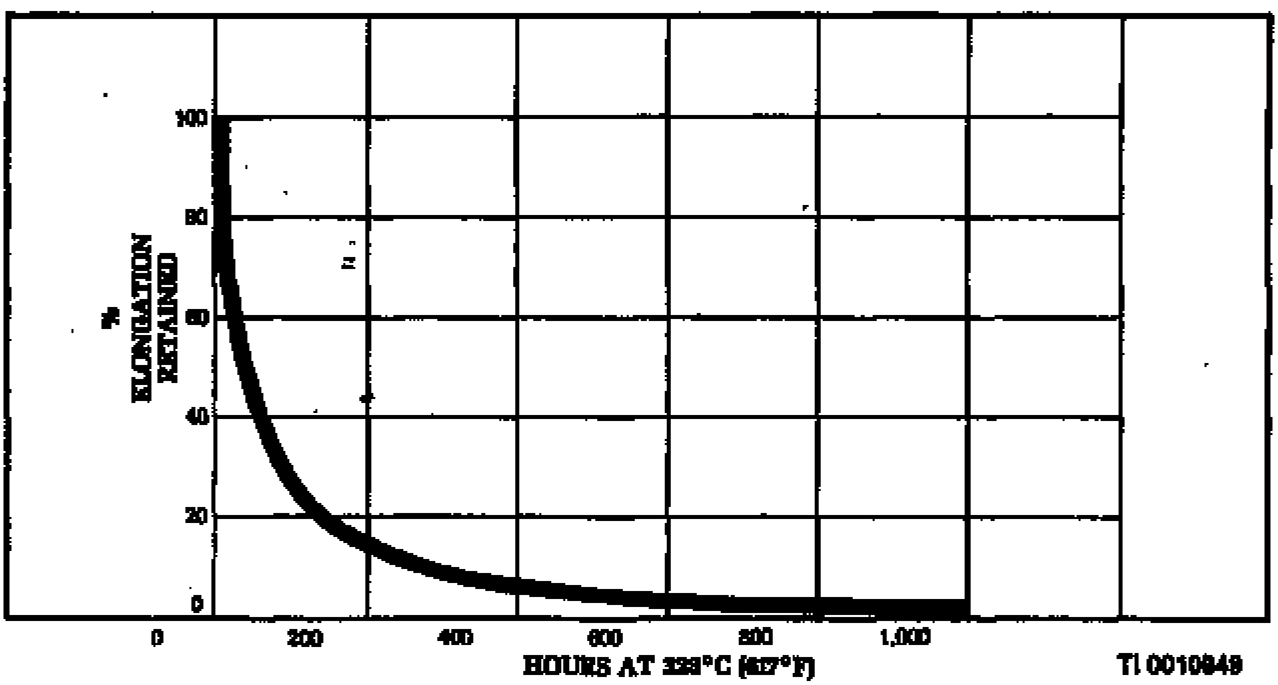
TENSILE STRENGTH VS. AGING IN AIR AT 325°C (617°F)

(Type HN Film, 25 μm (1 mil))



ULTIMATE ELONGATION VS. AGING IN AIR AT 325°C (617°F)

(Type HN Film, 25 μm (1 mil))



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DD/NITSA No. 3
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TIME REQUIRED FOR REDUCTION IN ULTIMATE ELONGATION FROM 70% TO 1%

(Type HN Film, 25 µm (1 mil))

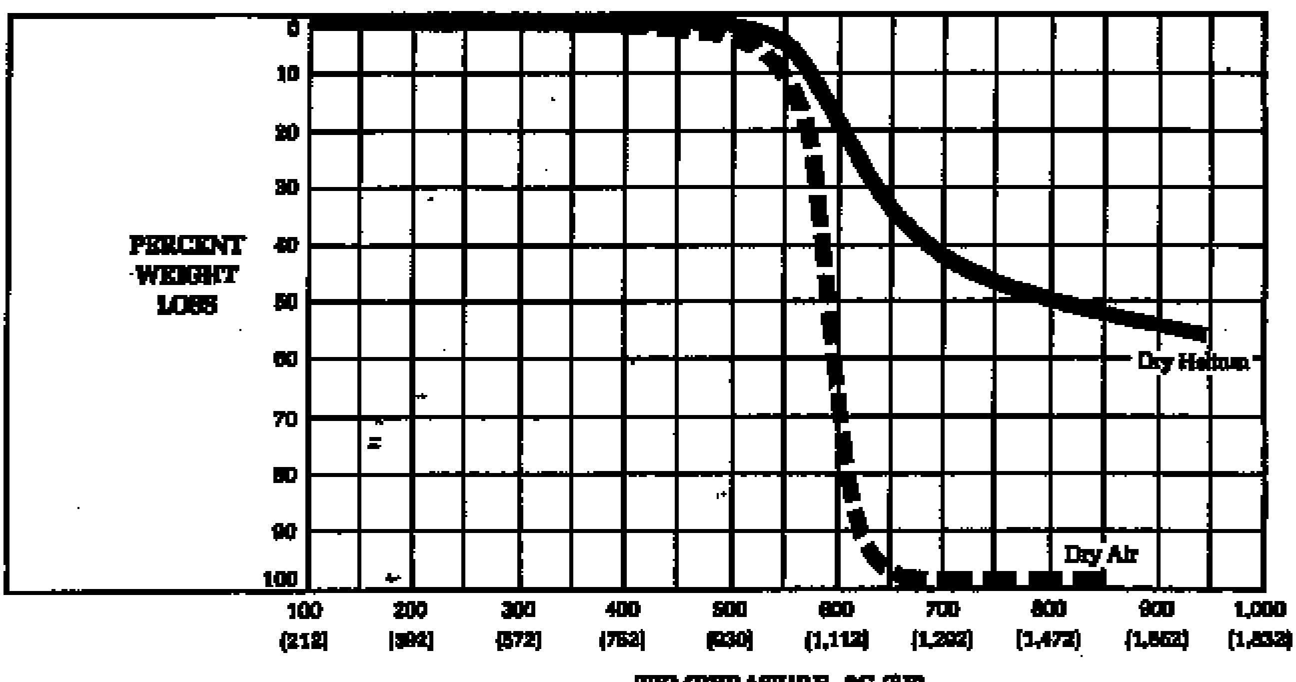
Temperature	Air Environment*
450°C (840°F)	2 hours
425°C (800°F)	5 hours
400°C (750°F)	12 hours
375°C (710°F)	2 days
350°C (660°F)	6 days
325°C (620°F)	1 month
300°C (570°F)	3 months
275°C (530°F)	1 year
250°C (480°F)	8 years

*KAPTON polyimide film is subject to oxidative degradation. Hence, when tested in a helium environment, KAPTON has shown a useful life of at least an order of magnitude greater than that in air.

WEIGHT LOSS AT (3°C)/MINUTE TEMPERATURE RISE

(Type HN Film, 25 µm (1 mil))

KAPTON® polyimide film has significantly extended life in reduced oxygen environments at high temperatures. Using a Du Pont 1090 Thermal Analyzer System, the weight loss characteristics of KAPTON in air and helium at elevated temperatures are shown below.



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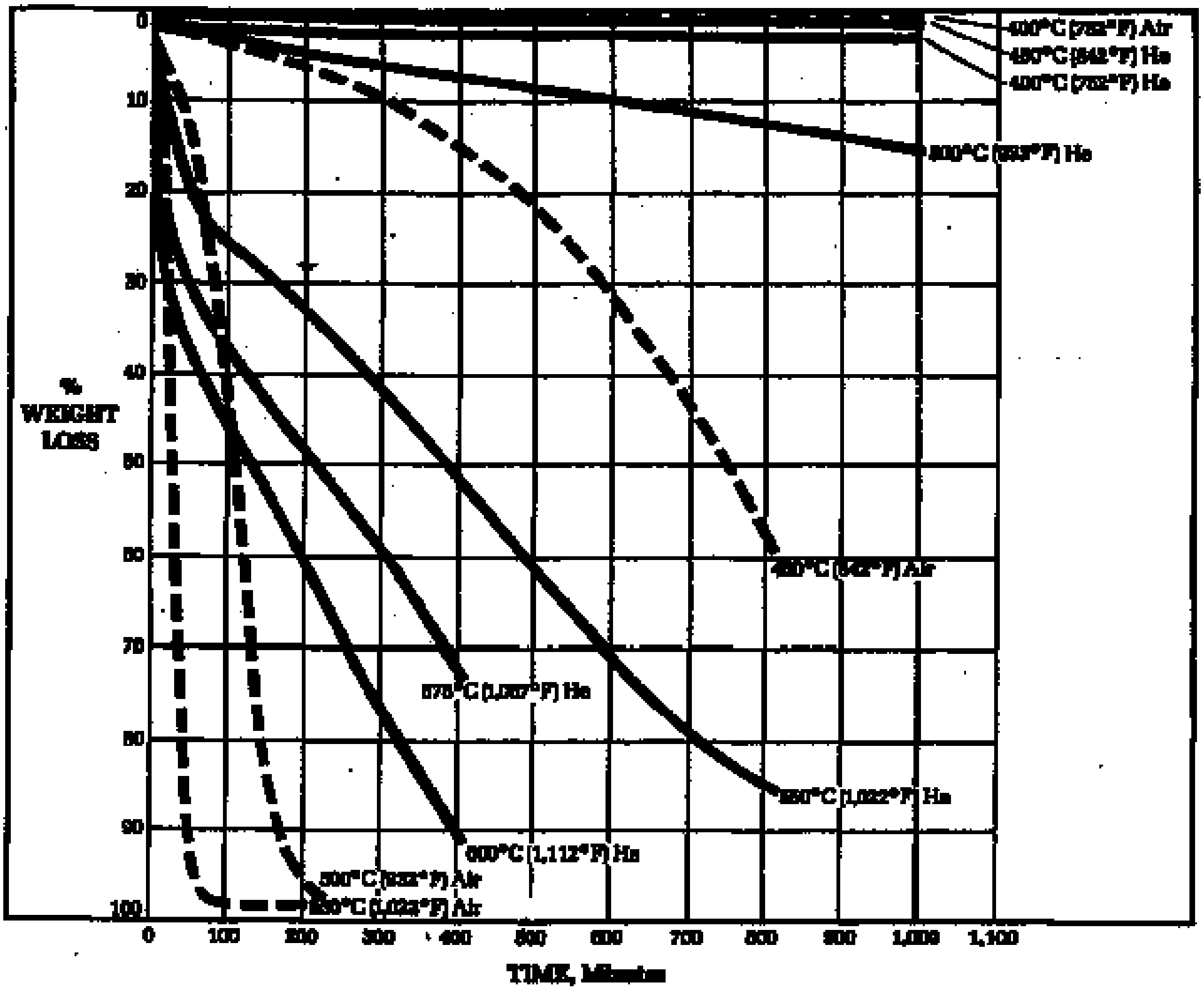
ISOTHERMAL WEIGHT LOSS

(Type HN Film, 25 μm (1 mil))



TI 0010951

ELECTRICAL PROPERTIES

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TI 0010852

DD/NHTSA No. 3
00194

KAPTON® Type HN and VN Film

TYPICAL ELECTRICAL PROPERTIES

PROPERTY	TYPICAL VALUE	TEST CONDITION	TEST METHOD
Dielectric Strength			
25 µm (1 mil)	303 v/µm 7,700 v/mil		
50 µm (2 mil)	240 v/µm 6,100 v/mil	60 hertz	ASTM D-149-81
75 µm (3 mil)	205 v/µm 5,200 v/mil	¼" electrodes	
125 µm (5 mil)	154 v/µm 3,900 v/mil	500 volts/sec rise	
Dielectric Constant			
25 µm (1 mil)	3.4	1 kilohertz	ASTM D-150-81
50 µm (2 mil)	3.4		
75 µm (3 mil)	3.5		
125 µm (5 mil)	3.5		
Dissipation Factor			
25 µm (1 mil)	.0018	1 kilohertz	ASTM D-150-81
50 µm (2 mil)	.0020		
75 µm (3 mil)	.0020		
125 µm (5 mil)	.0026		
Volume Resistivity			
25 µm (1 mil)	1.5×10^{17} ohm•cm		ASTM D-257-78 (1983)
50 µm (2 mil)	1.5×10^{17} ohm•cm		
75 µm (3 mil)	1.4×10^{17} ohm•cm		
125 µm (5 mil)	1.0×10^{17} ohm•cm		

KAPTON® Type FN Film

TYPICAL ELECTRICAL PROPERTIES

PROPERTY	120FN616	150FN019	250FN029
Dielectric Strength			
Volts/mil	6,900	5,000	5,000
Volts/µm	272	197	197
Dielectric Constant	3.1	2.7	3.0
Dissipation Factor	.0015	.0013	.0013
Volume Resistivity			
ohm•cm @ 23°C (73°F)	1.4×10^{17}	2.3×10^{17}	1.9×10^{17}
ohm•cm @ 200°C (392°F)	4.4×10^{14}	3.6×10^{14}	3.7×10^{14}

TI 0010953

DD/NHTSA No. 3
09195

EFFECT OF HUMIDITY

(Type HN Film, 25 μm (1 mil))

Because the water content of KAPTON® polyimide film can affect its electrical properties, electrical measurements were made on 1 mil film after exposure to environments of varying relative humidities at 23°C (73°F).

The results of these measurements are graphed below.

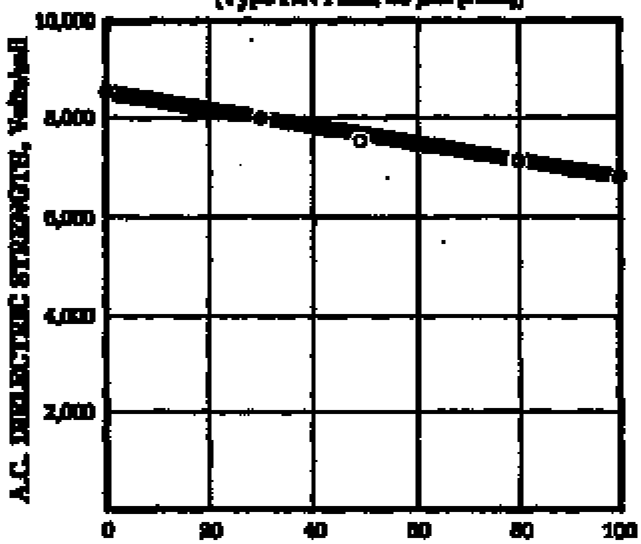
RELATIVE HUMIDITY VS. ELECTRICAL PROPERTIES OF KAPTON

% RELATIVE HUMIDITY	A.C. DIELECTRIC STRENGTH V/μm	(V/mil)	DIELECTRIC CONSTANT	DISSIPATION FACTOR
0	339	(8600)	3.0	.0015
30	315	(8000)	3.3	.0017
50	303	(7700)	3.5	.0020
80	280	(7100)	3.7	.0027
100	268	(6800)	3.8	.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.

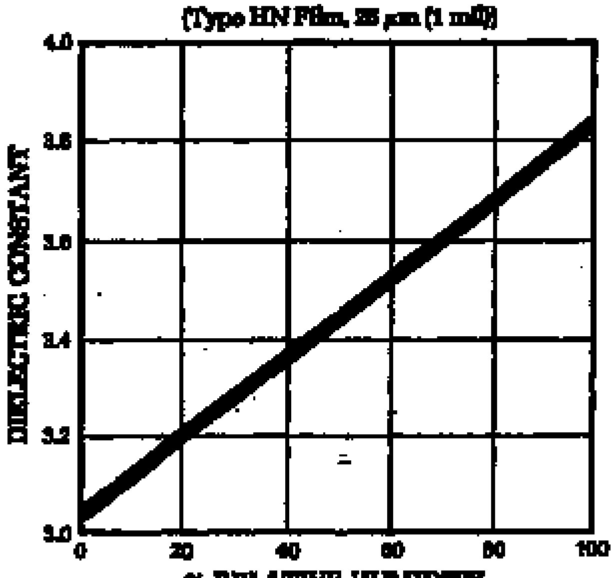
A.C. DIELECTRIC STRENGTH VS. RELATIVE HUMIDITY

(Type HN Film, 25 μm (1 mil))



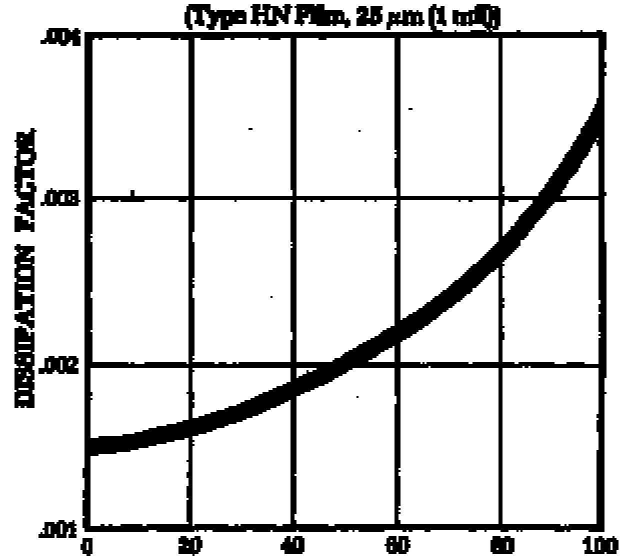
DIELECTRIC CONSTANT VS. RELATIVE HUMIDITY

(Type HN Film, 25 μm (1 mil))



DISSIPATION FACTOR VS. RELATIVE HUMIDITY

(Type HN Film, 25 μm (1 mil))



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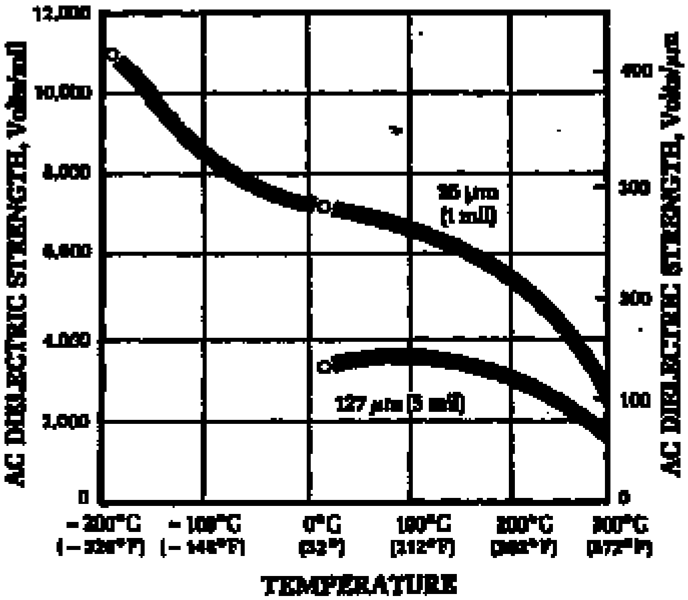
EFFECT OF TEMPERATURE

As the graphs below indicate, extreme changes in temperature have relatively little effect on the excellent room temperature electrical properties of KAPTON® polyimide film.

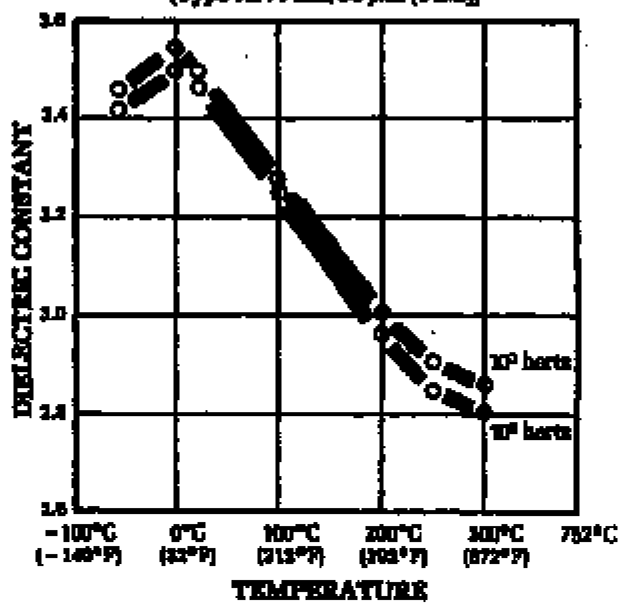
AC DIELECTRIC STRENGTH VS. TEMPERATURE

(Type HN Film, 25 μm (1 mil))



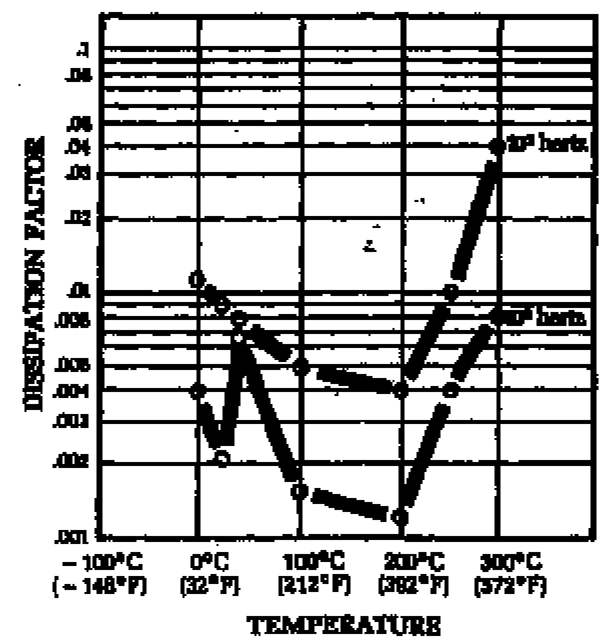
DIELECTRIC CONSTANT VS. TEMPERATURE

(Type HN Film, 25 μm (1 mil))



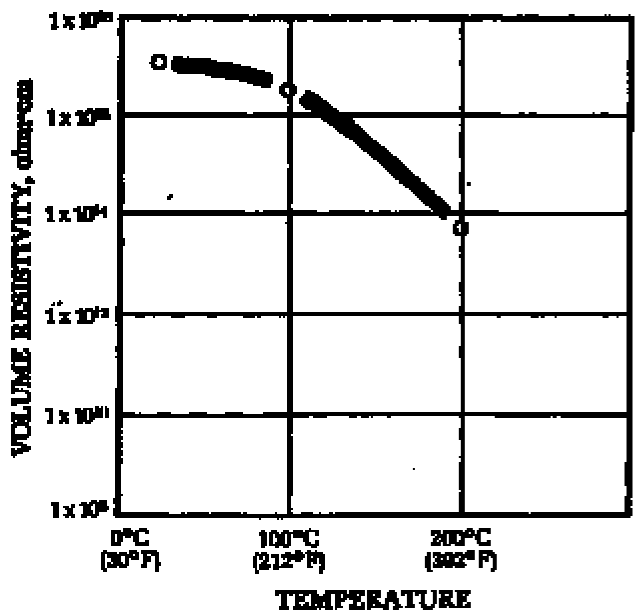
DISSIPATION FACTOR VS. TEMPERATURE

(Type HN Film, 25 μm (1 mil))



VOLUME RESISTIVITY VS. TEMPERATURE

(Type HN Film, 25 μm (1 mil))



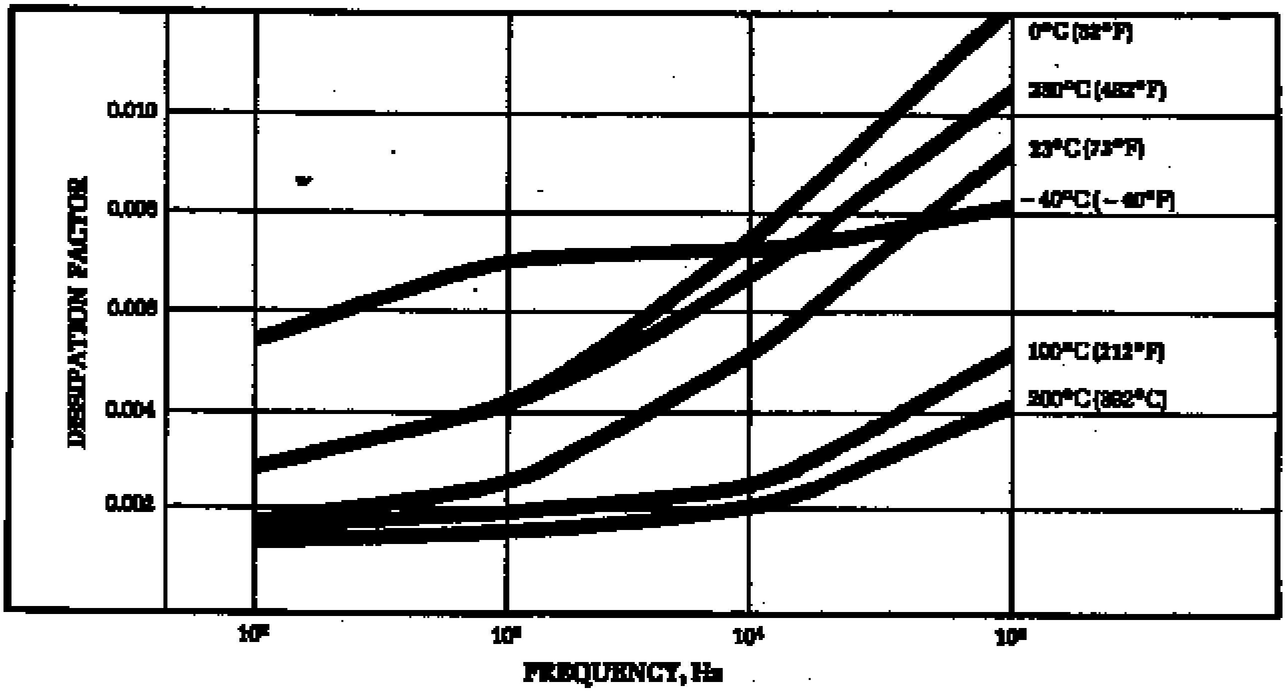
TI 0010955

EFFECT OF FREQUENCY

The effects of frequency on the value of the dielectric constant and dissipation factor at various isotherms are shown below.

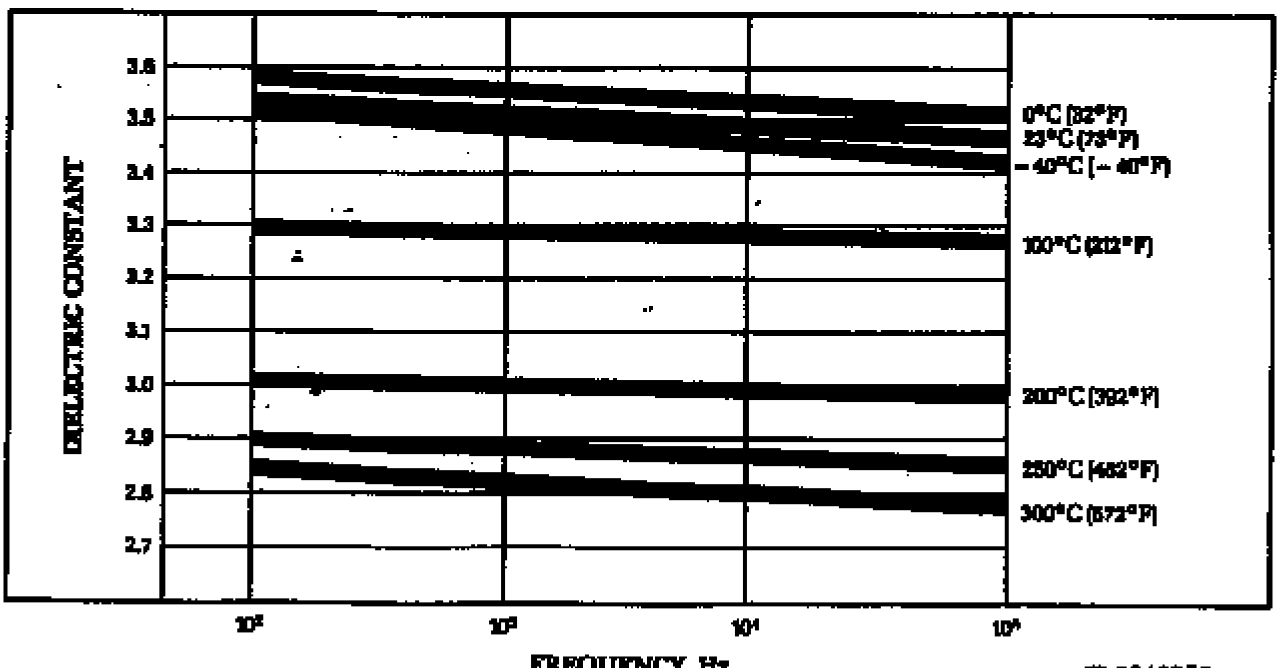
DISSIPATION FACTOR VS. FREQUENCY

(Type HN Film, 25μm (1 mil))



DIELECTRIC CONSTANT VS. FREQUENCY

(Type HN Film, 25 μm (1 mil))



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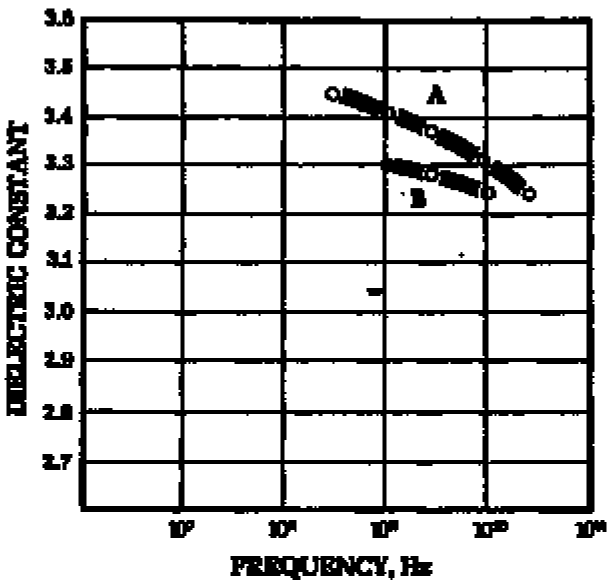
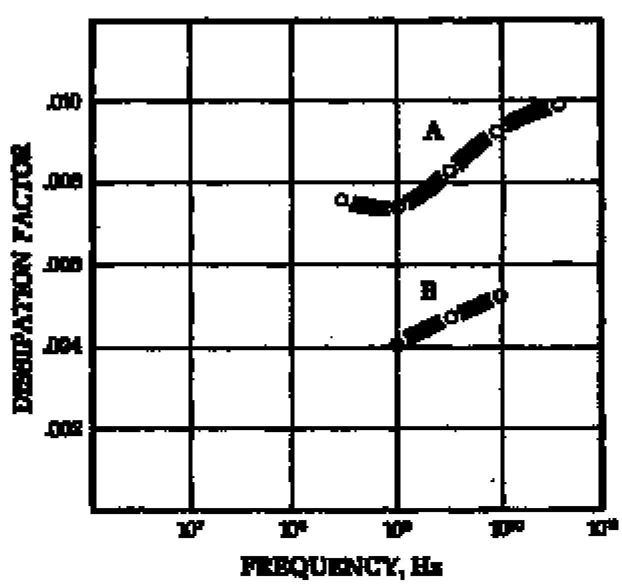
DIELECTRIC PROPERTIES IN GIGAHERTZ FREQUENCY RANGE

[Type HN Film, 125μ (5 mil)]*



[Type HN Film, 125μm (5 mil)]*



*Technical Report AFML-TR-[illegible]—Curve A is 500H KAPTON as received and measured at [illegible]°C and [illegible]% RH with the electric field in the plane of the sheet. Curve B is the same measurement after conditioning the film at [illegible]°C for [illegible] hours. Performance of 500HN is believed equivalent to 500H.

TRACKING RESISTANCE

A 125μm (5 mil) KAPTON® polyimide film, Type HN, has a tracking resistance of 181 seconds as measured by ASTM D-495-64. The failure was due to true tracking rather than erosion, etc.

CORONA LIFE

Like all organic materials, KAPTON is attacked by corona and will ultimately fail dielectrically when exposed continuously to corona. At moderate levels of corona exposure, devices insulated with KAPTON have survived up to 3,000 hours, giving reasonable assurance that brief exposures to corona will not significantly affect the life of a properly designed insulation system based on KAPTON.

Corona threshold voltage and corona intensity are functions of many parameters, including insulation thickness, air gap thickness, and device shape. Consult with a Du Pont technical representative on the suitability of KAPTON for specific applications where corona may be present.

TI 0010957

CHEMICAL PROPERTIES

KAPTON® Type HN Film 25 μm (1 mil)

CHEMICAL PROPERTIES

PROPERTY	TYPICAL VALUES (25 μm (1 mil)) % Tensile Retained	% Elongation Retained	TEST CONDITION	TEST METHOD
CHEMICAL RESISTANCE				
Isopropanol	96	94	10 min @ 23°C	IPC TM-650 Method 2.3.2B
Toluene	99	91		
MEK	99	90		
Methylene Chloride/ Trichloroethylene (50/50)	98	85		
2N HCl	98	89		
2N NaOH	82	54		
FUNGUS RESISTANCE	Nonnutrient			IPC TM-650 Method 2.6.1
MOISTURE ABSORPTION	1.8% Type HN & VN		50% Relative Humidity at 23°C	ASTM D-570-81
	2.8% Type HN & VN		Immersion for 24 hrs at 23°C (73°F)	
HYGROSCOPIC COEFFICIENT OF EXPANSION	22 ppm/% RH		23°C (73°F), 20-80% Relative Humidity	
PERMEABILITY				
GAS	cc/(100 in²•24 hr•atm)		23°C (73°F), 50% Relative Humidity	ASTM D-1434-82
Carbon Dioxide	45			
Oxygen	25			
Hydrogen	250			
Nitrogen	6			
Helium	415			
VAPOR				
Water	g/(m²•d) 54	g/(100 in²•24 hr) 3.5		ASTM E-96-80

RADIATION RESISTANCE*

PROPERTY	TYPICAL VALUES (25 μm (1 mil)) % Tensile Retained	% Elongation Retained	TEST CONDITION	TEST METHOD
Gamma (Savannah River)	Still Flexible (180° Bend)		Exposure: 4.16 × 10⁷ Gy	
Electron (Van de Graaf)	Retains 50% of Original Elongation		Exposure: 6 × 10⁷ Gy	
Neutron Plus Gamma (Brookhaven)	Darkened but Tough		Exposure: 10⁵ Gy	

*Due to its excellent radiation resistance, KAPTON is frequently used in high radiation environments where a thin, flexible insulating material is required. In outer space, KAPTON is used both alone and in combination with other materials where radiation resistance at minimum weight is necessary. KAPTON is also used in nuclear reactors and linear accelerators. Many of these applications require testing that 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 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 which protect KAPTON from direct exposure to LOCA sprays are required.

TI 0010959

KAPTON® Type VN Film

CHEMICAL PROPERTIES

Typical chemical properties for Type VN film are similar to Type HN.

KAPTON® Type FN Film

CHEMICAL PROPERTIES

PROPERTY	120FN616	150FN019	400FN022
Moisture Absorption			
@ 23°C (73°F), 50% R.H.	1.3%	0.8%	0.4%
98% R.H.	2.5%	1.7%	1.3%
Water Vapor Permeability			
$g/m^2 \cdot d$	17.5	8.5	2.4
$g/100\ in^2 \cdot 24\ hrs$	1.13	.55	.16

TI 0010960

[illegible]

TYPE AND THICKNESS

TYPE	NOMINAL THICKNESS µm	NOMINAL THICKNESS mils	AREA FACTOR m²/kg	AREA FACTOR ft²/lb
30 HN	8	0.3	84	410
50 HN	13	0.5	55	272
75 HN	19	0.75	42	204
100 HN	25	1.0	28	136
200 HN	50	2.0	14	68
300 HN	75	3.0	9.2	45
500 HN	125	5.0	5.5	27
50 VN	13	0.5	55	272
75 VN	19	0.75	42	204
100 VN	25	1.0	28	136
200 VN	50	2.0	14	68
300 VN	75	3.0	9.2	45
500 VN	125	5.0	5.5	27
100FN099	25	1.0	23	110
120FN616	30	1.2	21	104
150FN999	38	1.5	14	68
150FN019	38	1.5	16	77
200FN011	50	2.0	11	54
200FN919	50	2.0	11	54
250FN029	63	2.5	10	49
300FN021	75	3.0	8.0	39
300FN929	75	3.0	8.0	39
400FN022	100	4.0	5.5	27
400FN031	100	4.0	6.1	30
500FN131	125	5.0	4.7	23
600FN051	150	6.0	4.3	21

NOMINAL CONSTRUCTION, Type FN Film

In the KAPTON® Type FN order code of 3 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 TEFLON® FEP fluorocarbon resin in mils. The symbol 9 is used to represent 13 µm (½ mil) and 6 to represent 2.5 µm (1/10 mil). Example: 120FN616 is a 120-gauge structure consisting of a 25 µm (1 mil) base film with a 2.5 µm (1/10 mil) coating of TEFLON on each side. Illustrated are several examples of the many types available.

TYPE	CONSTRUCTION FEP µm	FEP mils	HN µm	HN mils	FEP µm	FEP mils
100FN099			13	0.50	13	0.50
120FN616	2.5	0.10	25	1.00	2.5	0.10
150FN999	13	0.50	13	0.50	13	0.50
150FN019			25	1.00	13	0.50
200FN011			25	1.00	25	1.00
200FN919	13	0.50	25	1.00	13	0.50
250FN029			50	2.00	13	0.50
300FN021			50	2.00	25	1.00
300FN929	13	0.50	50	2.00	13	0.50
400FN022			50	2.00	50	2.00
400FN031			75	3.00	25	1.00
500FN131	25	1.00	75	3.00	25	1.00
600FN051			125	5.00	25	1.00

SAFETY AND HANDLING

Unheated KAPTON® polyimide film is insoluble in most common organic solvents after immersion for up to a year. However, KAPTON is dissolved by strong acids such as fuming nitric and concentrated sulfuric acid, particularly on heating, and is hydrolyzed by alkali and superheated steam.

KAPTON Type FN exhibits better chemical and oxidative resistance than Types HN and VN.

KAPTON film can be used safely at elevated temperatures with proper ventilation. At elevated temperatures, KAPTON can release small amounts of dimethyl acetamide residual solvent. Adequate ventilation in accordance with OSHA (29 CFR 1910.1000) will provide safe handling and use.

For additional information, users should refer to the following bulletin:

KAPTON® Polyimide Film – Safe Handling   E-72084

TI 0010863

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All inquiries should be directed to:

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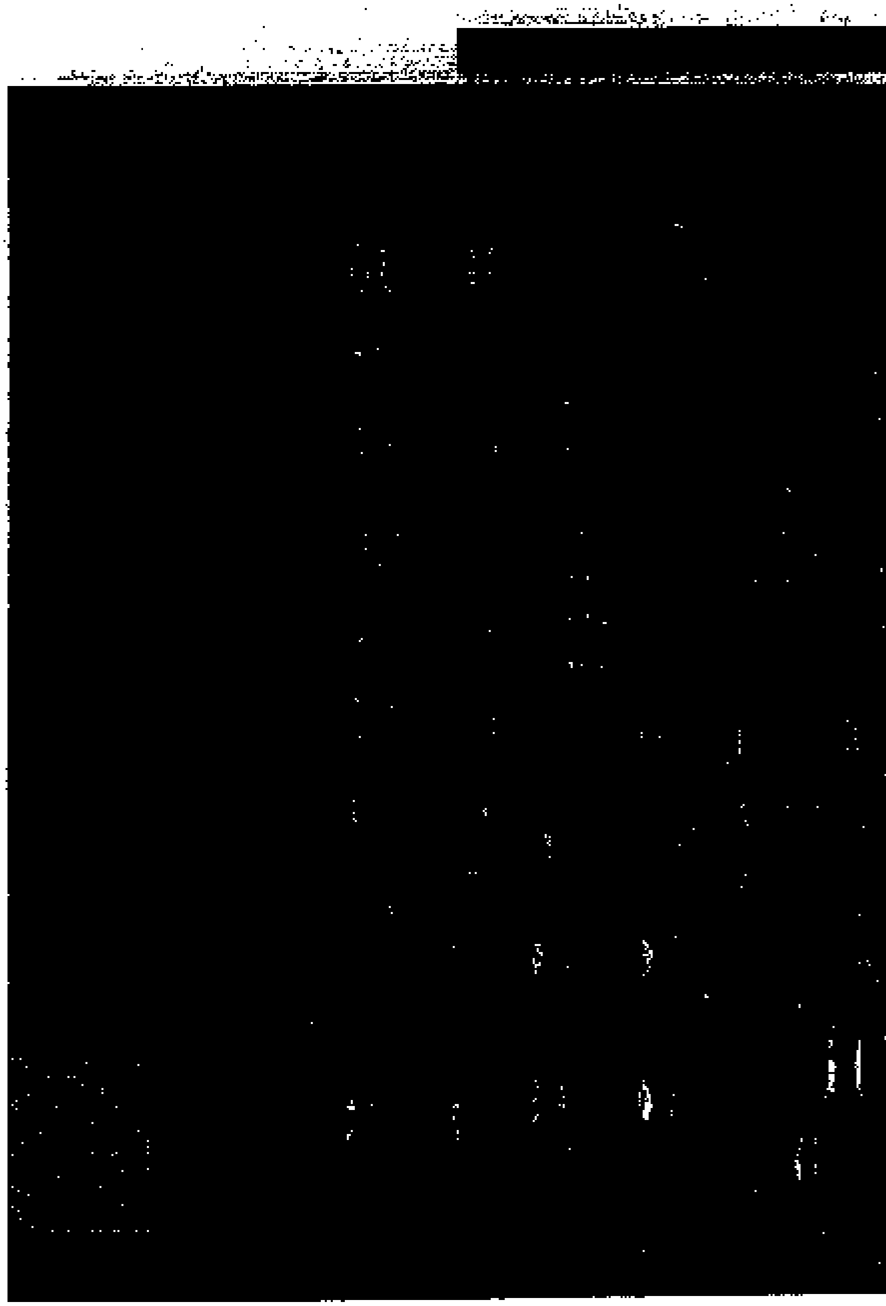
Kapton® Polyimide Film
FPC-E for
Fine Line and Metallized FPC

DuPont
Electronics

High Performance Films

- New E-Polymer Formulation
- Designed for Metallization
- Tailored Dimensional Properties (Thermal Expansion Matched to Copper)
- Low Absorption and Less Expansion in Water
- High/Durable Adhesion (85°C/85% RH)
- Low Level of Surface Contamination
- High Modulus



Available:
100FPC-E
200FPC-E
300FPC-E

DUPONT

TI 0010966

Kapton® FPC-E for High Resolution and Metallized FPC	
Market Coordinator-Harland Tate	**Technical Service-Steve Simpson**
Industry Need	**Typical Kapton® FPC-E Feature (Average)**
■ Tailored dimensional properties	■ CTE = 17 PPM/°C (35-260°C) CHE = 9 PPM/% RH Shrinkage = 0.03% (200°C)
■ Low water absorption	■ 2.2%
■ High/durable adhesion	■ >8 pli 90+% retension, 250 hrs at 85°C/85% RH
■ High modulus	■ 800 Kpsi
■ Higher productivity	■ Fast drying rate Fast adhesive cure rate Better stiffness for stability during processing

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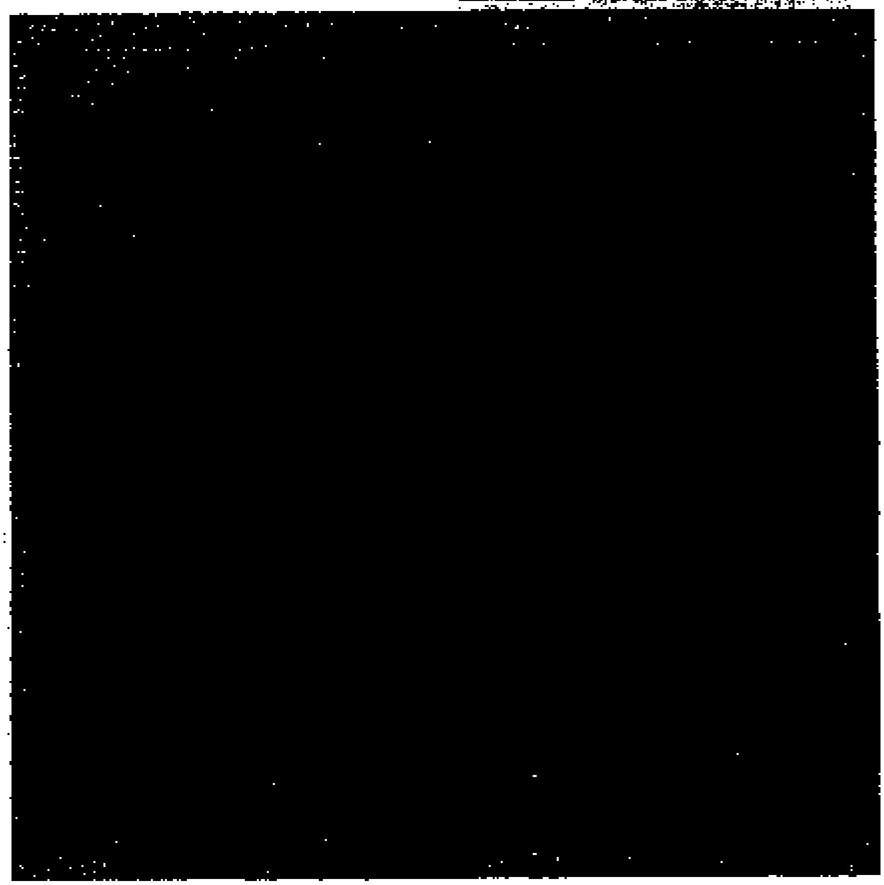
Kapton® Polyimide Film
TAB-E for High Resolution TAB

DuPont Electronics

High Performance Films

- New E-Polymer Formulation
- Substrate Film for either 2-layer (metallized) or 3-layer (adhesive coated) TAB
- High Modulus
- Tailored Dimensional Properties (Thermal Expansion Matched to Copper)
- Low Absorption and Less Expansion in Water
- High/Durable Adhesion (85°C/85% RH)
- Easily Etchable
- Fast Drying Rate
- Fast Adhesive Cure Rate



Available:
200TAB-E
300TAB-E

TI 0010963

DUPONT

Kapton® TAB-E for High Resolution TAB

Market Coordinator-Harland Tate	Technical Service-Steve Simpson
Industry Need	**Typical Kapton® TAB-E Feature (Average)**
■ High modulus	■ 800 Kpsi
■ Tailored dimensional properties	■ CTE = 17 PPM/°C (35-260°C) CHE = 9 PPM/% RH Shrinkage = 0.03% (200°C)
■ Low water absorption	■ 2.2%
■ High/durable adhesion	■ >6 pli 90+% retention, 250 hrs at 85°C/85% RH
■ Etchable	■ Common caustic solutions
■ Higher productivity	■ Fast drying rate Fast adhesive cure rate Better stiffness for stability during processing

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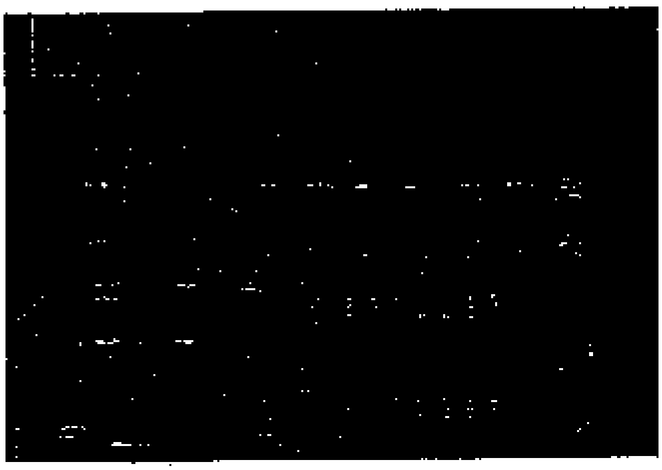
KAPTON® Polyimide Film
Advanced Flexible Dielectric Substrates For FPC/TAB Applications

DuPont Electronics

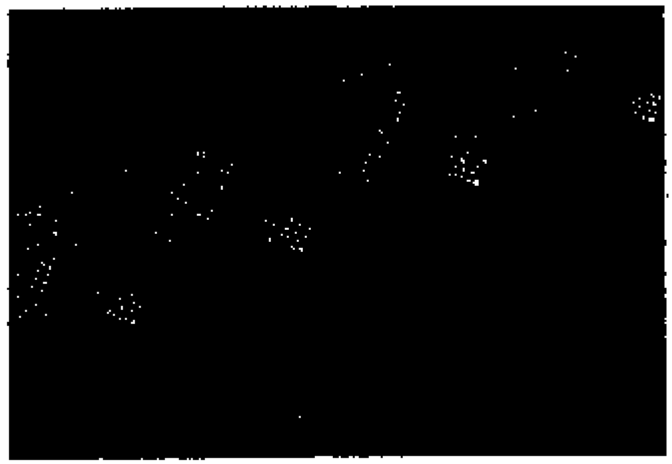
High Performance Films

J.A. Kreuz, S.N. Milligan, and R.F. Sutton

Flexible Printed Circuits

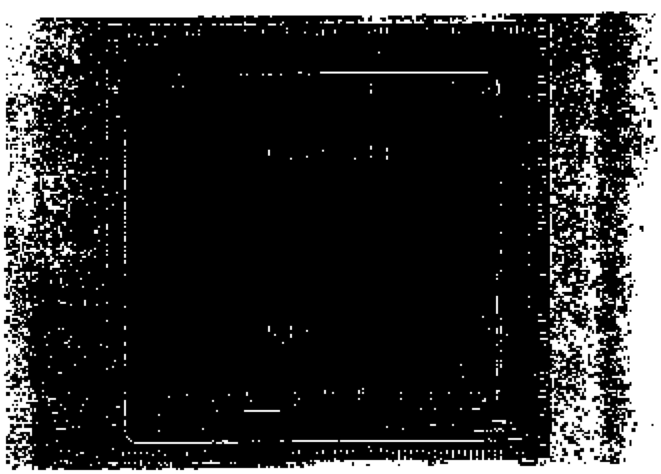


Fine Line

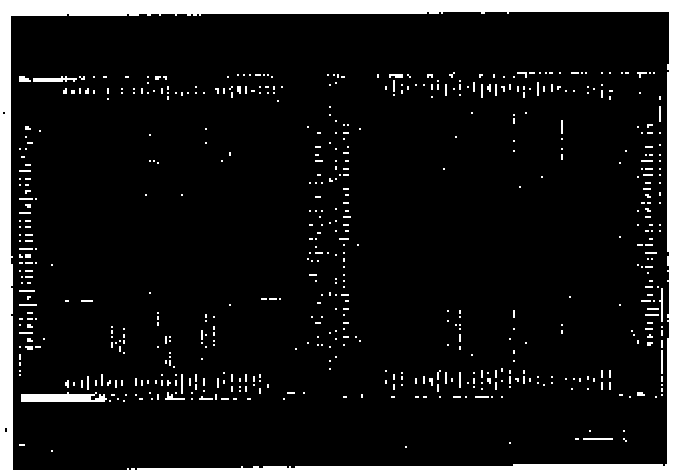


Roll Clads

Tape Automated Bonding



High Resolution TAB



TAB

DUPONT

TI 0010870

Introduction and Background

KAPTON polyimide film is a substrate used in flexible printed circuits (FPC), that provides significant advantages for both processing of circuitry and functionality of circuitry. Processing advantages include the capability to fabricate from roll to roll, high mechanical strength, and unique distortional resistance to harsh environments such as high temperature bonding stations and corrosive aqueous etchants.

Historically, functionality advantages have included several areas. Circuitry is dielectrically very reliable with excellent adhesion of the conductors. Its thinness and flexibility allow it to be installed into small volumes, requiring intricate and severe folding. These time-tested advantages have led to numerous applications. Examples are FPC's for electronic cameras, calculators, computers, communications equipment, distance detectors, aircraft harnesses, solar panels, space vehicles, missiles, etc. (Ref. 1). Additionally, a very specialized use in FPC's, where polyimide film has been utilized predominantly, is in Tape Automated Bonding (TAB). KAPTON polyimide film was in fact a component of the original TAB product when it was introduced by GE as the Minimod process in the early 1970's (Ref. 2 & 3). Still another form of FPC's is multilayer FPC's, which place additional demands on substrate mechanical and chemical properties.

Performance demands of polyimide film as a dielectric substrate for FPC applications have intensified greatly since its commercial introduction in 1965. These greater demands have stemmed from the design impetus for all circuitry, which is the progression to ultra-miniaturization of solid state memory and logic devices with increasingly greater lead counts. Continually higher circuit density is required to permit bonding to these various devices. As technology progresses, the design engineer, in desire for less expensive substrates, seeks thinner dielectrics, which will not distort under mechanical stresses of processing, and also dimensionally inert materials that defy exposure to heat and chemicals of processing. Along with greater functionality, there is the attendant quest for higher production yields.

Assessments of those properties of dielectric substrates which need improvements have been the subject of several recent papers, and of market studies by Du Pont. Heisinger (Ref. 4 & 5) has considered TAB substrate materials from the aspects of their functionality. Moniinger (Ref. 6) has further defined the properties needed. Even though most literature addresses the needs of the TAB substrate, the properties of an ideal FPC substrate, including multilayer flex, are probably about equivalent. The incentive for emphasis on TAB is that it offers an inexpensive route to gang bonding IC chips, and appears to be a commercially emerging technology, despite its 20 year age.

The general conclusion is that low CTE, low shrinkage to heat, low moisture absorption, high tensile modulus, and good chemical etchability are critical to advanced functionality. Additionally, the new substrates must not be inferior in electrical properties, nor in adhesiveless plating behavior, as compared to existing aromatic polyimide films. Indeed, we concur that these are the key properties requiring improvement. Accordingly, the most important *quantitative* property levels that have represented our product goals are summarized in Table 1.

Table 1

Properties of an Ideal TAB and High Performance FPC Substrate

Property	Goal Level
Shrinkage, 200°C, mils/in.	0.1
CTE, 35°-250°C, ppm/°C	17
Modulus, 23°C, Kpsi	750
H_2O Absorption, %	1.5
Chemically Etchable	Yes

Rationale for the properties of an ideal TAB/FPC substrate, shown in Table 1, are often dependent on subjective criteria, but some explanation for the quantitative values is in order. Shrinkage was established at 0.1mil/in, because it affords excellent ability to to precisely and repetitively align personality windows for the TAB process. It also affords precise registration of through-holes for multilayer applications, and of installation holes for large circuits. Further, low shrinkage provides consistent registration of the artwork pattern in circuitry connections. The CTE of 17ppm was chosen because of its match to copper from room temperature to solder bath temperatures (Ref. 7), for without such a match the stresses during a thermal change of several hundred degrees Celsius would cause excessive distortions. A modulus of 750Kpsi is believed to be an economic incentive, because it allows the design engineer to obtain adequate stiffness with 3-3mil film as an alternative to 5mil film with a modulus of 400Kpsi. A stiffer film is also easier to process into laminate.

Water absorption is a subjective goal to some extent, but the specific value of 1.5% is about at the limit of aromatic polyimides; another step forward to other polymeric structures is believed to be required to dramatically lower moisture absorption. Furthermore, moisture content of about 2% is about the limit of tolerance of most polyimide copper clads to sudden excursions to 250-300°C during TAB bonding without blistering.

Chemical etchability, with common polyimide etchants such as NaOH, or KOH, is advantageous, because some processes use etchants to make various holes in substrates. Caustic etching of holes is often used on two layer TAB, which consists of only polyimide/metal, and which is processed by forming holes in the substrate after the conductive layer (copper usually) is applied. If the product were not caustic etchable, its use would either be limited to three layer TAB (where the adhesive coated substrate is punched before the copper is laminated), or exotic etchants would be required with the attendant environmental problems.

Approaches to Attain Properties

All approaches to fabricate an advanced TAB/FPC substrate have emphasized alteration of the polyimide backbone structure. Out of these studies have come two new production films, which we believe have definite processing advantages, that are a direct consequence of the specific properties built into the films. These two films are designated as KAPTON-K and KAPTON-E, and they will be sold into both FPC and TAB end-uses. The Type-K is targeted at one and two sided circuitry via roll cladding. It is also intended for 3-layer TAB applications (use of adhesives) of medium complexity; e.g. 40-200 leads. The Type-E is targeted at multilayer and fine line circuitry where the conductor is bonded adhesivelessly. TAB applications are believed to lie in higher complexity systems with greater than 200 leads, as well as two conductor TAB.

Developmental Work to Achieve New Films

In order to acquire a high modulus and low CTE, random copolymerization of stiff diamine segments into the pyromellitic dianhydride/4,4'-oxydianiline polyimide was demonstrated. Polymerization of these stiff segments is under continued study, where the stiff polyimide segments are introduced into the chain as blocks rather than as random units. The advantage of such a method, is that it is likely to enhance the effect of stiff segments at much lower concentrations than if the segments were introduced in a random fashion. The main difficulty with the block copolymer approach is the one of authentically maintaining the block throughout the course of polymerizations/processing, and doing such a feat on a reproducible basis. In this regard, investigation in this area of polyimide chemistry, in addition to continuing, will be reported elsewhere at a later date.

Since the moisture absorption of copolymer formulations is not predictable, several empirical attempts were made to lower the moisture absorption as well as the dielectric constant, which is affected by moisture and is a recurring concern to circuit designers. In addition, adherability is a constant issue with any new substrate, and a part of this ongoing effort is to incorporate functional groups into the polymer chain which will promote adhesion either to various flexible printed circuit adhesives, or directly to copper in adhesiveless products.

Specific effects of stiff codiamine segments were demonstrated by investigation of paraphenylenediamine (PPD), introduced into the chain in a random fashion. A gradual increase in modulus with a corresponding decrease in CTE was found to be dependent on the PPD content. Figures 1 & 2 clearly define the behavior of these mechanical properties as a function of the mole percentage of PPD. In effect, this film has become known as Type-K.

In much the same fashion by which the formulation of Type-K was achieved, the systematic introduction of cosegments into the polymer chain was done to arrive at Type-E. Statistical design of the various compositions was utilized in order to reduce the total number of compositions that were investigated. At the same time, attention was given to alteration of promising compositions so that film manufacture was possible.

Fig. 1

Moduli of Experimental Copolyimide Films

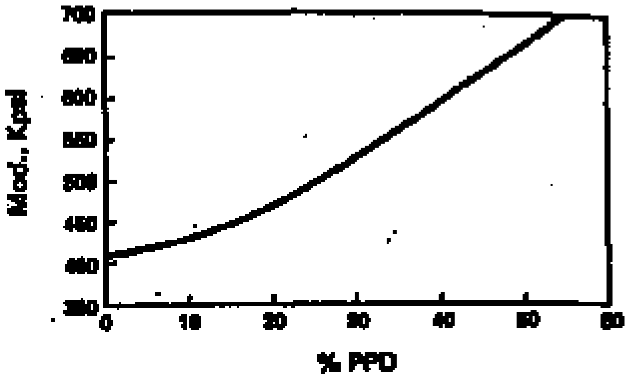
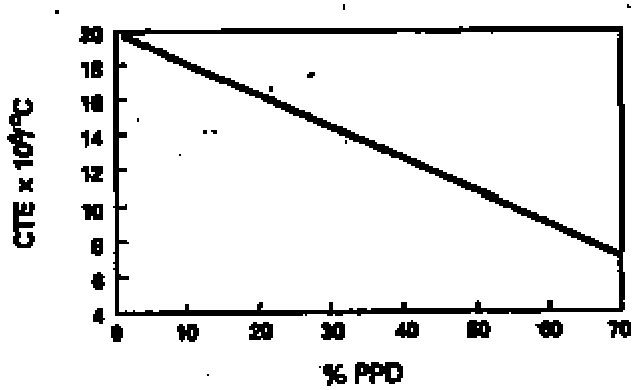


Fig. 2

Coefficients of Thermal Expansion Experimental Copolyimide Films



Typical Property Results

Selected typical properties of the goal level properties given in Table 1, are shown in Table 2. Table 3 provides additional properties of the two new films which are believed to be significant for both processability and for functionality. As indicated previously, Type-K is believed to be more functional than KAPTON Type-V for FPC roll to roll processing and for TAB, since it will provide greater stiffness at equivalent gage and even allow probable reduction in gage for many applications. The CTE match to copper is evident, and this too will afford greater utility without distortion in thermal excursions. The water absorption is actually higher that KAPTON, but when this fact is coupled with the surprising result that the film will expand and contract less than KAPTON during relative humidity changes (CHE), the trade-off appears to lean toward the Type-K. The caustic etchability of the film is actually more than KAPTON, whereas the electrical properties are about equivalent.

Film Type-E is a very high performance film that will serve the high technology demands of exceptional stiffness at thinner gages, and yet maintain a CTE match to copper. The lower water absorption will insure use of the film at high humidities in solder baths without blistering and the very low CHE will maintain excellent dimensional stability under a wide range of humidity conditions. Caustic etchability of the film will open its use to designers who wish to chemically mill holes in their circuits during processing. It will insure development and fabrication of two-conductor TAB with very high lead counts. Electrical properties are maintained to provide a very high level of circuitry performance.

Table 2

Typical Properties vs Goal Properties of Advanced Polyimide Substrates for FPC/TAB/Multilayer Flex Applications*

Property	Goal	Type-V	Type-K	Type-E
Shrink., 200°C, mils/in.	0.1	0.3	0.3	0.3
CTE, ppm/°C	17	35	17	17
Modulus, 23°C, Kpsi	750	400	630	800
H_2O Absorb., %	1.5	3.0	3.7	2.4
Etchable, OH^-	Yes	Yes	Yes	Yes

* All are 75mμ (3.0mil) films.

Table 3

Unique Pyroperties of New Polyimide Films Types-K & E for FPC/TAB/Multilayer Flex Applications*

	Type-V	Type-K	Type-E
CHE, ppm/%RH	17	14	9
H_2O, Permeability, gm/m²/day	22	28	4
OXYGEN, Permeability, cc/m²/day	114	105	4

* All are 75mμ (3.0mil) films.

Additional typical properties are shown in Table 4 to gain a better perspective on the behavior of these films relative to KAPTON Type-V. Characterization is continuing and available results show the hydrolytic stability of the Type-E films, as measured by change in elongation after 1000 hours exposure to 85% RH and 85°C, to be essentially equivalent after the aging period and under the conditions imposed. Thermal durability testing indicates that the new films have the same order of thermal life as does conventional KAPTON Type-V. Retentions of greater than 10% elongation after 100,000 hours at 200°C in an air atmosphere are anticipated.

TI 0010873

Table 4

Additional Properties of New Polyimide Films 3 Mil Types-K & E for FPC/TAB/Multilayer Flex Applications*

Property	Type-V	Type-K	Type-E
Tenacity, Kpsi	34	40	40
Elongation, %	80	60	40
Initial Tear(Graves), lb/mil	2.4	2.6	2.4
Propagating Tear(Elm.), gm/mil	12	17	6.5
Adhesion, pli	12	17	14
L-Color	33	34	49
Density, gm/cc	1.42	1.45	1.46
Diel. Str., v/mil	4500	5000	6000
Diel. Const.,			
100 Khz, 10% RH	3.1	3.1	3.2
100 Khz, 50% RH	3.5	3.6	3.4
Diss. Factor,			
100 Khz, 10% RH	0.0012	0.0022	0.0028
100 Khz, 50% RH	0.0065	0.0062	0.0054
Volume Resistivity, ohm-cm			
10% RH	3.6xE17	2.4xE17	3.1xE17
50% RH	1.8xE17	1.6xE17	1.3xE17
Surface Resistivity, ohm			
10% RH	9.3xE17	8.9xE17	13.0xE17
50% RH	0.1xE17	3.1xE17	1.3xE17

* All are 75mμ (3.0mil) films.

Conclusions

New polyimide films based on different polymer backbones have been developed for use in FPC and TAB applications. KAPTON Type-K offers increased modulus, a thermal coefficient match with copper, low shrinkage, and chemical etchability for one and two sided circuits via roll cladding and three layer TAB applications of medium complexity. KAPTON Type-E offers the same advantages with a higher modulus and reduced water absorption and hygroscopic expansion for multilayer and fine line circuitry.

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KAPTON® Polyimide Film
General Specifications
Bulletin GS-90-5

DuPont
Electronics

High Performance Films

INTRODUCTION

The Electronics Department of the Du Pont Company manufactures and sells a variety of high quality plastic film products.

These specifications describe the values and tolerances for film properties and characteristics of Kapton® polyimide film. Where necessary for thorough understanding, test methods and procedures have been included.

Any aspects of the specifications requiring further interpretation or clarification should be discussed with representatives of the Du Pont Electronics Department.

Types of Kapton Polyimide Film

Du Pont makes three types of "Kapton" polyimide film, Type HN, Type FN and Type VN.[1]

Type HN Film

"Kapton" Type HN is a tough aromatic polyimide film, exhibiting an excellent balance of physical, chemical and electrical properties over a wide temperature range, particularly at unusually high temperatures. Chemically, its polyimide polymer makeup is the result of a polycondensation reaction between pyromellitic dianhydride and 4,4'-diaminodiphenylether. "Kapton" HN is available in 30, 50, 100, 200, 300 and 500 gauges. Available by special request are other thicknesses such as 75 and 400 gauge.

Type FN Film

"Kapton" Type FN film is a heat sealable grade which retains the unique balance of properties that "Kapton" Type HN possesses over a wide temperature range. This is achieved by combining Type HN "Kapton" and Teflon® FEP fluorocarbon resin together in a composite structure. Listed below are those combinations commercially available at this time. Other combinations are available. Consult your Electronics Department marketing representative for further information.

Type VN Film

"Kapton" Type VN is the same tough polyimide film as Type HN Film, exhibiting an excellent balance of physical, chemical and electrical properties over a wide temperature range, with superior dimensional stability at elevated temperatures. This product is available in 50, 75, 100, 200, 300 and 500 gauges.

Certification

"Kapton" is certified to meet the requirements of the military specification MIL-P-46112 B (MR) in addition to the items covered by this specifications bulletin. Written confirmation is available with each delivery upon request.

	Construction (mils)		
Designation	**FEP**	**HN**	**FEP**
120FN616	0.10	1.00	0.10
100FN099		0.50	0.50
150FN999	0.50	0.50	0.50
150FN019		1.00	0.50
200FN919	0.50	1.00	0.50
200FN011		1.00	1.00
250FN029		2.00	0.50
300FN929	0.50	2.00	0.50
300FN021		2.00	1.00
400FN022		2.00	2.00
400FN031		3.00	1.00
500FN131	1.00	3.00	1.00
600FN051		5.00	1.00

[1] The specifications in this bulletin also apply to the alternative special versions of these standard types, Type A, Type V and Type F.

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PROPERTIES OF TYPE HN FILM

Mechanical

	Property Value						
	Film Thickness (mils)						
Property	0.30	0.50	1.00	2.00	3.00	5.00	Method
Tensile Strength psi, at 23°C, Machine Direction (MD) and, Transverse Direction (TD), (Minimum)	18,000	20,000	24,000	24,000	24,000	24,000	ASTM D-882-81, Method A using an Instron Tensile Tester (specimen size: 1/2" x 6", jaw separation: 4", jaw speed: 2"/min.). Calculate the average of 5 specimens based on original measured thickness.
Elongation, % MD and TD (Minimum)	25	35	40	45	50	50	Same as above method.
Shrinkage, % MD and TD at 400°C (Maximum)	4.0	4.0 **	2.5	2.5	2.5	2.5	MIL-P-46112B (MR). The percent shrinkage is obtained for either the MD or TD by using the average of three measurements in either direction before and after conditioning. Prior to measurement the 8-1/2"x11" specimen is conditioned by freely suspending for 2* hours in an oven controlled to 400° ± °C.
Moisture absorption, % (Maximum)	4.0	4.0	4.0	4.0	4.0	4.0	ASTM D-570-81, using 24 hour immersion at 23°C. Average of 3 specimens.

*1 hour for 30 & 50 gauge film.

Electrical

	Property Value						
	Film Thickness (mils)						
Property	0.30	0.50	1.00	2.00	3.00	5.00	Method
Dielectric Strength, AC volts/mil, (Minimum)	3,000	3,000	6,000	5,000	4,500	3,000	ASTM D-149-81. (Average of 10 specimens.) Flat sheets in air placed between 1/4" diameter brass electrodes with 1/32" edge radius subjected to 60 cycles AC voltage at 500 volts/sec. rate of rise to the breakdown voltage.
Volume Resistivity, ohm-cm at 200°C (Minimum)	10[illegible]	10[illegible]	10[illegible]	10[illegible]	10[illegible]	10[illegible]	ASTM D-257-78
Dielectric constant at 1 kHz (Maximum)	4.0	4.0	3.9	3.9	3.9	3.9	ASTM D-150-81. Use conducting silver paint electrodes, two terminal system of measurement at standard conditions. Results are based on an average of 5 tests using measured thickness of specimens.
Dissipation factor at 1 kHz (Maximum)	.0070	.0060	.0036	.0036	.0036	.0036	Same as above method.

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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 criterion of failure. "Kapton" is routinely tested at the manufacturing site in the following manner:

Sheets of film 8-1/2" x 11" are freely suspended in an oven at 400°C. The temperature of the oven is monitored with a thermocouple to insure a temperature accuracy of ±2°C. Sheets are removed after 2 hours* and tested on an Instron Tensile Tester as described above under "Elongation." The elongation (at 23.5°C) of the film should not be less than 10% after this aging at 400°C. This conforms to the "Elongation after Aging at 400°C" test (paragraph 4.4.5) and "Elongation, percent, after 2 hour 400°C" requirement (Table 1) of MIL-P-46112 B (MR).

Underwriters Laboratories Inc. lists a thermal index of 200°C–220°C (depending on gauge and type) for mechanical properties and 220°C–240°C (depending on gauge and type) for electrical properties under their file no. E39505 for "Kapton" polyimide film.

PROPERTIES OF TYPE FN FILM

Heat Seal Strength

Film to Film Seals

The heat seal peel strength between the coated and uncoated side of one side coated "Kapton" polyimide film or the coated to coated side of one or two side coated "Kapton" is measured in the following manner: Seals are made in a jaw sealer at 350°C, 20 psi, 20 sec. dwell time. After cooling, the seals are cut to 1" wide strips using a Thwing-Albert JDC sample cutter or equivalent. The strength of the seal is measured with an Instron type tensile tester. Seal strength is defined as the peak instantaneous strength occurring in each seal. Five specimen values are averaged.

The minimum peel strength between the coated sides of one or two side coated "Kapton" polyimide film will be 600 gms./inch except for 120FN616 which will be 450 gms./in. The minimum peel strength between the coated and uncoated side of one side coated "Kapton" will be 450 gms./inch.

Film to Copper Seals for 120FN616 Film

The ability of 120FN616 film to adhere to copper is measured by using the same heat seal peel strength technique as described above.

The peel strength obtained when 120FN616 is sealed to the untreated side of 3/4 oz. GT copper foil (1 mil) will be a minimum of 250 gms./in.

As-Received Strength (Cold peel) of Bonds Between the Type HN "Kapton" and "Teflon" Layers

The bond between the Type HN "Kapton" and Teflon® fluorocarbon resin layers on all type FN products except 120FN616 will have a minimum peel strength of 225 gms./in. as measured using an Instron type tensile tester and a 180° peel.

Dielectric Strength

Gauge Construction	Min. Breakdown (Volts/mil)	Test Method
120FN616	4000	
100FN099	3000	
150FN099	3000	
150FN019	3500	Average of 10 samples tested per ASTM D-149-61. Flat sheets in air placed between 1/4" diameter brass electrodes with 1/32" edge radius subjected to 60 cycles AC voltage. Rise is 500 volts/sec. to the breakdown voltage.
200FN919	3000	
200FN011	3000	
250FN029	2500	
300FN929	2500	
300FN021	2500	
400FN022	2000	
400FN031	2700	
500FN131	2200	
500FN051	2100	

*1 hour for 30 & 50 gauge film.

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PROPERTIES OF TYPE VN FILM

Mechanical

Property	Property Value — Film Thickness (mils)						Method
	0.50	0.75	1.00	2.00	3.00	5.00	
Tensile Strength, psi, at 23°C, Machine Direction (MD) and Transverse Direction (TD) (Minimum)	20,000	20,000	24,000	24,000	24,000	24,000	ASTM D-882-81, Method A using an Instron Tensile Tester (specimen size: 1/2" x 6", jaw separation: 4", jaw speed: 2"/min.). Calculate the average of 5 specimens based on original measured thickness.
Elongation, % MD and TD (Minimum)	35	35	45	50	50	50	Same method as above.
Shrinkage, % MD and TD after 60 min. at 200°C (Maximum)	0.10	0.10	0.10	0.05	0.05	0.05	The percent shrinkage is obtained for either the MD or TD by using the average of three measurements in either direction before and after conditioning. Temperature exposure 200° ± 2°C for one hour. Measurements must be made at the same temperature and humidity conditions before and after conditioning. To assure sample/ambient equilibrium before and after conditioning, specimens should be exposed for three hours.
Moisture absorption, % Maximum	4.0	4.0	4.0	4.0	4.0	4.0	ASTM D-570-81, using 24 hour immersion at 23°C. Average of 3 specimens.

Electrical

Property	Property Value — Film Thickness (mils)						Method
	0.50	0.75	1.00	2.00	3.00	5.00	
Dielectric Strength, volts/mil, AC (Minimum)	3,000	3,000	6,000	5,000	4,500	3,000	ASTM D-149-81. (Average of 10 specimens.) Flat sheets in air placed between 1/4" diameter brass electrodes with 1/32" edge radius subjected to 60 cycles AC voltage at 500 volts/sec. rate of rise to the breakdown voltage.
Volume Resistivity, ohm-cm at 200°C. (Minimum)	$10^{[illegible]}$	$10^{[illegible]}$	$10^{[illegible]}$	$10^{[illegible]}$	$10^{[illegible]}$	$10^{[illegible]}$	ASTM D-257-78
Dielectric constant at 1 kHz (Maximum)	3.9	3.9	3.9	3.9	3.9	3.9	ASTM D-150-81. Use conducting silver paint electrodes, two terminal system of measurement at standard conditions. Results are based on an average of 5 tests using measured thickness of specimens.
Dissipation factor at 1 kHz (Maximum)	0.0050	0.0050	.0036	.0036	.0036	.0036	Same method as above.

TI 0010950

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 criterion of failure. "Kapton" is routinely tested at the manufacturing site in the following manner:

Sheets of film 8-1/2" x 11" are freely suspended in an oven at 400°C. The temperature of the oven is monitored with a thermocouple to insure a temperature accuracy of ± 2°C. Sheets are removed after 2 hours and tested on an Instron Tensile Tester as described above under "Elongation." The elongation (at 23.5°C) of the film should not be less than 10% after this aging at 400°C. This conforms to the "Elongation after Aging at 400°C" test (paragraph 4.4.5) and "Elongation, percent, after 2 hour 400°C" requirement (Table 1) of MIL-P-46112 B(MR).

Underwriters Laboratories Inc. lists a thermal index of 200°C–220°C (depending on gauge and type) for mechanical properties and 220°C–240°C (depending on gauge and type) for electrical properties under their file no. E39505 for "Kapton" polyimide film.

GENERAL

Material

Type HN and Type VN Film—A polyimide polymer in the form of a film.

Type FN Film—A combination of "Kapton" polyimide film Type HN with Teflon® FEP fluorocarbon resin on one or both sides.

Uniformity

Material shall be uniform in composition and free from defects which impair serviceability and/or appearance in proven applications.

Cores

Cores shall be of sufficient strength to prevent collapsing on handling. Standard core I.D.'s are 3" and 6" with the following specifications: 3" I.D. is 3.032" ± 0.008", 6" I.D. is 6.028" ± 0.010". Core material will be plastic for 3" I.D. cores less than 5/8" wide. Core material will be fibre for 3" I.D. cores wider than 5/8" and 6" I.D. cores. A split 3" I.D. fibre core is standard for all universal rolls. Core width for universal wind is 2-3/4".

If these cores are not suitable, further information on other options may be obtained from your Electronics Department marketing representative.

Width Tolerance

The maximum variation in film width from that specified on the order shall be as follows:

Slit Width Range	Tolerance
7/8" or less Universal only	± 7 mils
1" or less	± 15 mils
1-1/16"–4"	± 30 mils
4-1/16" or wider	± 60 mils

Type	Nominal Thickness		Width Range		Pad Rolls (I.D x O.D.) (in.)					Universal Rolls (I.D x O.D.) (in.)			Area Factor
	Mils	µm	Min. in.	Max. in.	3x6*	3x8-1/2	6x8-1/2	6x11	6x14	3x6	3x8	3x12	(ft²/lb)
30HN	0.3	8	3/16	60			•						410
50HN	0.5	13	3/16	62	•		•						272
100HN	1.0	25	3/16	60	•	•		•			•	•	136
200HN	2.0	50	3/16	60	•	•		•	•		•	•	68
300HN	3.0	75	3/16	60	•	•		•	•				45
500HN	5.0	125	3/16	60	•	•		•	•				27
50VN	0.5	13	7/8	62				•					272
75VN	0.75	19	7/8	60				•					181
100VN	1.0	25	7/8	60				•	•				136
200VN	2.0	50	7/8	60				•	•				68
300VN	3.0	75	7/8	60				•	•				45
500VN	5.0	125	7/8	60				•	•				27
100FN099	1.0	25	1/8	36	•					•			110
120FN616	1.2	30	1/8	36	•	•		•		•	•	•	104
150FN099	1.5	38	1/8	36	•					•			68
150FN019	1.5	38	1/8	36	•	•		•		•	•	•	77
200FN011	2.0	50	3/16	36	•	•					•		54
200FN919	2.0	50	3/16	36	•	•					•		54
250FN029	2.5	63	1/8	36	•	•					•	•	43
300FN021	3.0	75	3/16	36	•	•				•	•		39
300FN929	3.0	75	3/16	36	•	•				•	•		39
400FN022	4.0	100	3/16	36		•		•					27
400FN031	4.0	100	3/16	36		•		•					30
500FN131	5.0	125	3/16	36		•		•					23
600FN051	6.0	150	1/2	36		•		•					21

*3"x6" pad roll is available in widths up to 7/8" only in 100HN, 200HN, 300HN, 500HN, 150FN019, 200FN011, 200FN919, 250FN029, 300FN021, 300FN929.
* O.D. Tolerance is ± 1/4" for pads and ± 1/2" for universal.
* Type HN, FN and VN films in pads are supplied in width increments of 1/16".
Most films are supplied in width increments of 1/32" in widths 3/16" to 2".
* All universal rolls are available in 1/32" width increments with 7/8" maximum widths. The minimum width is 1/8" for 3" x 8" (I.D. x O.D.); the minimum width is 3/16" for 3" x 6", and 3" x 12" (I.D. x O.D.).

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Roll Types

Kapton® film is supplied in two types of rolls, pad and universal wind. Available film widths and roll O.D.'s are specified below.

Specifications for pad rolls are:

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

Specifications for the universal rolls are:

1. The difference between the length of projecting core on each side shall not exceed 3/16".
2. Film shall not project from the main body of the roll more than 1/8".
3. The outside and starting ends of the film shall be fastened in such a manner as to prevent unwinding.
4. Roll face depression, the difference between the highest and lowest points unstressed, shall not exceed 3/16".
5. Width of traverse is 1-3/4", -1/4", +1/8".

Splices

Description

Three types of splice are available.

1. Mylar® polyester film based yellow tape splice (standard).
2. "Kapton" polyimide film based splice (special requirements only).
3. Heat seal splice (Type FN) in width, 12" or less.

Splices will be sufficiently smooth and wrinkle-free so as not to distort adjacent layers of film and approximately centered to ±1/4".

Tape splices are standard on all gauges of "HN" and "VN" film and also on all gauges of "FN" film more than 12" wide.

Tape splices are made as follows. A butt splice with film ends covered on both sides of the film with splice tape. For films less than 0.002" thick a 1" wide pressure sensitive tape is used. For films 0.002" thick and greater a 2" wide pressure sensitive tape will be used.

Heat seal splices are made as follows. On all films but 250FN029 the splice is an overlap splice a minimum of 3/8" long. On 250FN029 a butt splice is made using 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 put-ups and pad put-ups for two side FEP structures. Pad put-ups of one side 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 a universal put-up and on the bottom as it unwinds from a pad.

Maximum Splices per Slit Roll

The minimum average footage between splices for most rolls is shown in Table 1. To calculate the maximum number of splices in a roll divide the nominal feet per roll by the minimum average length between splices and subtract one.

Splice Placement

Table 1 shows the minimum length between splices and from the beginning and end of a roll, for most "Kapton" rolls. No splice is allowed, however, once a roll has reached the minimum O.D.

Table 1. Splice Data—Kapton® Polyimide Film

Core I.D. (in.)	Roll O.D. (in.)	Roll	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
			Minimum Average Splice Free Length (Feet)																
3 6	8 9-1/2	Pad	[illegible]	600	500	500	300	350	150	250	145	250	450	250	200	65	145	150	125
3 6	9-1/2 11	Pad	—	—	500	540	425	340	[illegible]	425	350	[illegible]	375	310	325	200/245	225	165	170
3	8 12	Universal*	—	—	—	[illegible]	610	—	—	510	350	425	400*	410	330	420/340	250	170	—
			Minimum Length Between Splices or Beginning and End of a Roll (Feet)																
3 6	8 9-1/2	Pad	—	100	100	100	100	100	—	100	100	100	100	100	100	100	100/75	75	—
3 6	9-1/2 11	Pad	—	—	100	100	100	100	75	—	100	—	100	100	100	100	100/75	75	75
3	8 12	Universal	—	—	—	100	100	100	75	150	150	150	150	150	150	—	—	—	—

NOTES: [1] To 60" wide for 30HN, 52" wide for 50HN
[2] To 60" wide
[3] To 6" wide
[4] To 18" wide. For widths greater than 18" to the maximum, the minimum average footage will be one half that shown in the table.
[5] 1/8" to 7/8" wide

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Average Thickness Tolerances (Unit Weight)

Test Method and Sampling Procedure

Weigh test specimens equal to the width of slit roll and not less than 1/2 meter long to the nearest 0.10 gram on a torsion balance.

To confirm average thickness tolerances, obtain a sample consisting of a minimum of one specimen from each of several randomly selected slit rolls as follows:

Slit Roll Width	Minimum Number of Slit Rolls to be Sampled
Under 6"	25 ÷ slit roll width (in.)
6" and Over	4

Type HN Film Thickness (mils)	Unit Weight (g/m²)	
	Minimum	Maximum
0.30	7.6	14.0
0.50*	14.0	26.0
0.75*	21.3	32.5
1.00*	32.7	38.7
2.00*	65.9	77.9
3.00*	101.9	118.4
5.00*	165.5	192.5

* Applies to Type VN films also.

Type FN Film Gauge & Construction	Minimum	Maximum
120FN616	41	53
100FN929	37	55
150FN929	61	85
150FN019	53	74
200FN919	77	104
200FN011	77	104
250FN029	87	113
300FN021	111	142
300FN929	111	142
400FN022	163	200
400FN031	146	176
500FN131	186	239
600FN051	211	269

Micrometer Thickness

Thickness tolerances are based on a statistical analysis of routine process control data.

Test Method

Make the following measurements to confirm that film from a single slit roll meets the micrometer tolerances:

1. Measure in accordance with ASTM-D-374-79, Method A or C.
2. Obtain the average of 10 randomly selected readings from a minimum area of 12 square inches. Recheck before rejecting any slit roll. Abnormal readings may occasionally result from dust particles or spot surface imperfections. Discard such readings as they will adversely affect the accuracy of measurements designated to indicate general sheet thickness.

Type HN Gauge	Nominal Thickness (mils)	Thickness Tolerances (mils)	
		Minimum	Maximum
30	0.30	0.24	0.36
50*	0.50	0.35	0.65
75*	0.75	0.60	0.90
100*	1.00	0.85	1.15
200*	2.00	1.75	2.25
300*	3.00	2.72	3.28
500*	5.00	4.65	5.35

*Applies to Type VN films also.

Type FN Gauge	Nominal Thickness (mils)	Thickness Tolerances (mils)	
		Minimum	Maximum
120FN616	1.20	1.10	1.40
100FN929	1.00	0.75	1.25
150FN929	1.50	1.20	1.80
150FN019	1.60	1.25	1.75
200FN919	2.00	1.70	2.30
200FN011	2.00	1.70	2.30
250FN029	2.50	2.30	2.83
300FN021	3.00	2.60	3.40
300FN929	3.00	2.60	3.40
400FN022	4.00	3.60	4.40
400FN031	4.00	3.60	4.40
500FN131	5.00	4.50	5.50
600FN051	6.00	5.40	6.60

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Gauge Depression

To reduce web handling difficulties which would occur if film representing thickness extremes were shipped in the same roll, a gauge depression standard is applied.

Roll depression is the difference in diameter between the hardest and softest part of the roll or the difference between the undepressed and depressed (finger pressure) diameter at the softest part, whichever is greater.

Table 2 lists the maximum allowable depression for most pad rolls. There is no gauge depression standard for universal wind since that roll is limited to a maximum of 7/8" wide.

Table 2. Kapton® Polyimide Film Gauge Depression Standards—Pad Rolls

Put-Up		Maximum allowable depression in 1/32" increments												
		Roll Widths (in.)												
I.D. (in.)	O.D. (in.)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	22" & Wider
3 [illegible]	[illegible] [illegible]-1/2	[illegible]	[illegible]	[illegible]	[illegible]	5	6	7	7	7	7	[illegible]	[illegible]	[illegible]
[illegible] 6	[illegible]-1/2 11	[illegible]	7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11	11	[illegible]	[illegible]	13	[illegible]
[illegible] 6	13 14	–	[illegible]	[illegible]	[illegible]	11	11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17	17

PACKAGING AND MARKING

Packaging

Kapton® shall be adequately packed to prevent loss of contents or damage during shipment.

All film will be wrapped with a non-fibrous material.

Marking

"Kapton" is identified as follows to allow complete traceability back to the raw materials and processing conditions:

	Shipping Container	Package	Core Label[a]
1. Scheduled Date	X	X	X
2. Customer Order Number	X	X	X[c]
3. Du Pont Order Number	X	X	X
4. Gauge	X	X	X
5. Type	X	X	X
6. Width	X	X	X
7. No. of Rolls per Container	X	X	
8. Net Weight	X	X	
9. Footage			X
10. Mill Roll Number	X	X	X
11. I.D. and O.D.[b]	X	X	

[a] Affixed to the core on all cores, 2-1/4" wide and over. Included with the package on all cores less than 2-1/4" wide.
[b] Inside diameter of core and nominal outside diameter of roll.
[c] Available for up to 12 characters.

TI 0010994

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TI 0010985

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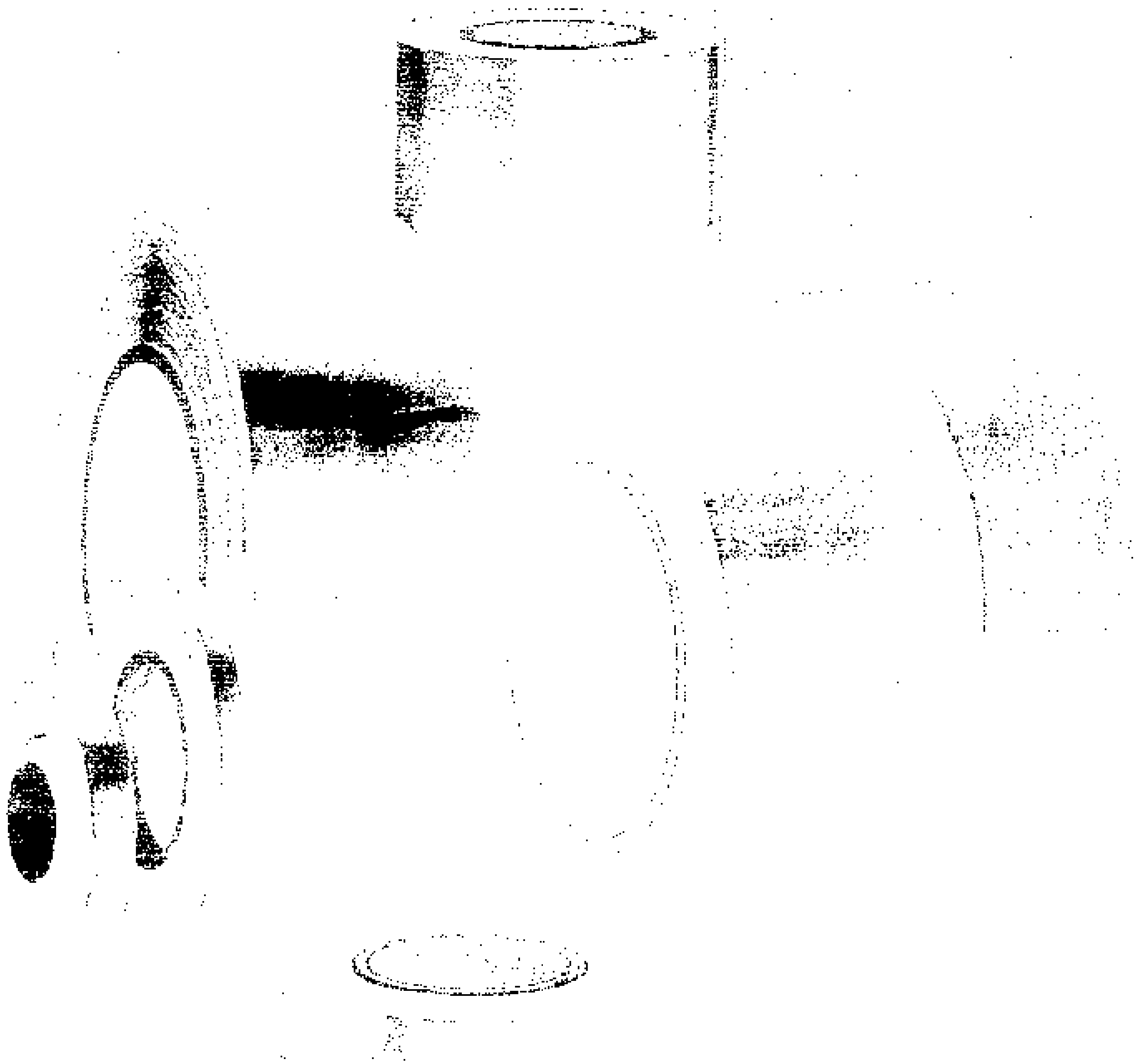
Kapton®

POLYIMIDE FILM

SUMMARY OF PROPERTIES



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TI 0010986

PHYSICAL & THERMAL PROPERTIES

Contents

Page

GENERAL INFORMATION

[illegible]

- [illegible] is available in 0.3, 0.5, 1, 2, 3 and 5 mils.
- KAPTON Type V [illegible] all-polyimide film with all of the properties of Type H, plus superior dimensional stability [illegible] is available in 2, 3 and 5 mils.
- KAPTON Type F, a Type H film coated on one or both sides with TEFLON* FEP fluorocarbon resin to impart heat sealability, to provide a moisture barrier and to enhance chemical resistance. It is available in a variety of constructions.

Note: This bulletin provides a summary of typical properties for all three KAPTON polyimide films Type H, Type V and Type F. Additional data should be obtained from your Du Pont Industrial Films Division representative for specification purposes.

*Reg. U.S. Pat. Off.

TI 0010987

DD/NHTSA No. 3
00230

KAPTON® Type H Film

25 μm (1 mil)

PHYSICAL PROPERTIES

PHYSICAL PROPERTIES	TYPICAL VALUES 78K (−195°C)	296K (23°C)	473K (200°C)	TEST METHOD
Ultimate Tensile (MD) Strength, MPa (psi)	241 (35,000)	172 (25,000)	117 (17,000)	ASTM D-882-81
Yield Point (MD) at 3%, MPa (psi)		69 (10,000)	41 (6,000)	ASTM D-882-81
Stress to Produce (MD) 5% Elongation, MPa (psi)		90 (13,000)	59 (8,500)	ASTM D-882-81 ASTM D-882-81
Ultimate Elongation (MD)%	2	75	80	ASTM D-882-81
Tensile Modulus, GPa (MD) (psi)	3.5 (510,000)	3.0 (430,000)	1.86 (260,000)	ASTM D-882-81
Impact Strength, J/mm (kg-cm)		23 (6)		Du Pont Pneumatic Impact Test
Folding Endurance MIT		10,000 cycles		ASTM D-2176-69
Tear Strength—Propagating (Elmendorf), g		8		ASTM D-1922-67
Tear Strength—Initial (Graves), g (g/mil)		510 (510)		ASTM D-1004-66
Density, g/cm³		1.42		ASTM D-1505-68
Coefficient of Friction Kinetic (Film-to-Film)		.42		ASTM D-1894-78
Refractive Index (Becke Line)		1.78		Encyclopaedic Dictionary of Physics, Vol. 1
Poisson's Ratio		.34		Avg. 3 Samples Elongated at 5%, 7%, 10%

MD—Machine Direction

THERMAL PROPERTIES

THERMAL PROPERTIES	TYPICAL VALUES	TEST CONDITION	TEST METHOD
Melting Point	NONE		ASTM E-794-8
Zero Strength Temperature	1088K (815°C)	.14 MPa (20 psi) load for 5 seconds	Du Pont Hot Bar Test
Coefficient of Linear Expansion	2.0×10^{-5} m/m/K (2.0×10^{-5} in/in/°C)	259 to 311K (−14°C to 38°C)	ASTM D-696-44
Coefficient of Thermal Conductivity, W/m-K $\left(\frac{(cal)(cm)}{(cm^2)(sec)(°C)}\right)$	0.155 (3.72×10^{-4}) 0.163 (3.89×10^{-4}) 0.178 (4.26×10^{-4}) 0.189 (4.51×10^{-4})	296K (23°C) 348K (75°C) 473K (200°C) 573K (300°C)	Model TC-1000 Twin Heatmeter Comparative Tester
Specific Heat	1.09 (.261)	J/g-K (cal/g/°C)	Differential Calorimetry
Flammability	94 VTM-0		UL-94 (1-24-80)
Shrinkage	(See chart on Page 7)		IPC Method 2-2-2-A
Heat Sealability	Not Heat Sealable		
Limiting Oxygen Index	100H-38		ASTM D-2863-77
Smoke Generation	100H — DM = less than 1	NBS Smoke Chamber	NFPA-258 procedures
Glass Transition Temperature (Tg)	A second order transition occurs in KAPTON between 633K (360°C) and 683K (410°C). This is assumed to be the glass transition temperature. Different measurement techniques produce different results within the above temperature range.		

KAPTON® Type V Film

PROPERTY	TYPICAL VALUES Film Gauge				TEST METHOD
	25 µm (1 mil)	50 µm (2 mil)	75 µm (3 mil)	125 µm (5 mil)	
Tensile Strength MPa (psi) @ 296K (23°C). Machine Direction (MD) and Transverse Direction (TD).	172 (25,000)	172 (25,000)	172 (25,000)	172 (25,000)	ASTM D-882, Method A using an Instron Tensile Tester (specimen size: 25 × 127 mm (1" × 5", jaw separation: 50 mm (2"). Jaw speed: 50 mm (2"/min.) Average of 5 specimens based on original measured thickness.
Elongation, % MD and TD	75	70	70	70	Same method as above
Shrinkage, % MD and TD Typical after 60 min. @ 473K (200°C).	0.10	.02	.02	.02	Average of 3 measurements in each direction before and after exposure to 473K (200°C) for 60 min. Film must be allowed to come to equilibrium with equivalent room conditions before and after exposure.

KAPTON® Type F Film

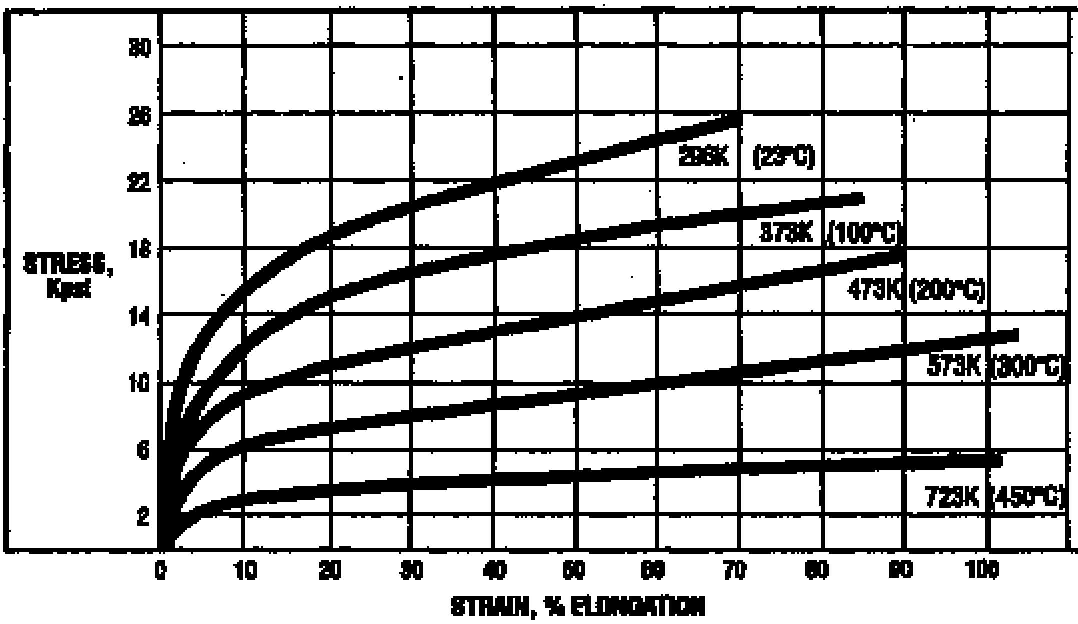
PROPERTY	TYPICAL VALUES Film Type*		
	120F616	150F019	250F029
Ultimate Tensile Strength (MD), MPa (psi)			
296K (23°C)	165 (24,000)	117 (17,000)	172 (25,000)
473K (200°C)	110 (16,000)	76 (11,000)	110 (16,000)
Yield Point at 3% (MD), MPa (psi)			
296K (23°C)	62 (9,000)	50 (7,300)	69 (10,000)
473K (200°C)	38 (5,500)	28 (4,000)	55 (8,000)
Stress at 5% Elongation (MD), MPa (psi)			
296K (23°C)	86 (12,500)	62 (9,000)	
473K (200°C)	52 (7,500)	38 (5,500)	
Ultimate Elongation (MD)			
296K (23°C)%	65	75	60
473K (200°C)%	95	85	
Tensile Modulus, MD GPa (psi)			
296K (23°C)	2.86 (415,000)	2.21 (320,000)	
473K (200°C)	1.48 (215,000)	1.19 (173,000)	
Impact Strength at 296K (23°C)			
g·m (Kg-cm/µm)	70 (7)	70 (7)	
g·m/µ (Kg-cm/mil)	2.3 (6.0)	1.8 (4.6)	
Tear Strength—Propagating (Elmendorf)			
g		20	
g/µm (g/mil)	0.39 (10)	0.53 (13.5)	0.47 (12)
Tear Strength—Initial (Graves)			
g		650	
g/µm (g/mil)	19 (750)	17 (435)	
Weight % Polyimide	80	57	73
Weight % FEP	20	43	27
Density $Kg/m^3 x10^{-3}$	1.53	1.67	1.57

*Since 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 TEFLON FEP fluorocarbon resin in mils. The symbol 9 is used to represent 13 µm (½ mil), and 6 to represent 2.5 µm (1/10 mil). Example: 120F616 is a 120-gauge structure consisting of a 25 µm (1-mil) base film with a 2.5 µm (1-10 mil) coating of TEFLON on each side. See page 22 for construction explanation.

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 below. Such properties as tensile strength and modulus have an inverse relation with temperature, while elongation peaks to a maximum value at about 573K (300°C). Other factors such as humidity, film thickness, and Instron elongation rate were found to have only a negligible effect on the shape of the 296K (23°C) curve.

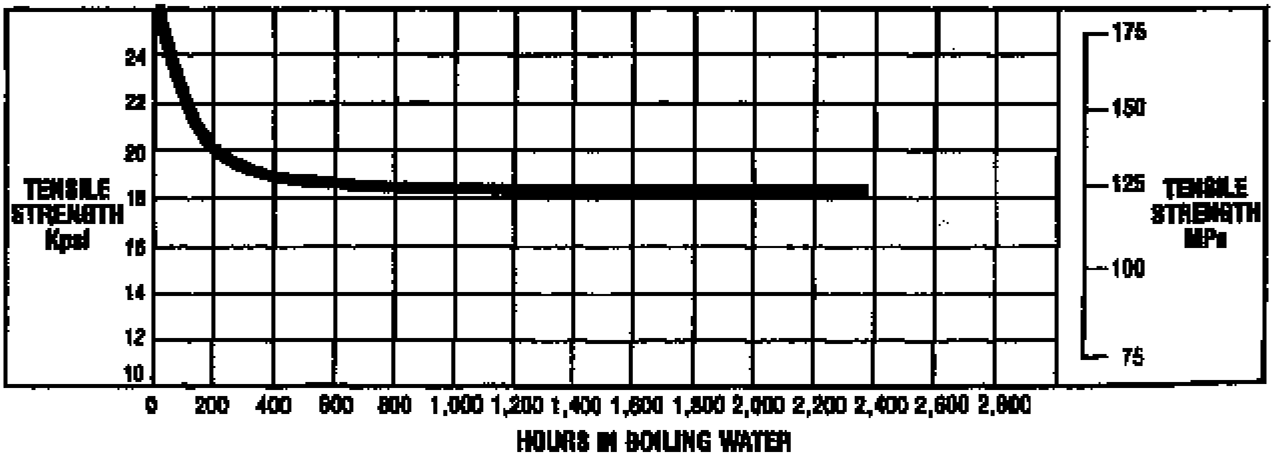
TENSILE STRESS STRAIN CURVES
(Type H Film 25 μm (1 mil))



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 below, will reduce the level of film properties, sufficient tensile and elongation remain to insure good mechanical performance. A decrease in the temperature and the water concentration will reduce the rate of KAPTON property reduction while higher temperatures and pressures will increase it.

TENSILE STRENGTH AFTER EXPOSURE TO 373K (100°C) WATER
(Type H Film 25 μm (1 mil))



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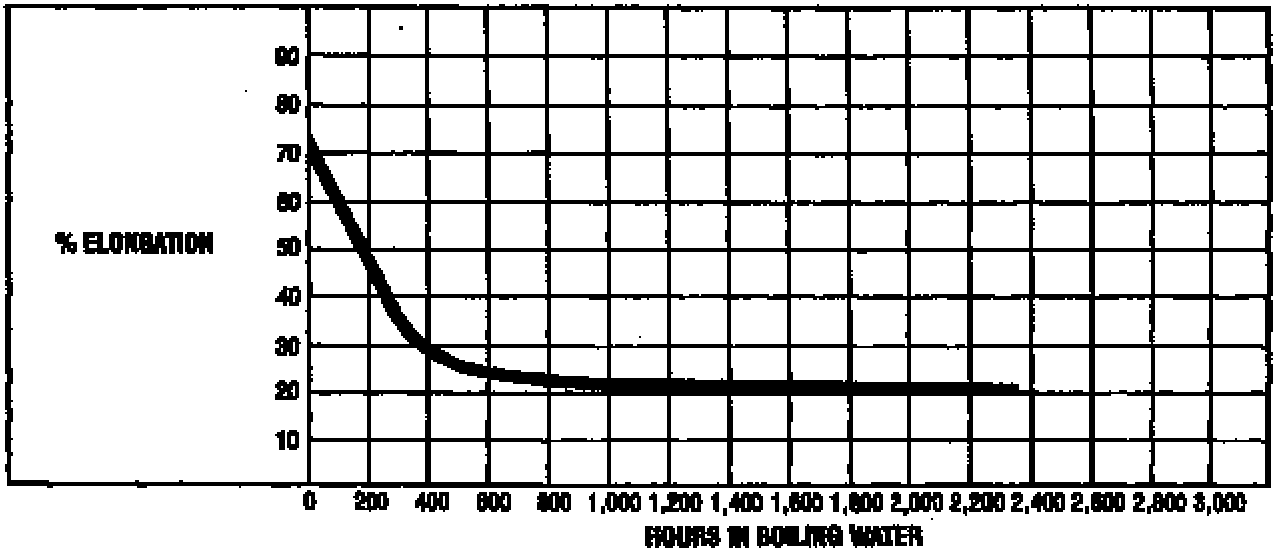
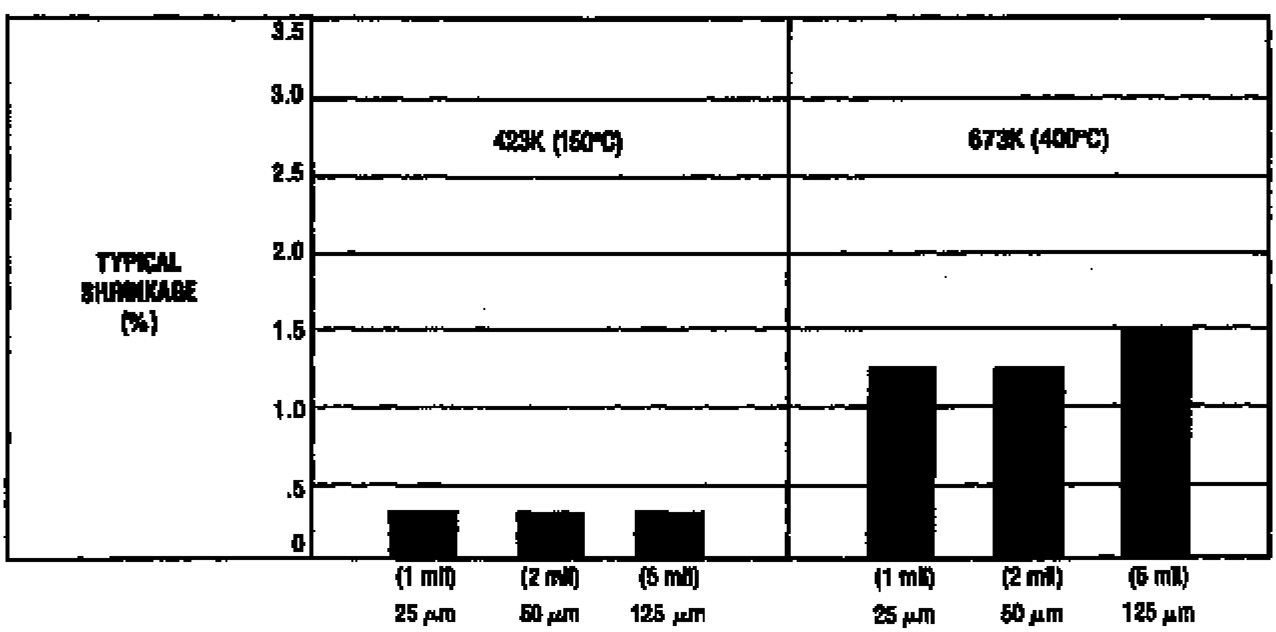
ULTIMATE ELONGATION AFTER EXPOSURE IN 373K (100°C) WATER
(Type H Film 25 μm (1 mil))



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 graphs below. Once the film has been exposed, the normal values for thermal expansion listed on Page 6 can be expected.

RESIDUAL SHRINKAGE VS. EXPOSURE TEMPERATURE AND GAUGE
(Type H Film)



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DD/NHTSA No. 3
90234

THERMAL COEFFICIENT OF EXPANSION

(Type H Film 25 μm (1 mil)) Thermally Exposed

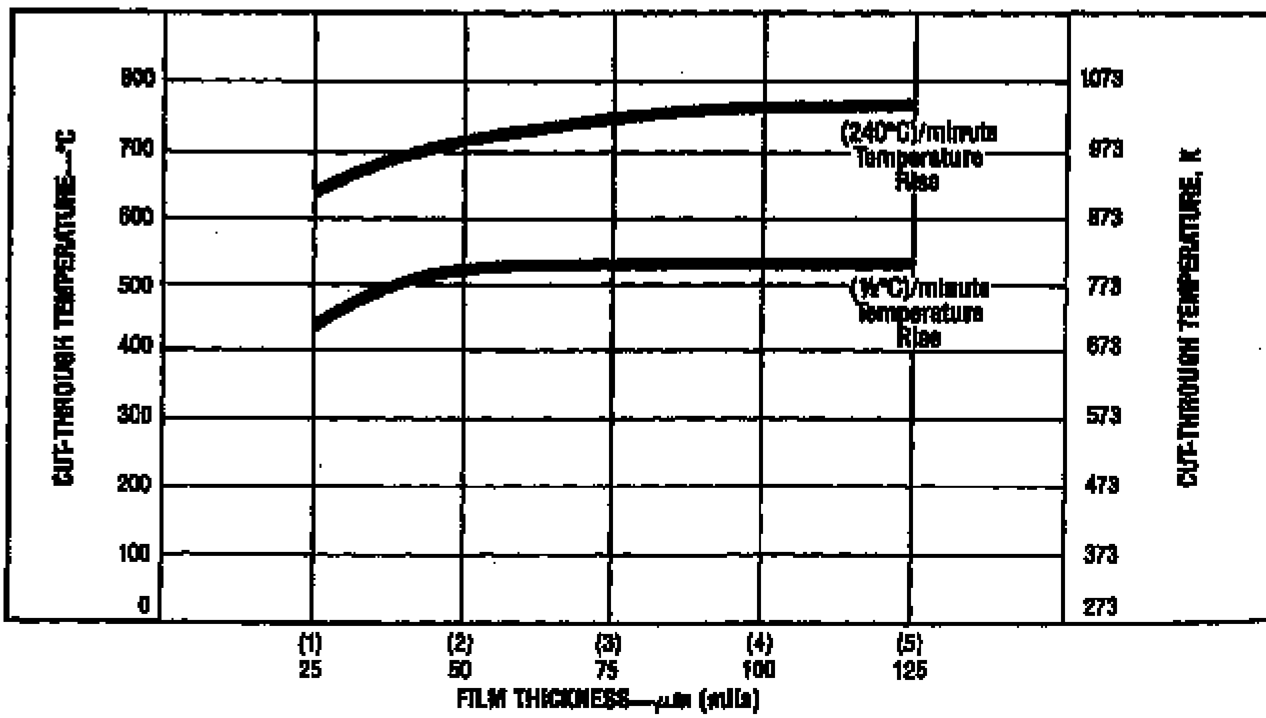
Temperature Range	"α" cm/cm·K x 10^{-5}
296-373K (23-100°C)	1.80
373-473K (100-200°C)	3.10
473-573K (200-300°C)	4.85
573-673K (300-400°C)	7.75
296-673K (23-400°C)	4.55

CUT-THROUGH AND COLD FLOW

Most organic films exhibit a tendency to flow or thin out under high compressive stresses, especially at elevated temperatures. KAPTON® polyimide film possesses an extremely high resistance to such stresses. Test procedures described in ASTM D-876-61 have been adapted to flat films to provide the data below. Stresses range from an infinitely high point load to 83 MPa (12,000 psi) at cut-through for a 25 μm (1 mil) film.

CUT-THROUGH TEMPERATURE VS. RATE OF TEMPERATURE RISE AND GAUGE

(Type H Film)



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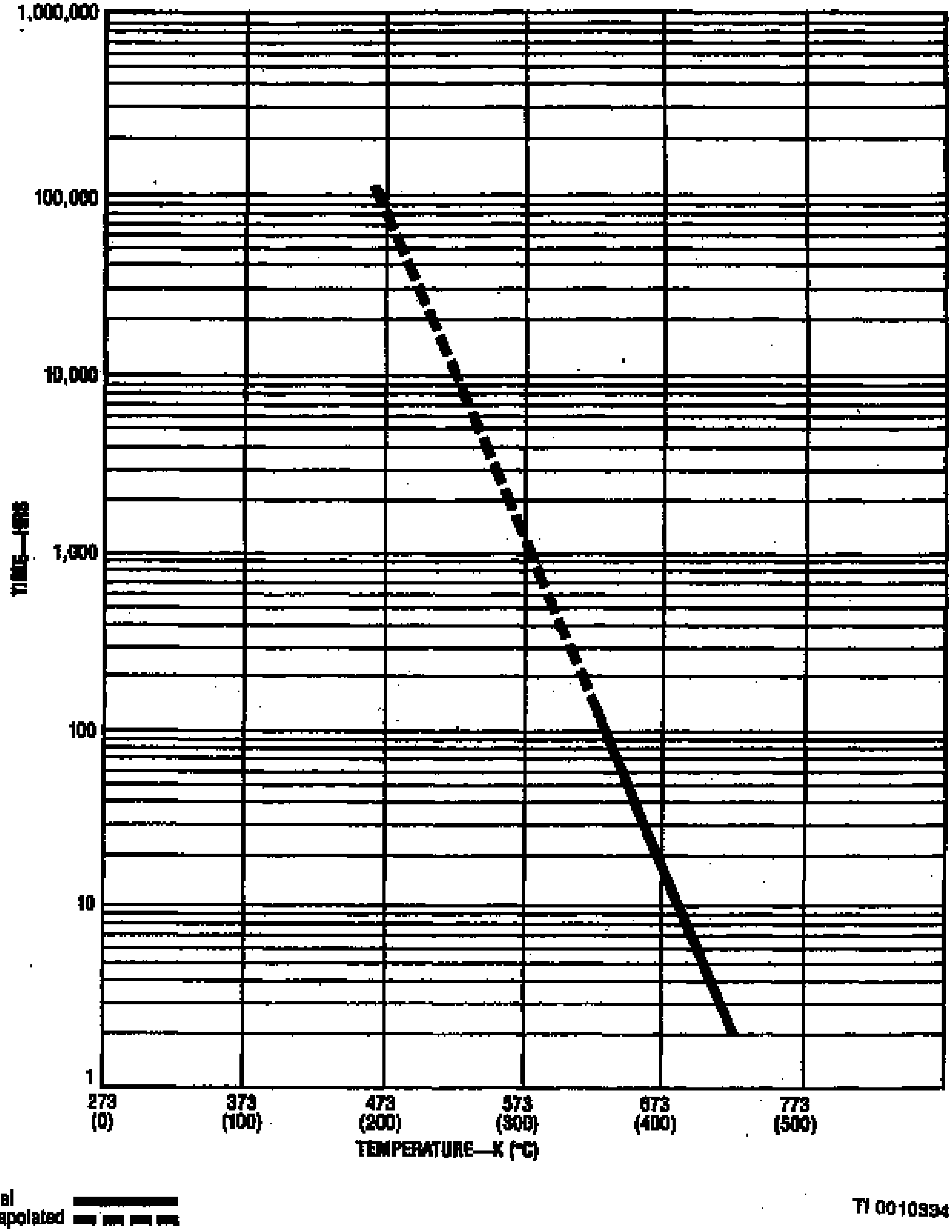
RESISTANCE TO CUT-THROUGH VS. TEMPERATURE

(Type H Film—25 μm (1 mil))



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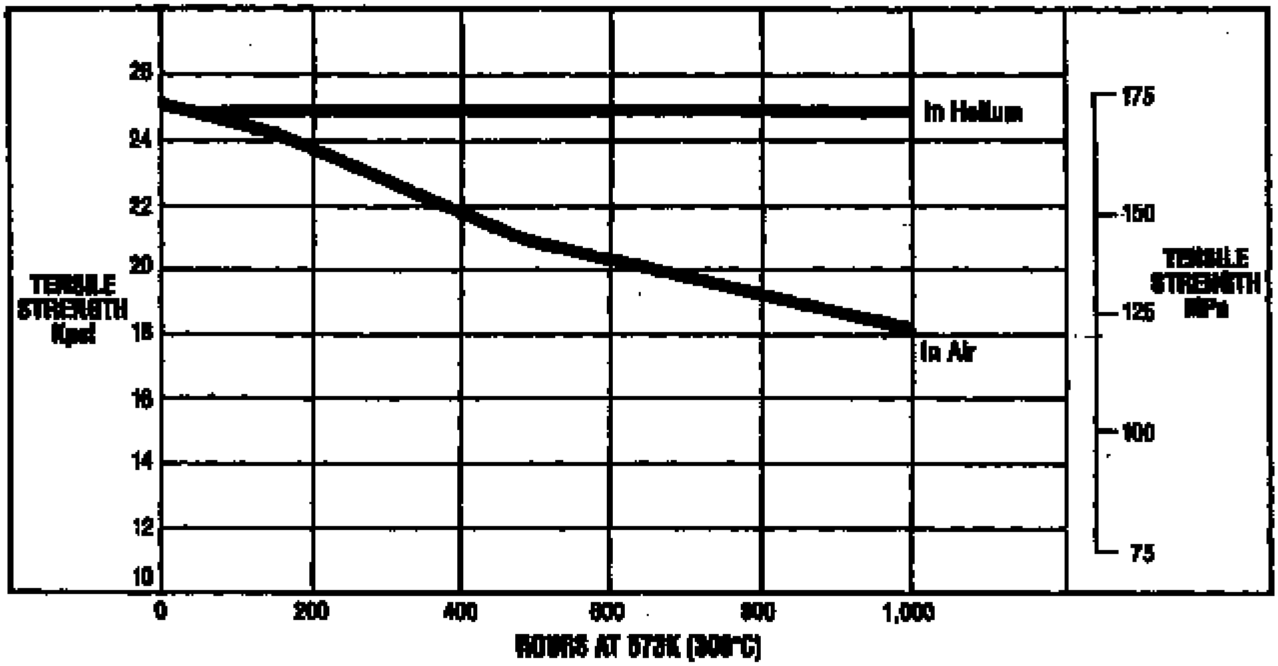
08236

THERMAL AGING

KAPTON® polyimide film is subject to oxidative degradation. Therefore its useful life is a function of both temperature and oxygen concentration in the test environment. The effect of these factors is shown below.

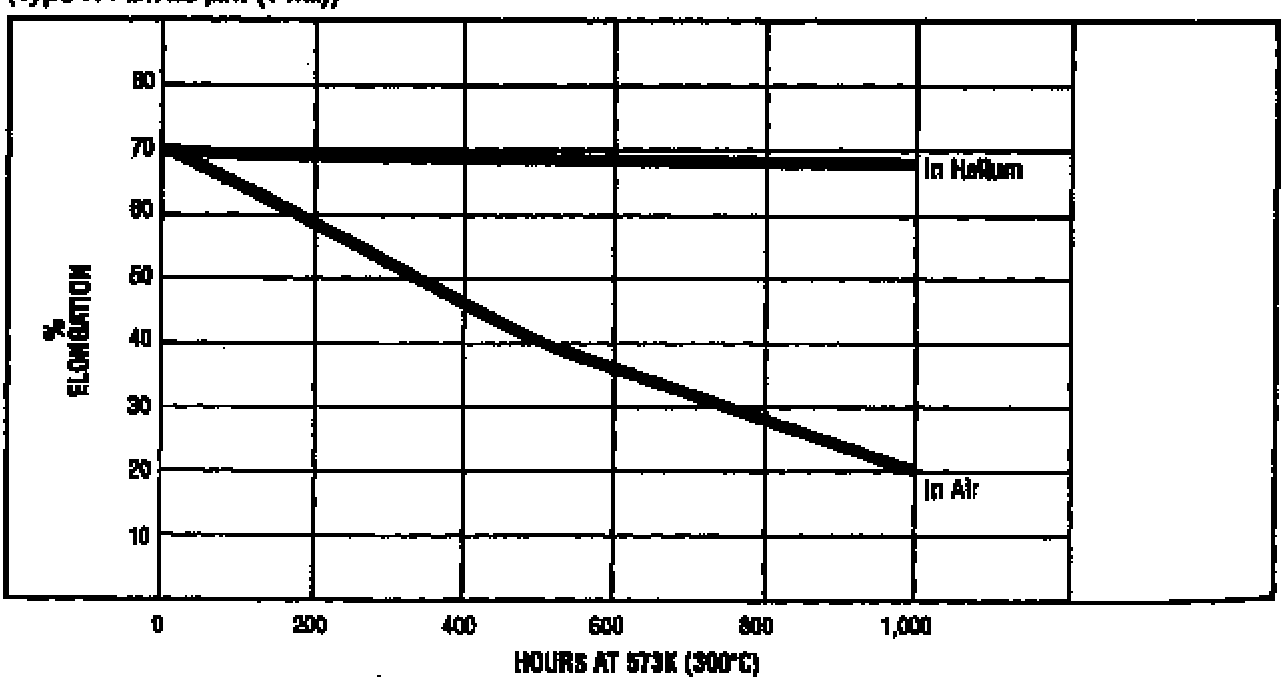
TENSILE STRENGTH VS. AGING AT 575K (300°C)

(Type H Film 25 μm (1 mil))



ULTIMATE ELONGATION VS. AGING AT 575K (300°C)

(Type H Film 25 μm (1 mil))



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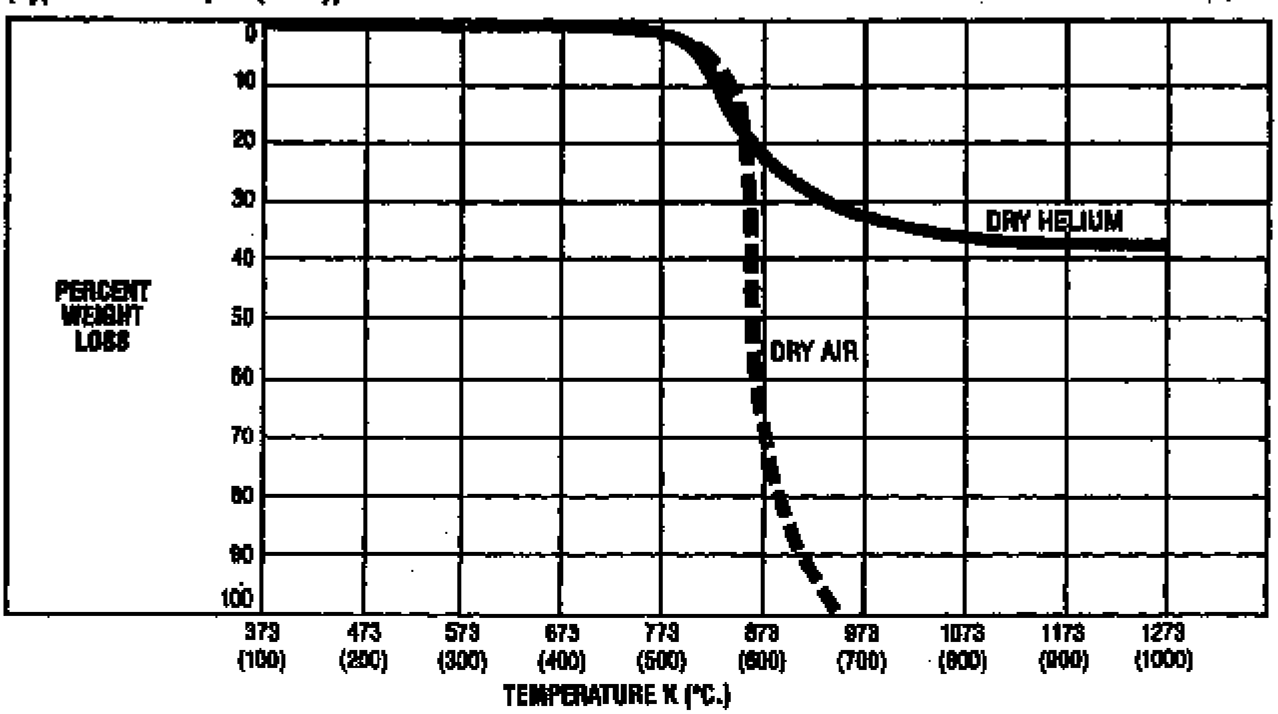
08337

TIME REQUIRED FOR REDUCTION IN ULTIMATE ELONGATION FROM 70% to 1%
(Type H Film 25 μm (1 mil))

Temperature		Environment	
		Air	Helium
723K	(450°C)	2 hours	22 hours
698K	(425°C)	5 hours	3½ days
673K	(400°C)	12 hours	2 weeks
648K	(375°C)	2 days	2 months
623K	(350°C)	6 days	1 year
573K	(300°C)	3 months	—
548K	(275°C)	1 year	—
523K	(250°C)	8 years	—

WEIGHT LOSS AT (3°C)/MINUTE TEMPERATURE RISE
(Type H Film 25 μm (1 mil))



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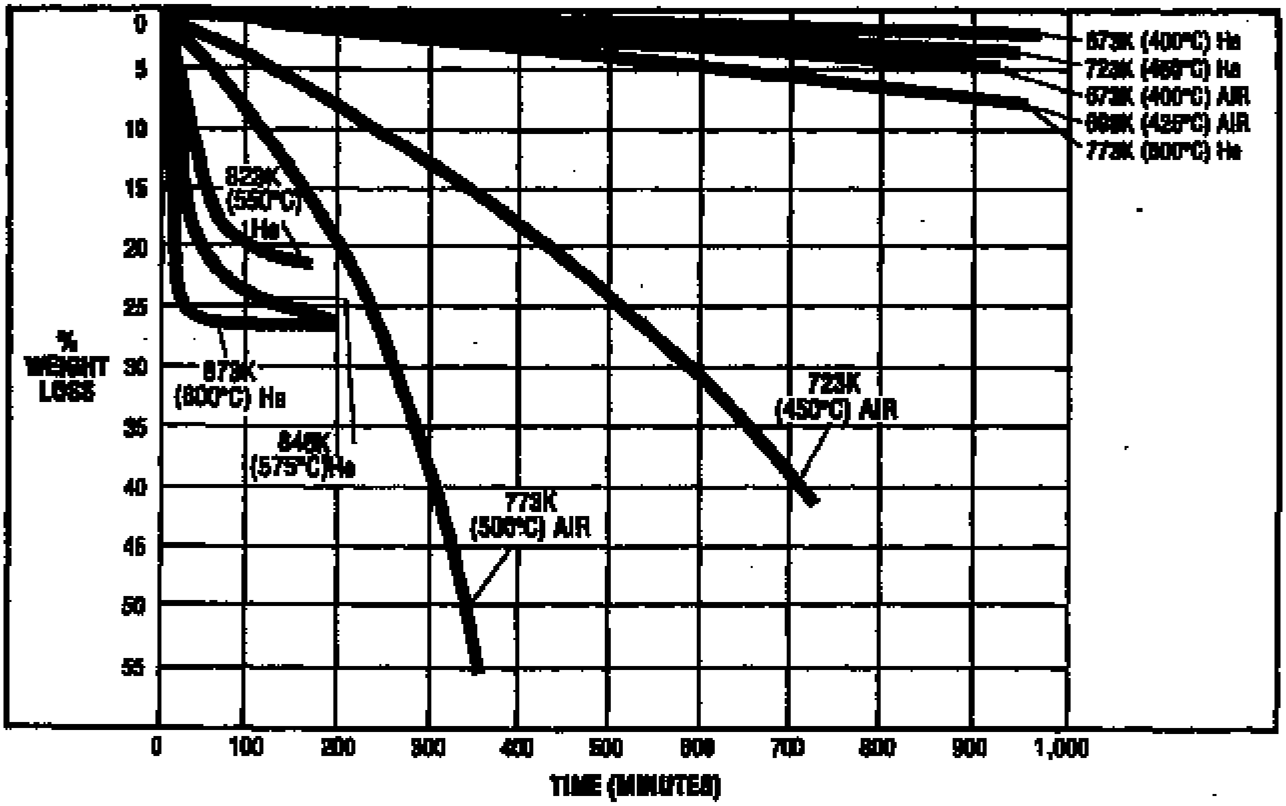
06238

ISOTHERMAL WEIGHT LOSS

(Type H Film 25 μm (1 mil))



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ELECTRICAL PROPERTIES

KAPTON® Type H Film

TYPICAL ELECTRICAL PROPERTIES

PROPERTY	TYPICAL VALUE	TEST CONDITION	TEST METHOD
Dielectric Strength			
25 μm (1 mil)	276 V/μm (7,000 V/mil)	60 hertz	ASTM D-149-81
50 μm (2 mil)	213 V/μm (5,400 V/mil)	¼" electrodes	
75 μm (3 mil)	181 V/μm (4,600 V/mil)		
125 μm (5 mil)	142 V/μm (3,600 V/mil)		
Dielectric Constant			
25 μm (1 mil)	3.5	1 kilohertz	ASTM D-150-81
50 μm (2 mil)	3.6		
75 μm (3 mil)	3.7		
125 μm (5 mil)	3.7		
Dissipation Factor			
25 μm (1 mil)	.0026	1 kilohertz	ASTM D-150-81
50 μm (2 mil)	.0025		
75 μm (3 mil)	.0025		
125 μm (5 mil)	.0027		
Volume Resistivity			
25 μm (1 mil)	1×10^{14} ohm-m	125 volts	ASTM D-257-78
50 μm (2 mil)	8×10^{14} ohm-m		
75 μm (3 mil)	5×10^{14} ohm-m		
125 μm (5 mil)	1×10^{15} ohm-m		

KAPTON® Type V Film

TYPICAL ELECTRICAL PROPERTIES

PROPERTY	TYPICAL VALUE	TEST CONDITION	TEST METHOD
Dielectric Strength			
50 μm (2 mil)	213 V/μm (5,400 V/mil)	60 hertz	ASTM D-149-81
75 μm (3 mil)	181 V/μm (4,600 V/mil)	¼" electrodes	
125 μm (5 mil)	142 V/μm (3,600 V/mil)		
Dielectric Constant			
50 μm (2 mil)	3.6	1 kilohertz	ASTM D-150-81
75 μm (3 mil)	3.7		
125 μm (5 mil)	3.7		
Dissipation Factor			
50 μm (2 mil)	.0025	1 kilohertz	ASTM D-150-81
75 μm (3 mil)	.0025		
125 μm (5 mil)	.0027		
Volume Resistivity			
50 μm (2 mil)	8×10^{14} ohm-m	125 volts	ASTM D-257-78
75 μm (3 mil)	6×10^{14} ohm-m		
125 μm (5 mil)	1×10^{14} ohm-m		

TI 0010999

DB/NHTSA No. 3
00241

KAPTON® Type F Film

TYPICAL ELECTRICAL PROPERTIES

PROPERTY	120F616	150F019	250F029
Dielectric Strength Total volts volts/μm (volts/mil)	 7,500 267 (6,800)	 6,300 165 (4,200)	 157 (4,000)
Dielectric Constant	2.8	3.0	
Dissipation Factor	.0022	.0014	
Volume Resistivity ohm-m @ 296K (23°C) (ohm-cm.) ohm-m @ 473K (200°C) (ohm-cm.)	 1.5×10^{14} (1.5×10^{16}) 5×10^{12} (5×10^{14})	 10^{16} (10^{18}) 10^{14} (10^{16})	 7×10^{15} (7×10^{17})

EFFECT OF HUMIDITY

(Type H Film 25 μm (1 mil))

Because the water content of KAPTON® polyimide film can effect its electrical properties, electrical measurements were made on 1 mil film after exposure to environments of varying relative humidities at 296K (23°C).

The results of these measurements are given below.

RELATIVE HUMIDITY VS. ELECTRICAL PROPERTIES OF KAPTON

% RELATIVE HUMIDITY	AC DIELECTRIC STRENGTH V/μm	(V/mil)	DIELECTRIC CONSTANT	DISSIPATION FACTOR
0	307	(7,800)	3.0	.0018
30	287	(7,300)	3.3	.0021
50	276	(7,000)	3.5	.0025
80	256	(6,500)	3.7	.0037
100	244	(6,200)	3.9	.0047

For calculations involving absolute water content, 50% RH in our study is equal to 1.3% water in the film and 100% RH is equal to 2.9% water, the maximum adsorption possible regardless of the driving force.

TI 0011000

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DB/NHTSA No. 3
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TI 0011002

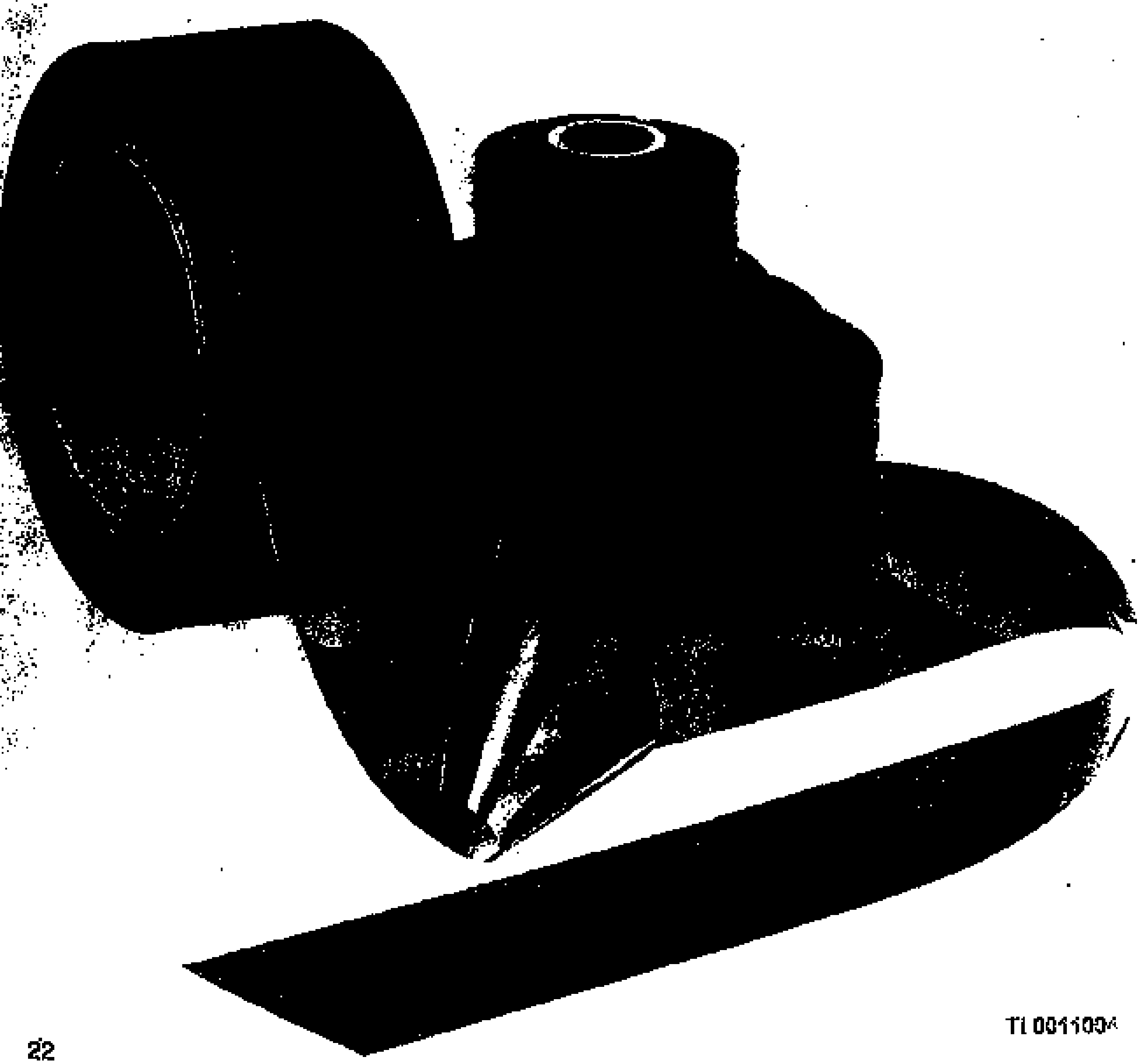
INQUIRIES

NOMINAL CONSTRUCTION, Type F Film

In the KAPTON® Type F order code of 3 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 TEFLON® FEP fluorocarbon resin in mils. The symbol 9 is used to represent 13 μm (½ mil) and 6 to represent 2.5 μm (1/10 mil). Example: 120F616 is a 120 gauge structure consisting of a 25 μm (1-mil) base film with a 2.5 μm (1/10 mil) coating of TEFLON on each side. Illustrated are 3 examples of the many types available.

ORDER CODE	NOMINAL THICKNESS		"TEFLON" FEP		"KAPTON" TYPE H		"TEFLON" FEP	
	μm	mils	μm	mils	μm	mils	μm	mils
120F616	30	1.2	2.5	0.1	25	1	2.5	0.1
150F019	38	1.5	0	0	25	1	13	½
250F029	64	2.5	0	0	51	2	13	½

ORDER CODE	STANDARD WIDTHS		AREA FACTOR	
	mm	inches	m²/Kg	FT²/LB.
120F616	3.18-914	1/8-36	21.3	104
150F019	3.18-914	1/8-36	15.8	77
250F029	3.18-914	1/8-36	11.1	49



TI 001100

KAPTON® Type V Film

CHEMICAL PROPERTIES

Typical chemical properties for Type V film are similar to Type H.

KAPTON® Type F Film

CHEMICAL PROPERTIES

PROPERTY	120F616	150F019	400F022
Moisture Absorption @ 298K (25°C), 50% R.H. 98% R.H.	 1.3% 2.5%	 .8% 1.7%	 .4% 1.2%
Water Vapor Permeability $g/m^2 \cdot d$ (gm./(100 in²) (24 hrs.) $g/m^2 \cdot d \cdot \mu m$ (g./(100 in²)(24 hrs./mil)	 13.7 (0.89) 0.44 (1.07)	 8.8 (0.57) 0.35 (0.85)	 3.6 (0.23) 0.14 (0.32)

TI 0011005

KAPTON® Type H Film

25 μm (1 mil)

CHEMICAL PROPERTIES

PROPERTY	TYPICAL VALUES (~25 μm (1 mil)) % Tensile Retained	% Elongation Retained	% Modulus Retained	TEST CONDITION/METHOD
RESISTANCE TO:				Days immersed at Room Temperature
Benzene	100	82	100	365
Toluene	99	91	97	365
Methanol	100	73	140	365
Acetone	67	62	160	365
10% Sodium Hydroxide		Degrades		5
Glacial Acetic Acid	85	62	102	36 days @ 383K (110°C)
p-Cresol	100	77	102	22 days @ 473K (200°C)
Transformer Oil	100	100	100	180 days @ 423K (150°C)
Water pH = 1	65	30	100	14 days @ 373K (100°C)
pH = 4.2	65	30	100	14 days @ 373K (100°C)
pH = 7.0	65	20	100	168 days @ 373K (100°C)
pH = 8.9	65	20	100	14 days @ 373K (100°C)
pH = 10.0	60	10	100	4 days @ 373K (100°C)
RADIATION RESISTANCE				
Gamma (Savannah River)		Still Flexible (180° Bend)		Exposure: 4.16×10^7 Gy
Electron (Van de Graaff)		Retains 50% of Original Elongation		Exposure: 6×10^7 Gy
Neutron plus Gamma (Brookhaven)		Darkened but tough		Exposure: 10^8 Gy
FUNGUS RESISTANCE		Inert		Soil Burial
MOISTURE ABSORPTION		1.3% Type H		50% Relative Humidity at 296K (23°C)
		2.9% Type H & V		Immersion for 24 hours at 296K (23°C)
HYGROSCOPIC COEFFICIENT OF EXPANSION		2.2×10^{-5} m/m/% Relative Humidity		295K (72°F) 20%-80% Relative Humidity
PERMEABILITY				
Gas		ml/m²·MPa-day (cc/(100 in²) (24 hrs.) (atm/mil))		
Carbon Dioxide		6.9 (45)		ASTM D-1434-63 @ 296K (23°C)
Hydrogen		38 (250)		
Nitrogen		0.9 (6)		
Oxygen		3.8 (25)		
Helium		63 (415)		
Water Vapor		g/m²·day 54 g/(100 in²) (24 hrs.)/mil 5.4		ASTM E-96-63T

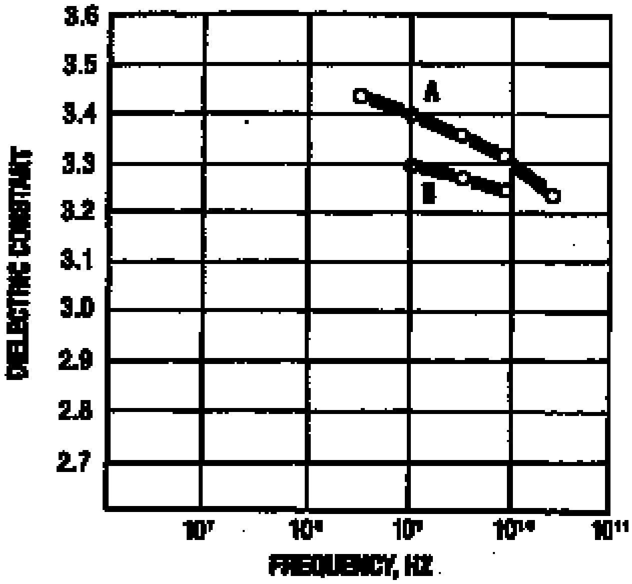
TI 0011006

DD/NHTSA No. 3
00248

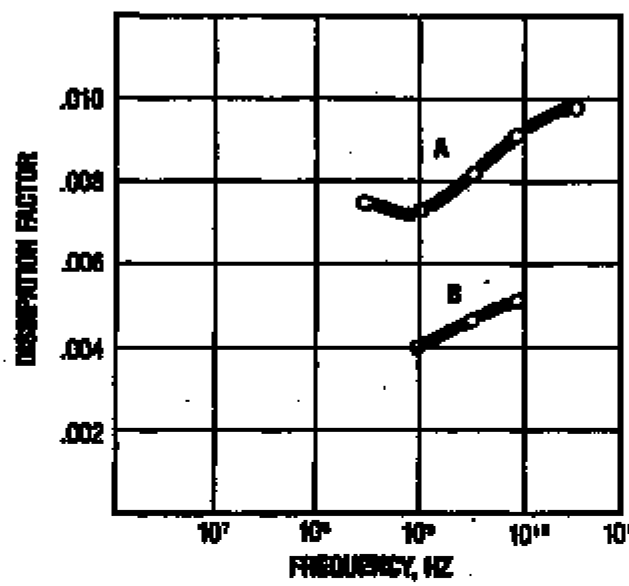
CHEMICAL PROPERTIES

DIELECTRIC PROPERTIES IN GIGAHERTZ FREQUENCY RANGE

(Type H Film, 125μm (5 mil))*



(Type H Film, 125μm (5 mil))*



*Technical Report AFML-TR-72-39—Curve A is 500H KAPTON as received and measured at 23°C 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 for 48 hours.

TRACKING RESISTANCE

A 125 μm (5 mil) KAPTON® polyimide film, Type H, has a tracking resistance of 163 seconds as measured by ASTM D-495-61. The failure was due to true tracking rather than erosion, etc.

CORONA LIFE

Like all organic materials, KAPTON is attacked by corona and will ultimately fail dielectrically when exposed continuously to corona. At moderate levels of corona exposure, devices insulated with KAPTON have survived up to 3,000 hours, giving reasonable assurance that brief exposures to corona will not significantly affect the life of a properly designed insulation system based on KAPTON.

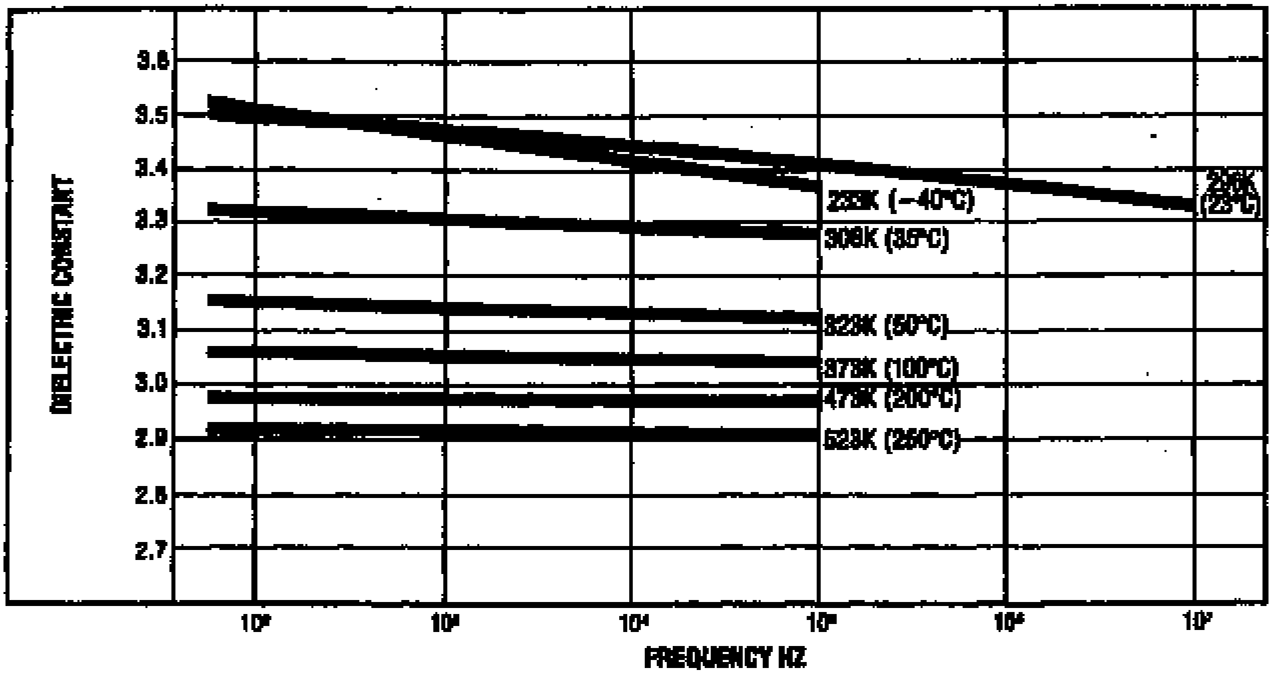
Corona inception voltage and corona intensity are functions of many parameters, including insulation thickness, air gap thickness, and device shape. Consult with a Du Pont technical representative on the suitability of KAPTON for specific applications where corona may be present.

EFFECT OF FREQUENCY

The effects of frequency on the value of the dielectric constant and dissipation factor at various isotherms are shown below.

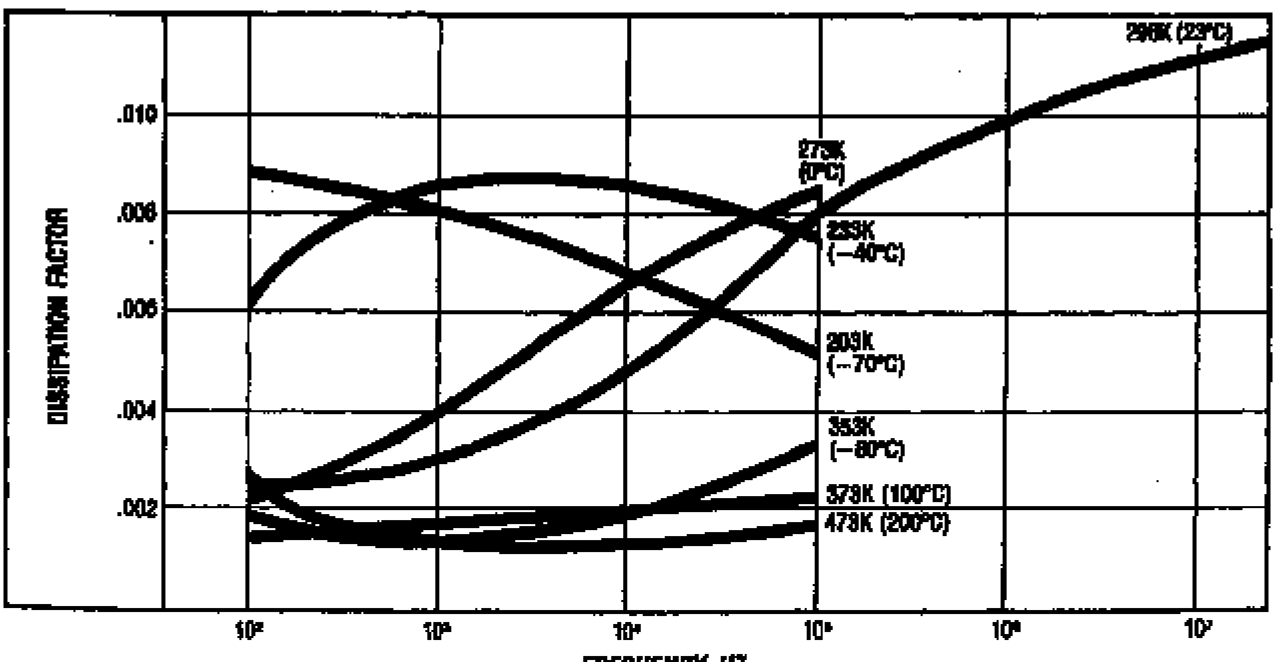
DIELECTRIC CONSTANT VS. FREQUENCY

(Type H Film 25 μm (1 mil))



DISSIPATION FACTOR VS. FREQUENCY

(Type H Film 25 μm (1 mil))



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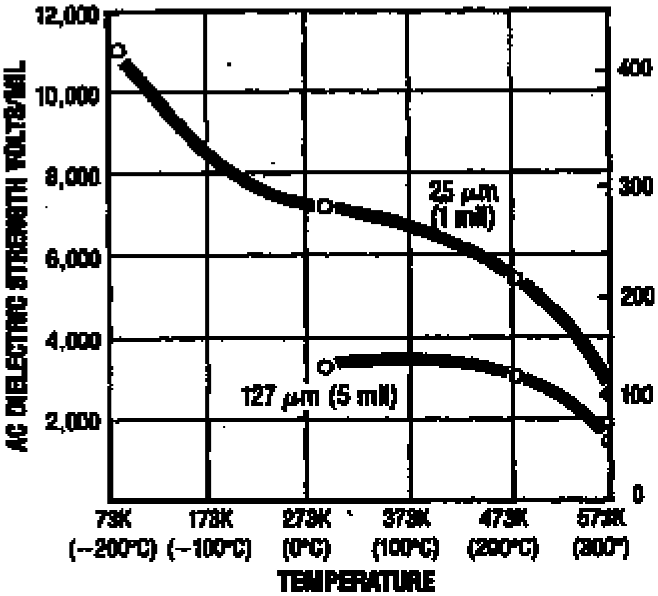
00251

EFFECT OF TEMPERATURE

As the graphs below indicate, extreme changes in temperature have relatively little affect on the excellent room temperature electrical properties of KAPTON.

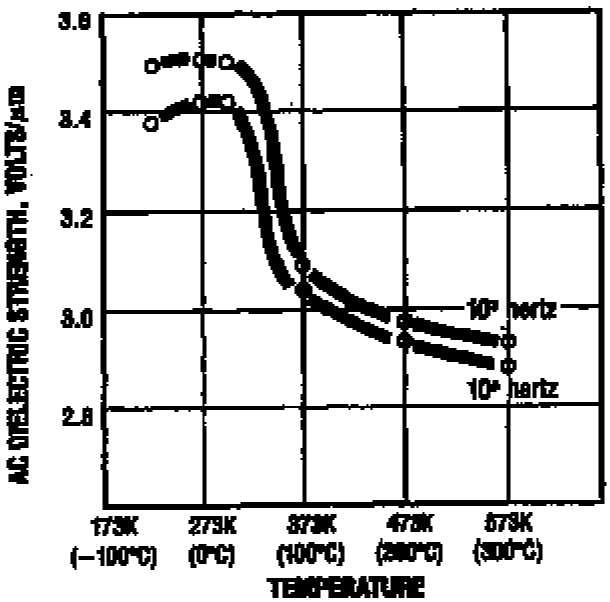
AC DIELECTRIC STRENGTH VS. TEMPERATURE

(Type H Film)



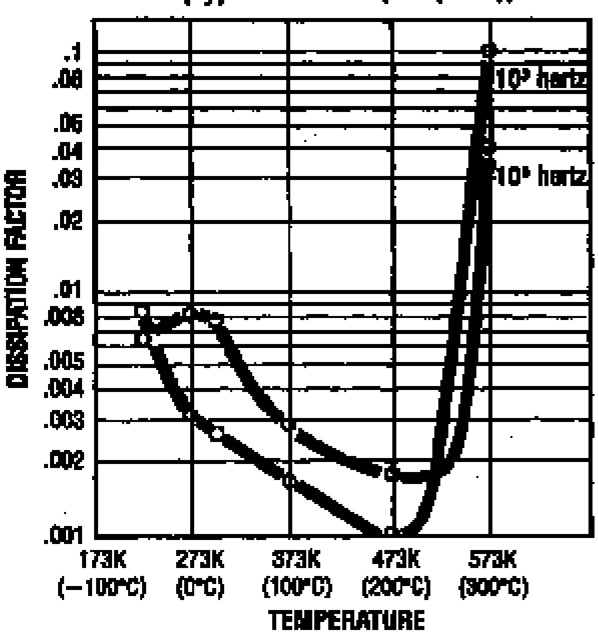
DIELECTRIC CONSTANT VS. TEMPERATURE

(Type H Film—25 μm (1 mil))



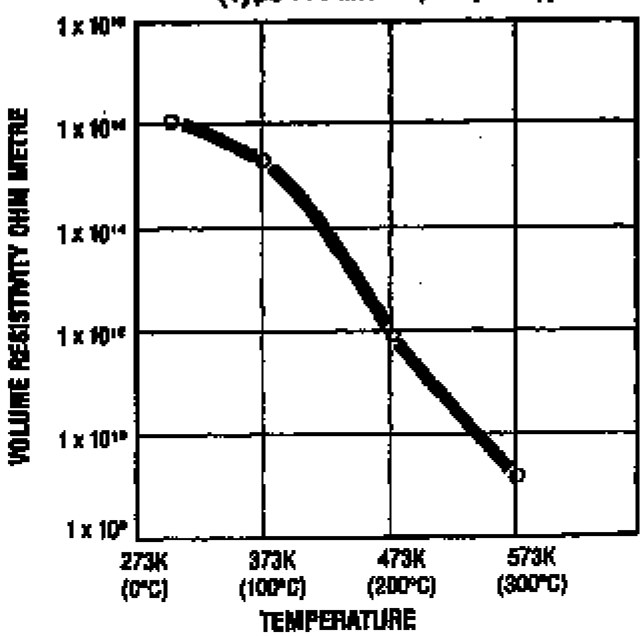
DISSIPATION FACTOR VS. TEMPERATURE

(Type H Film 25 μm (1 mil))



VOLUME RESISTIVITY VS. TEMPERATURE

(Type H Film 25 μm (1 mil))



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CHEMICAL PROPERTIES

Kapton

POLYIMIDE FILM

ADHESION TO KAPTON®

KAPTON® polyimide film, made only by Du Pont, is available in three basic film types. Type H KAPTON is 100% polyimide film. Type F is coated on one or both sides with a TEFLON® FEP fluorocarbon adhesive and Type V is a plain polyimide film having superior dimensional stability properties. Typical property information for KAPTON is found in Bulletin E-72087, "Summary of Properties." Specifications are found in Bulletin E-67824, "Industry Specifications Bulletin FC-85-2." For flexible printed circuit applications the trade specification IPC-FC-231/Sheet 1, applies to KAPTON.

ADHESIVE SELECTION

For some applications KAPTON must be bonded to other materials, such as copper foil, which requires the use of an adhesive. Optimum adhesion results are usually obtained from commercially coated KAPTON which is available from a variety of suppliers such as those listed in Bulletin E-72091, "Suppliers of Adhesive Coatings on KAPTON." This listing represents most of those companies offering coated KAPTON but should not be regarded as a complete listing. Detailed information on the use of these adhesive coated products can be obtained from the supplier's bulletins. Specific requirements for copper laminates produced as substrates for flexible printed circuits are outlined in trade specifications:

- USA: IPC-FC-241
- British: BS-4584
- German: DIN-40802

When commercially coated film is not suitable for an application, most vendors offer a dry film form of their adhesives for use as a bonding film in laminations. However, better adhesion is normally obtained from commercial solution coatings than from the dry bonding film. The dry film adhesive does have the advantage that it can be cut to shapes which cover only that portion of the polyimide film where adhesion is desired.

If neither commercially coated polyimide film nor adhesive bonding film is suitable for the application, the remaining option is for the user to apply a solution adhesive. Some generic classes of adhesives which bond KAPTON include acrylics, epoxies, butyral-phenolics, polyesters, silicones, urethanes, fluorocarbons and blends of these materials.

Selection of an adhesive is usually dependent on the properties required of the adhesive and the demands of the application. Property considerations are the thermal rating, chemical resistance, fill and flow characteristics, flexibility, peel strength, flammability, moisture resistance and insulation resistance. Also to be considered is the ease of processing, lamination temperature and whether the lamination is to be made in continuous roll equipment or in a platen press.

ADHESIVE PROPERTIES

Adhesives used with KAPTON Type H are usually a modified version of the generic adhesive family (e.g., modified-epoxy). These formulations are proprietary to the suppliers of coated KAPTON and require specific processing conditions to achieve the maximum bond strength. Always use the supplier's recommended lamination conditions for the specific adhesive you select.

Listed in Table I are several adhesive types along with information on typical lamination temperatures and maximum operating temperatures (short term exposure). When using an epoxy adhesive, anhydride curing agents are preferred. If an amine curing agent must be used, avoid an excess of curing agent as the free alkaline materials can degrade the polyimide.

TABLE 1

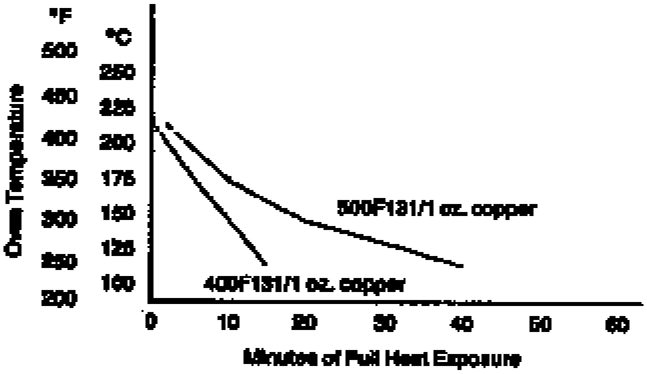
Adhesive Types	Lamination Temperatures °F (°C)	Maximum Operating Temperature °F (°C)
Fluorocarbons	550-600 (290-315)	to 500 (260)
Polyimides	500-700 (260-370)	to 650 (345)
Epoxies	73-450 (23-230)	to 600 (315)
Pressure Sensitive Silicones	73-300 (23-150)	to 500 (260)
Rubber-Phenolics	300-400 (150-205)	to 500 (260)
Acrylics	350-375 (175-190)	to 550 (290)
Polyesters	275-300 (135-150)	to 220 (105)

Solution forms of most of the adhesives above are available from suppliers of adhesives to the electronics industry. Listings of suppliers can be found in buyer's guides for electronic products. Bulletin E-74149, "Suppliers of Adhesives to the Electronics Industry," provides a representative listing of adhesive suppliers who can be consulted with for specific adhesive needs.

DUPONT

Given in Figure 3 are minimum times to dry laminates of Type F to copper prior to dip soldering. The times are different than in Figure 2 due to the presence of the copper foil.

FIGURE 3
DRYING CONDITIONS FOR KAPTON TYPE F LAMINATES PRIOR TO DIP SOLDERING



SOLDERING AND PRESS CONDITIONS FOR TYPE H LAMINATES

The recommended predrying conditions prior to dip soldering and platen pressing laminates based on type H film will vary according to type of thermoset adhesive used in addition to factors mentioned for Type F laminates. The moisture retention and permeability of the film and adhesive must be considered along with the impermeability of the copper foil layers. Consult your laminate supplier for recommended predrying conditions specific to the combination of materials supplied.

EFFECTS OF HUMIDITY ON PEEL STRENGTH

Humidity can have a large effect on peel strength with certain adhesive systems, and RH ought to be controlled in peel strength measurements. A summary of our investigation into this phenomenon is given in Table III. Results show that those adhesives having functional groups capable of absorbing water vapor will promote high peel strengths at high RH and low peel strengths at low RH. Between an RH of 10% and an RH of 70%, the effect can be as large as 6 lbs. per lineal inch (10.5 N/cm). Those adhesives which do not have hygroscopic functional groups are not affected by RH changes in terms of peel values.

TABLE III
EFFECTS OF RELATIVE HUMIDITY ON PEEL STRENGTH

Adhesive Type	Peel Strength, lb./in. (N/cm) 10% RH	70% RH
Acrylic	5.8 (10.2)	11.5 (20.1)
Epoxy-Amide	5.4 (9.5)	10.0 (17.5)
Epoxy-Novolac	2.0 (3.5)	2.1 (3.7)
Phenolic-Butyral	3.8 (6.7)	5.2 (9.1)
Phenolic-Nitrile	4.7 (8.2)	4.3 (7.5)

EFFECT OF SURFACE ON PEEL STRENGTH

The top surface of KAPTON is referred to as the "bright" or "shiny" side. The bottom side is "dull" and purposely roughened in the manufacture of the film to improve film handling characteristics. Most adhesives bond better to the dull side of the film. The effect is generally 1-2 lbs. per lineal inch (1.8-3.5 N/cm) but can be as high as 4 lbs. per inch (7.0 N/cm) or negligible depending on the adhesive system used.

Experience has also shown that peel strength normally increases with the thickness of the film. Within a laminate based on a given film thickness, a range of peel strengths can also be expected, which is inherent in the film surface, the adhesive system and the test method applied. For example, a typical peel strength range for an acrylic adhesive is 6 lbs./in. (10.5 N/cm). For 100H this range can result in values as low as 2 lbs./in. (3.5 N/cm).

Unless specifically recommended by the adhesive supplier, the surface of KAPTON should be used as received. If the film has been contaminated with grease or oils, it should be cleaned with solvent (such as methylethyl ketone or toluene). Metal surfaces should be thoroughly cleaned. For best adhesion, they should be roughened mechanically or by chemical treatment.

When higher adhesion levels are required for a given adhesive system, the range of the peel strength values for the laminate may usually be reduced if the surface of the film is mechanically or chemically abraded, light pumice scrubbing or caustic etching. Caution must be exercised with any such treatment to avoid damaging the film.

EFFECT OF THERMAL TREATMENT ON PEEL STRENGTH

High thermal treatment of KAPTON will often improve bondability. Temperatures of about 400°C for as long as 5-10 minutes are required, and structural changes probably occur.

Studies of adherability of typical printed circuit adhesives to heat treated KAPTON and standard KAPTON have shown that heat treatment provides an advantage with most adhesives. The greatest advantage was gained with acrylic, epoxy, phenolic butyrals and phenolic nitriles. Improvement over standard film averaged from 40% to 97% for these adhesive types.

KAPTON® Type H Film

25 μm (1 mil)

CHEMICAL PROPERTIES

PROPERTY	TYPICAL VALUES (~25 μm (1 mil)) % Tensile Retained	% Elongation Retained	% Modulus Retained	TEST CONDITION/METHOD
RESISTANCE TO:				Days Immersed at Room Temperature
Benzene	100	82	100	365
Toluene	99	91	97	365
Methanol	100	73	140	365
Acetone	67	62	160	365
10% Sodium Hydroxide		Degrades		5
Glacial Acetic Acid	85	62	102	36 days @ 383K (110°C)
p-Cresol	100	77	102	22 days @ 473K (200°C)
Transformer Oil	100	100	100	180 days @ 423K (150°C)
Water pH = 1	65	30	100	14 days @ 373K (100°C)
pH = 4.2	65	30	100	14 days @ 373K (100°C)
pH = 7.0	65	20	100	186 days @ 373K (100°C)
pH = 8.9	65	20	100	14 days @ 373K (100°C)
pH = 10.0	60	10	100	4 days @ 373K (100°C)
RADIATION RESISTANCE				
Gamma (Savannah River)		Still Flexible (180° Bend)		Exposure: 4.16×10^7 Gy
Electron (Van de Graaff)		Retains 50% of Original Elongation		Exposure: 6×10^7 Gy
Neutron plus Gamma (Brookhaven)		Darkened but tough		Exposure: 10^8 Gy
FUNGUS RESISTANCE		Inert		Soil Burial
MOISTURE ABSORPTION		1.3% Type H		50% Relative Humidity at 296K (23°C)
		2.9% Type H & V		Immersion for 24 hours at 296K (23°C)
HYGROSCOPIC COEFFICIENT OF EXPANSION		2.2×10^{-5} m/m/% Relative Humidity		295K (72°F) 20%-80% Relative Humidity
PERMEABILITY Gas		ml/m²·MPa·day {cc/(100 in²) (24 hrs.) (atm/mil)}		
Carbon Dioxide		6.9 (45)		ASTM D-1434-63 @ 296K (23°C)
Hydrogen		38 (250)		
Nitrogen		0.9 (6)		
Oxygen		3.8 (25)		
Helium		63 (415)		
Water Vapor		g/m²·day 84 g/(100 in²) (24 hrs.)/mil 5.4		ASTM E-96-63T

TI 0011015

DD/NETSA No. 3
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TI 0011016

KAPTON® Type V Film

CHEMICAL PROPERTIES

Typical chemical properties for Type V film are similar to Type H.

KAPTON® Type F Film

CHEMICAL PROPERTIES

PROPERTY	120F616	150F019	400F022
Moisture Absorption			
@ 296K (23°C), 50% R.H.	1.3%	.8%	.4%
98% R.H.	2.5%	1.7%	1.2%
Water Vapor Permeability			
$g/m^2 \cdot d$	13.7	8.8	3.5
(gm./(100 in²) (24 hrs.)	(0.89)	(0.57)	(0.23)
$g/m^2 \cdot d \cdot \mu m$	0.44	0.35	0.14
(g./(100 in²)(24 hrs./mil)	(1.07)	(0.85)	(0.32)

TI 0011017

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00259

Kapton®
Polymide Film

DuPont
Electronics

High Performance Films

TI 0011018

TI 0011019

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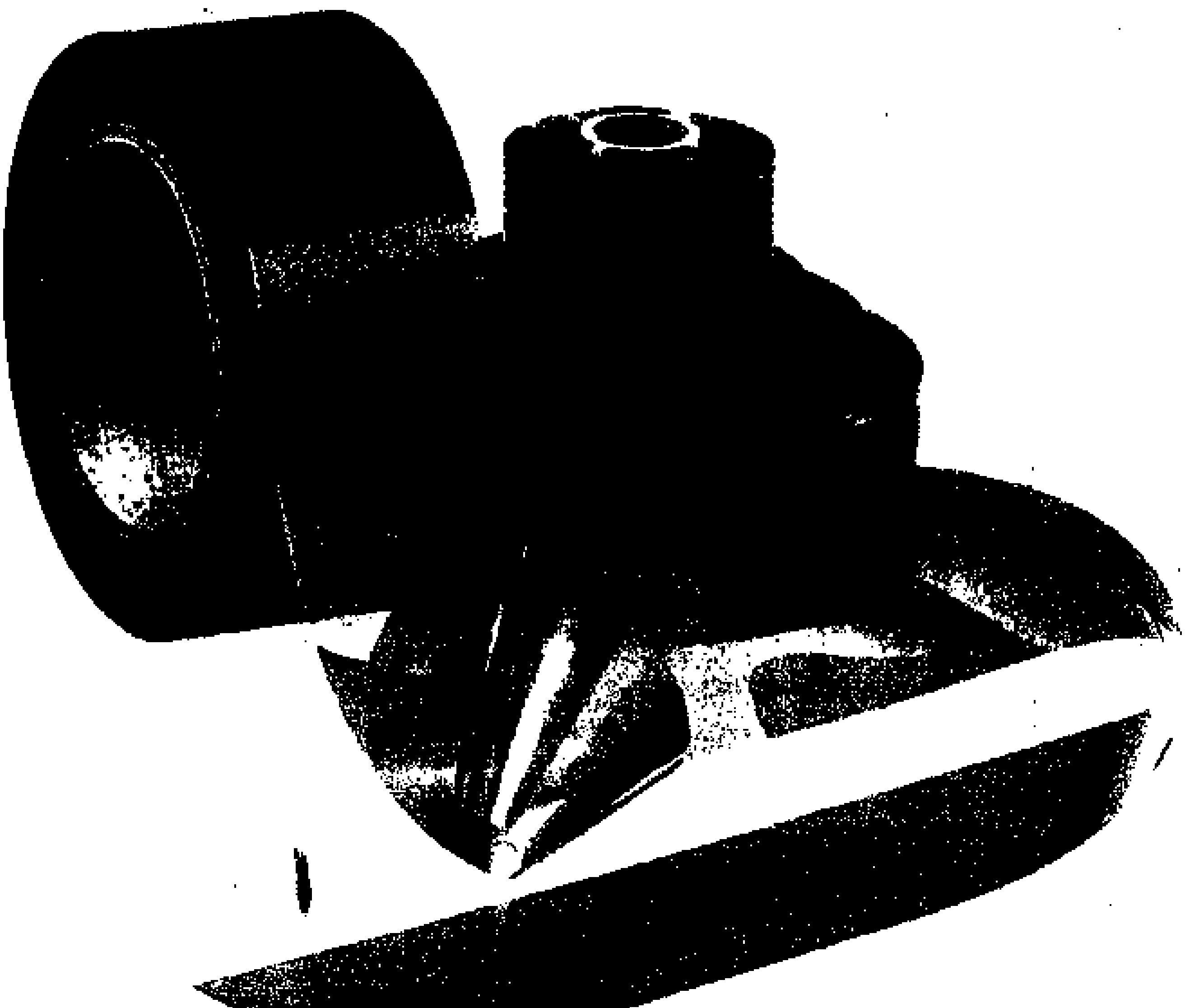
TI 0011020

NOMINAL CONSTRUCTION, Type F Film

In the KAPTON® Type F order code of 3 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 TEFLON® FEP fluorocarbon resin in mils. The symbol 9 is used to represent 13 μm (½ mil) and 6 to represent 2.5 μm (1/10 mil). Example: 120F616 is a 120 gauge structure consisting of a 25 μm (1-mil) base film with a 2.5 μm (1/10 mil) coating of TEFLON on each side. Illustrated are 3 examples of the many types available.

ORDER CODE	NOMINAL THICKNESS		"TEFLON" FEP		"KAPTON" TYPE H		"TEFLON" FEP	
	μm	mils	μm	mils	μm	mils	μm	mils
120F616	30	1.2	2.5	0.1	25	1	2.5	0.1
150F019	38	1.5	0	0	25	1	13	½
250F029	64	2.5	0	0	51	2	13	½

ORDER CODE	STANDARD WIDTHS		AREA FACTOR	
	mm	inches	m^2/Kg	FT^2/LB.
120F616	3.18-914	1/8-36	21.3	104
150F019	3.18-914	1/8-36	15.8	77
250F029	3.18-914	1/8-36	11.1	49



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TI 0011025

DD/NHTSA No. 3
00267

Form 417 Rev.2F

Inland Fisher Guide - Impact Test Facility

Request for Testing

Test No. 95-IFS7101 Run No. SD 17375 ITF Tech. D. Brown Test Date 05 Dec 95

Submitted By George Panson (signature) George Panson Phone # 6-2730 Date 11/27/95 Use NA where Not Applicable

Type of Test Static Deployment

ONE Occupant Defined Per Sheet

One Or Two Occupant Test

Buck ID.__________ Pulse No.__________

Occupant Location

Occupant Type

ATD # I-__________

Occupant Position__________

Body Line Dimensions Head____/____Hip____/____Knee____/____Ankle____/____

INSTRUMENT DESCRIPTION AND IDENTIFICATION

Channels Required Serial Number

SIR Cab Pres-1 TM160 __________
SIR Cab Pres-2 TM160 __________
SIR Cab Pres-3 TM160 __________
-----End of List-----

Timing light Generator TM302 17C Pin Number__________

Test Film Process Film

KineticSystems HTMS 3000 TM381 1- __________
KineticSystems HTMS 3000 TM381 2- __________
KineticSystems HTMS 3000 TM381 3- __________
KineticSystems HTMS 3000 TM381 4- __________
KineticSystems HTMS 3000 TM381 5- __________
KineticSystems HTMS 3000 TM381 6- __________

Dial Indicators TM199 __________

Firing Controls TM390 Dr V____Dr C____Resistance____

Volt Ohm Meter TM___ Ps V____Ps C____Resistance 2.10-2

Firing Controls TM390-2 Dr Dial________Pas Dial 60

Compressed Gas Timer 1____Timer 2____Timer 3____Timer 4____

Accumulator Pres. Tank 1____Tank 2____Tank 3____

Tank#____Volume____UTT106-102____

Conditioning Chamber __________

Temperature Indicator TM254 __________

Thermometer TM251 __________

Tank Test Stand TM374 __________

Air/Nitrogen Purge Gauge TM369-25 __________

35mm Film Roll Number 8663 __________

Additional Instruments __________

TM 509-4 Ohm Meter

Technician Comments__________

G.M. CONFIDENTIAL

Kapton
POLYIMIDE FILM

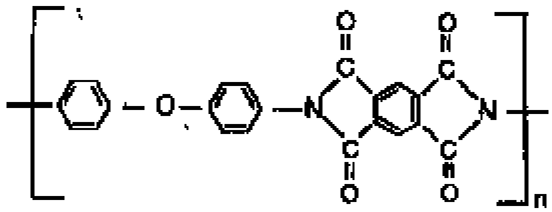
safe handling

Industrial Films Division

SAFETY IN HANDLING AND USE

Introduction

KAPTON polyimide film is a strong, tough, transparent amber-colored plastic film exhibiting excellent physical, chemical and electrical properties over an extremely wide temperature range. It has the structure:



KAPTON is produced in three forms, Type H, Type V, and Type F. Type H is the basic uncoated polyimide film. Type V is similar to Type H but has superior dimensional stability. Type F is coated on one or both sides with Teflon* FEP fluorocarbon resin which imparts heat sealability, provides a moisture barrier, and enhances chemical resistance.

KAPTON is used as insulation for wire and cable, formed coils, magnet wire and transformers, and motor slot liners, among other uses. It also is used as a substrate for flexible printed circuits.

This booklet provides guidelines for the safe handling of KAPTON during processing, use, and disposal.

Users of Type F KAPTON should also refer to DuPont bulletin "Teflon* Fluorocarbon Resins — Safety in Handling and Use."

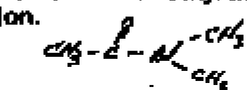
I. GENERAL PROPERTIES

KAPTON Type H and Type V, exhibits no melting point or softening point. A one-mil thick film has a zero-strength temperature of 815°C (1500°F). Zero-strength is measured as the maximum temperature at which the film will sustain a load of 138 KPa (20 psi) for 5 seconds.

KAPTON is insoluble in most common organic solvents after immersion for up to a year (Ref. 1). The hydrolytic stability of KAPTON Type H has been measured after 168 days exposure to boiling water. The film retained 65% of its tensile properties and 20% of its elongation. KAPTON is dissolved by strong acids (Ref. 2, 3) such as fuming nitric and concentrated sulfuric acid, particularly on heating, and is hydrolyzed by alkali and super-heated steam.

KAPTON Type F exhibits better chemical, hydrolytic, and oxidative resistance than Types H and V.

KAPTON may contain up to 1% by weight of dimethyl acetamide residual solvent. At elevated temperatures, some of the solvent may be released and must be removed by exhaust ventilation or diluted to safe levels. OSHA (29 CRF 1910.1000) has established the safe level for dimethyl acetamide as ten parts per million.



II. PYROLYSIS STUDIES

Studies (Ref. 4, 5) have shown the outstanding thermal stability of polyimide film. Its rate of degradation is dependent upon the availability of oxygen. In air at about 500°C (932°F) KAPTON decomposes and completely disappears after twelve hours. At 450°C in air, carbon monoxide may be formed in significant amounts. In a vacuum or inert atmosphere, 60 to 65% of the film remains after prolonged aging at 1000°C (1832°F). The residue retains its original shape but has lost its mechanical strength. The major off-gases are carbon dioxide and carbon monoxide. (See chart)

*Reg. U.S. Pat & T M Off

Kapton

POLYIMIDE FILM

ADHESION TO KAPTON®

KAPTON® polyimide film, made only by Du Pont, is available in three basic film types. Type H KAPTON is 100% polyimide film. Type F is coated on one or both sides with a TEFLON® FEP fluorocarbon adhesive and Type V is a plain polyimide film having superior dimensional stability properties. Typical property information for KAPTON is found in Bulletin E-72087, "Summary of Properties." Specifications are found in Bulletin E-67624, "Industry Specifications Bulletin FC-85-2." For flexible printed circuit applications the trade specification IPC-FC-231/Sheet 1, applies to KAPTON.

ADHESIVE SELECTION

For some applications KAPTON must be bonded to other materials, such as copper foil, which requires the use of an adhesive. Optimum adhesion results are usually obtained from commercially coated KAPTON which is available from a variety of suppliers such as those listed in Bulletin E-72091, "Suppliers of Adhesive Coatings on KAPTON." This listing represents most of those companies offering coated KAPTON but should not be regarded as a complete listing. Detailed information on the use of these adhesive coated products can be obtained from the supplier's bulletins. Specific requirements for copper laminates produced as substrates for flexible printed circuits are outlined in trade specifications:

- USA: IPC-FC-241
- British: BS-4584
- German: DIN-40802

When commercially coated film is not suitable for an application, most vendors offer a dry film form of their adhesives for use as a bonding film in laminations. However, better adhesion is normally obtained from commercial solution coatings than from the dry bonding film. The dry film adhesive does have the advantage that it can be cut to shapes which cover only that portion of the polyimide film where adhesion is desired.

If neither commercially coated polyimide film nor adhesive bonding film is suitable for the application, the remaining option is for the user to apply a solution adhesive. Some generic classes of adhesives which bond KAPTON include acrylics, epoxies, butyral-phenolics, polyesters, silicones, urethanes, fluorocarbons and blends of these materials.

Selection of an adhesive is usually dependent on the properties required of the adhesive and the demands of the application. Property considerations are the thermal rating, chemical resistance, fill and flow characteristics, flexibility, peel strength, flammability, moisture resistance and insulation resistance. Also to be considered is the ease of processing, lamination temperature and whether the lamination is to be made in continuous roll equipment or in a platen press.

ADHESIVE PROPERTIES

Adhesives used with KAPTON Type H are usually a modified version of the generic adhesive family (e.g., modified-epoxy). These formulations are proprietary to the suppliers of coated KAPTON and require specific processing conditions to achieve the maximum bond strength. Always use the supplier's recommended lamination conditions for the specific adhesive you select.

Listed in Table I are several adhesive types along with information on typical lamination temperatures and maximum operating temperatures (short term exposure). When using an epoxy adhesive, anhydride curing agents are preferred. If an amine curing agent must be used, avoid an excess of curing agent as the free alkaline materials can degrade the polyimide.

TABLE 1

Adhesive Types	Lamination Temperatures °F (°C)	Maximum Operating Temperature °F (°C)
Fluorocarbons	550-600 (290-315)	to 500 (260)
Polyimides	500-700 (260-370)	to 650 (345)
Epoxies	73-450 (23-230)	to 600 (315)
Pressure Sensitive Silicones	73-300 (23-150)	to 500 (260)
Rubber-Phenolics	300-400 (150-205)	to 500 (260)
Acrylics	350-375 (175-190)	to 550 (290)
Polyesters	275-300 (135-150)	to 220 (105)

Solution forms of most of the adhesives above are available from suppliers of adhesives to the electronics industry. Listings of suppliers can be found in buyer's guides for electronic products. Bulletin E-74149, "Suppliers of Adhesives to the Electronics Industry," provides a representative listing of adhesive suppliers who can be consulted with for specific adhesive needs.

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III. FLAMMABILITY

Lewis and Stabler (Ref. 6) report the flammability characteristics of polyimide film as "self-extinguishing." KAPTON has a 94 VTM-O rating, the highest given in the U.L. 94 verticle burning test for thin films. The oxygen index is 37% for 100 H film (ASTM 2863).

IV. HANDLING PRACTICES

Safe handling of Type H and V KAPTON polymide films at high temperatures requires 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 at higher temperatures will depend on the combined factors of film quantity, temperature, and exposure time. For additional information on the Teflon® FEP coatings used on Type F KAPTON, refer to the booklet — "Teflon® Fluorocarbon Resins — Safety in Handling and Use."

A. 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 sufficient off-gases to be of toxicological significance.

Ventilation practices should follow the same common sense rules applicable to any soldering procedure. Normal ventilation provided for worker comfort usually provides adequate safety. During hot-wire stripping, it is recommended that exhaust ducts be used at the workbench.

There have been no reports of ill effects during soldering or hot-wire stripping of wire and cable insulated with KAPTON.

B. 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 is rated for use 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. Since the quantity of film heated is usually relatively small (less than one pound), ventilation requirements seldom exceed those for normal welding work. Because of the possibility of inadvertent overheating, however, the use of a small fan or elephant-trunk exhaust is advisable.

C. 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. KAPTON can be expected to be stable in landfills.

D. Fire Hazards

Whether in storage or use, KAPTON is unlikely to add appreciably to the hazards of fire. Bulk quantities of KAPTON (over 100 pounds) 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. This type of equipment is standard in fighting many types of fire. 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.

E. Static Electricity

The processing of KAPTON polyimide film can cause the generation of a strong static charge. Unless this charge is bled off as it forms through the use of ionizing radiation or metal tinsel, it can build to many thousands of volts and discharge to people or to 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.

REFERENCES

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2. C. E. Sroog, A. L. Endrey, S. V. Abrams, C. E... W. M. Edwards, and K. L. Oliver, J. Poly. Sci... 3(4), 1373-90 (1965).

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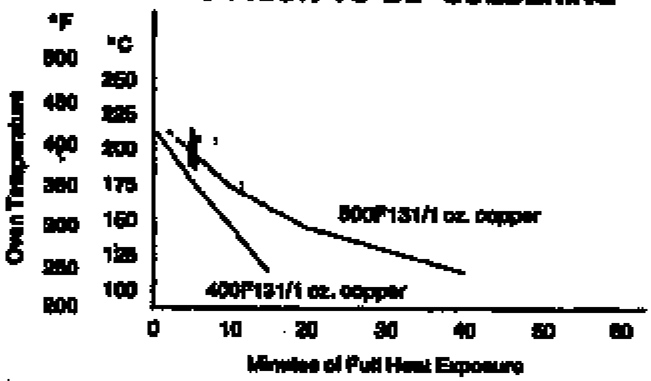
Given in Figure 3 are minimum times to dry laminates of Type F to copper prior to dip soldering. The times are different than in Figure 2 due to the presence of the copper foil.

FIGURE 3
DRYING CONDITIONS FOR KAPTON TYPE F LAMINATES PRIOR TO DIP SOLDERING



SOLDERING AND PRESS CONDITIONS FOR TYPE H LAMINATES

The recommended predrying conditions prior to dip soldering and platen pressing laminates based on type H film will vary according to type of thermoset adhesive used in addition to factors mentioned for Type F laminates. The moisture retention and permeability of the film and adhesive must be considered along with the impermeability of the copper foil layers. Consult your laminate supplier for recommended predrying conditions specific to the combination of materials supplied.

EFFECTS OF HUMIDITY ON PEEL STRENGTH

Humidity can have a large effect on peel strength with certain adhesive systems, and RH ought to be controlled in peel strength measurements. A summary of our investigation into this phenomenon is given in Table III. Results show that those adhesives having functional groups capable of absorbing water vapor will promote high peel strengths at high RH and low peel strengths at low RH. Between an RH of 10% and an RH of 70%, the effect can be as large as 6 lbs. per lineal inch (10.5 N/cm). Those adhesives which do not have hygroscopic functional groups are not affected by RH changes in terms of peel values.

TABLE III
EFFECTS OF RELATIVE HUMIDITY ON PEEL STRENGTH

Adhesive Type	Peel Strength, lb./in. (N/cm) 10% RH	70% RH
Acrylic	5.8 (10.2)	11.5 (20.1)
Epoxy-Amide	5.4 (9.5)	10.0 (17.5)
Epoxy-Novolac	2.0 (3.5)	2.1 (3.7)
Phenolic-Butyral	3.8 (6.7)	5.2 (9.1)
Phenolic-Nitrile	4.7 (8.2)	4.3 (7.5)

EFFECT OF SURFACE ON PEEL STRENGTH

The top surface of KAPTON is referred to as the "bright" or "shiny" side. The bottom side is "dull" and purposely roughened in the manufacture of the film to improve film handling characteristics. Most adhesives bond better to the dull side of the film. The effect is generally 1-2 lbs. per lineal inch (1.8-3.5 N/cm) but can be as high as 4 lbs. per inch (7.0 N/cm) or negligible depending on the adhesive system used.

Experience has also shown that peel strength normally increases with the thickness of the film. Within a laminate based on a given film thickness, a range of peel strengths can also be expected, which is inherent in the film surface, the adhesive system and the test method applied. For example, a typical peel strength range for an acrylic adhesive is 6 lbs./in. (10.5 N/cm). For 100H this range can result in values as low as 2 lbs./in. (3.5 N/cm).

Unless specifically recommended by the adhesive supplier, the surface of KAPTON should be used as received. If the film has been contaminated with grease or oils, it should be cleaned with solvent (such as methylethyl ketone or toluene). Metal surfaces should be thoroughly cleaned. For best adhesion, they should be roughened mechanically or by chemical treatment.

When higher adhesion levels are required for a given adhesive system, the range of the peel strength values for the laminate may usually be reduced if the surface of the film is mechanically or chemically abraded, light pumice scrubbing or caustic etching. Caution must be exercised with any such treatment to avoid damaging the film.

EFFECT OF THERMAL TREATMENT ON PEEL STRENGTH

High thermal treatment of KAPTON will often improve bondability. Temperatures of about 400°C for as long as 5-10 minutes are required, and structural changes probably occur.

Studies of adherability of typical printed circuit adhesives to heat treated KAPTON and standard KAPTON have shown that heat treatment provides an advantage with most adhesives. The greatest advantage was gained with acrylic, epoxy, phenolic butyrals and phenolic nitriles. Improvement over standard film averaged from 40% to 97% for these adhesive types.

4

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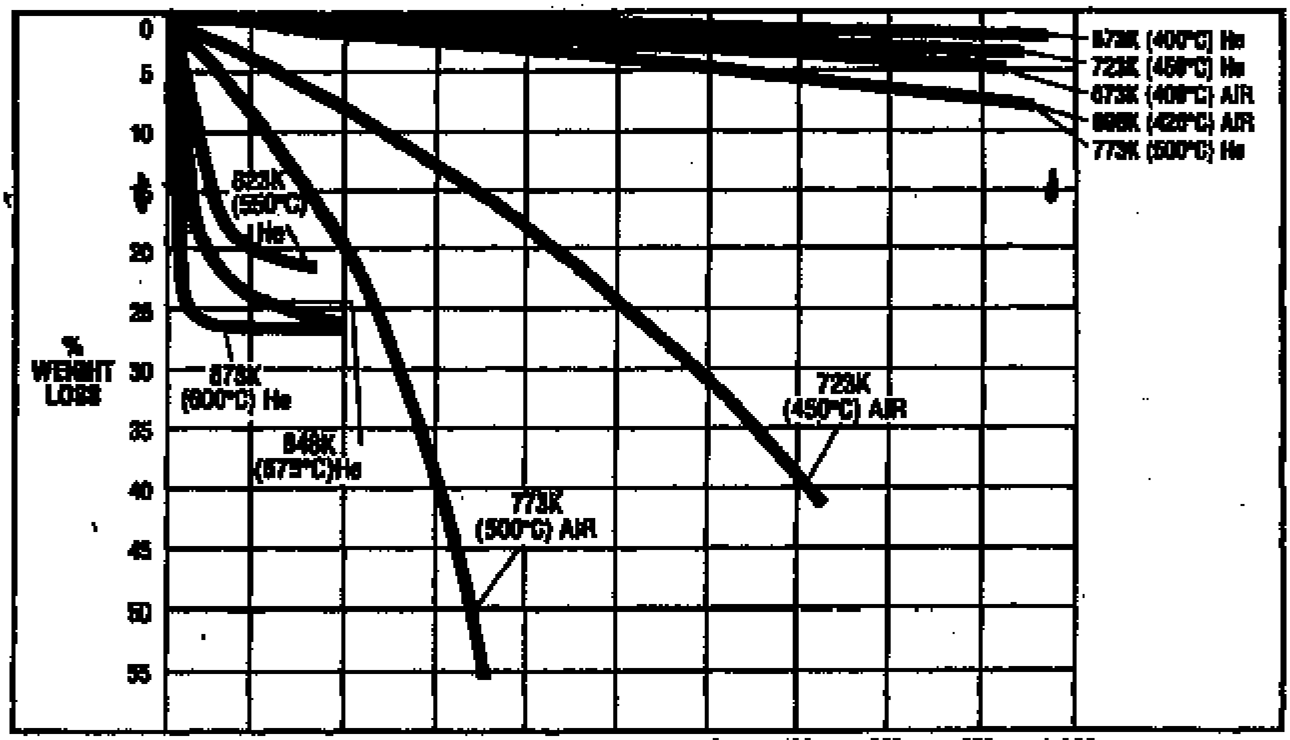
ISOTHERMAL WEIGHT LOSS
(Type H Film 25 μm (1 mil))



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KAPTON® Polyimide Film
Technical Bulletin

DuPont Electronics

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High Performance Substrates and Materials

September 1989

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KAPTON® Polyimide Film
Technical Bulletin

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DUPONT

TI 0011038

H-[illegible] Printed in U.S.A.

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DuPont Electronics

DU PONT

MATERIAL SAFETY DATA SHEET

IDENTIFICATION

NAME
HFC-134a

FORMULA
CH_2FCF_3

MANUFACTURER/DISTRIBUTOR
E. I. du Pont de Nemours & Co. (Inc.)

ADDRESS
Wilmington, DE 19898

CHEMICAL FAMILY
Halogenated Hydrocarbon

TSCA INVENTORY STATUS
Reported/Included

PRODUCT INFORMATION PHONE
(800) 441-9450

MEDICAL EMERGENCY PHONE
(800) 441-3637

TRANSPORTATION PHONE
CHEMTREC (800) 424-9300

PHYSICAL DATA

BOILING POINT
-26.5°C (-14.5°F) @ 736 mmHg

LIQUID DENSITY
1.21 g/cc @ 25°C (77°F)

VAPOR DENSITY (AIR = 1)
3.18

FORM
Liquefied Gas

COLOR
Colorless

PERCENT VOLATILE BY VOLUME
100

VAPOR PRESSURE
96 psig @ 25°C (77°F)

SOLUBILITY IN WATER
0.15% by wt at 25°C (77°F) & 14.7 psia

APPEARANCE
Clear

ODOR
Slight Ethereal

E-94938 Date: 4/88

TI 0011040

DD/NHTSA No. 3
08282

HAZARDOUS COMPONENTS

MATERIAL(S)	CAS NO.	APPROXIMATE %
Ethane,1,1,1,2-Tetrafluoro	811-97-2	100

HAZARDOUS REACTIVITY

STABILITY
Material is stable. However, avoid open flames and high temperatures.

INCOMPATIBILITY
Alkali or Alkaline earth metals—powdered Al, Zn, Be, etc.

DECOMPOSITION
HFC-134a can be decomposed by high temperatures (open flames, glowing metal surfaces, etc.) forming hydrofluoric acid—possibly carbonyl fluoride.

POLYMERIZATION
Will not occur.

FIRE AND EXPLOSION DATA

FLASH POINT
Will not burn. METHOD TOC

FLAMMABLE LIMITS IN AIR, % BY VOL.
LOWER Not applicable.
UPPER Not applicable.

AUTOIGNITION TEMPERATURE
Not determined.

FIRE AND EXPLOSION HAZARDS
Cylinders may rupture under fire conditions. Decomposition may occur.

EXTINGUISHING MEDIA
As appropriate for combustibles in area.

SPECIAL FIRE FIGHTING INSTRUCTIONS
Cool cylinders with water spray. Self-contained breathing apparatus (SCBA) may be required if cylinders rupture or release under fire conditions.

HEALTH HAZARD INFORMATION

PRINCIPAL HEALTH HAZARDS

Inhalation of high concentrations of vapor is harmful and may cause heart irregularities, unconsciousness or death. Intentional misuse can be fatal. Vapor reduces oxygen available for breathing and is heavier than air. Liquid contact can cause frostbite

Inhalation 4 Hour ALC: 567,000 ppm in rats

The compound is untested for skin and eye irritancy and is untested for animal sensitization.

Acute Toxicity in Animals
The effects in animals from short exposure by inhalation include no toxic effects observed at vapor concentrations up to 81,000 ppm. Lethargy and rapid respiration were observed at a vapor concentration of 205,000 ppm.

Pulmonary congestion, edema, and central nervous system effects occurred at a vapor concentration of 750,000 ppm. Cardiac sensitization occurred in dogs at 75,000 ppm from the action of exogenous epinephrine.

Subchronic Toxicity in Animals
Inhalation: The effects in animals from exposure by inhalation for two weeks include no observable adverse effects. Ingestion: No adverse effects were observed in male and female rats administered 300 mg/kg/day of HFC-134a for 52 weeks.

No acceptable information is available to confidently predict the effects of excessive human exposure to this compound.

CARCINOGENICITY
HFC-134a is not listed as a carcinogen by IARC, NTP, OSHA, ACGIH, or Du Pont.

EXPOSURE LIMITS

PEL (OSHA): Not established.
TLV* (ACGIH): Not established.

SAFETY PRECAUTIONS
Avoid breathing vapor and liquid contact with skin or eyes. Provide adequate ventilation for storage, handling, and use, especially for enclosed and low spaces.

*TLV is a registered trademark of the American Conference of Governmental Industrial Hygienists.

HEALTH HAZARD INFORMATION (con't)

FIRST AID

IF HIGH CONCENTRATIONS ARE INHALED: Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Call a physician.

IN CASE OF EYE CONTACT: Immediately flush eyes with plenty of water for at least 15 minutes. Call a physician.

IN CASE OF SKIN CONTACT: Flush skin with water after excessive contact. Wash contaminated clothing before reuse. Treat for frostbite if necessary.

IF SWALLOWED: Ingestion is not considered a potential route of exposure.

NOTE TO PHYSICIANS

Because of possible disturbances of cardiac rhythm, catecholamine drugs, such as epinephrine, should be considered only as a last resort in life-threatening emergencies.

PROTECTION INFORMATION

GENERALLY APPLICABLE CONTROL MEASURES

Normal ventilation for standard manufacturing procedures is generally adequate. Local exhaust should be used when large amounts are released. Mechanical ventilation should be used in low places.

PERSONAL PROTECTIVE EQUIPMENT

Lined butyl gloves and chemical splash goggles should be used when handling liquid. Under normal manufacturing conditions, no respiratory protection is required when using this product. Self-contained breathing apparatus (SCBA) is required if a large release occurs.

DISPOSAL INFORMATION

SPILL, LEAK OR RELEASE

Ventilate area—especially low places where heavy vapors might collect. Remove open flames. Use self-contained breathing apparatus (SCBA) if large spill or leak occurs.

WASTE DISPOSAL

Contaminated HFC-134a can be recovered by distillation or removed to a permitted waste disposal facility. Comply with Federal, State, and local regulations.

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DUPONT

SHIPPING INFORMATION

DOT (172.101)

PROPER SHIPPING NAME
Refrigerant Gas, N.O.S.
(Tetrafluoroethane)

HAZARD CLASS
Nonflammable gas

UN NO.
1078

DOT/IMO (172.102)

PROPER SHIPPING NAME
Refrigerant Gas, N.O.S.
(Tetrafluoroethane)

HAZARD CLASS
Nonflammable gas, 2.2

UN NO.
1078

IMO LABEL
Nonflammable gas

OTHER INFORMATION

SHIPPING CONTAINERS
Cylinders, ton tanks, tank cars and tank trucks

STORAGE CONDITIONS
Clean, dry area. Do not heat above 125°F.

ADDITIONAL INFORMATION AND REFERENCES

NPCA - HMIS RATINGS

Health	1
Flammability	0
Reactivity	1
Personal Protection	-

Personal Protection rating to be supplied by user depending on use conditions.

DATE OF LATEST REVISION/REVIEW: 4/88
PERSON RESPONSIBLE FOR MSDS:
K. P. BROWN
Du Pont Co.
C&P Dept., Chestnut Run-709
Wilmington, DE 19898
(302) 999-3018

138337A

DuPont Electronics

DuPont Company
Barley Mill Plaza
P.O. Box [illegible]
Wilmington, Delaware [illegible]

Dear Customer:

Thank you for calling Du Pont. Enclosed please find the literature you requested on Kaptone. Your interest in our product is greatly appreciated.

Also enclosed is my business card if additional information or technical assistance is needed.

Sincerely,

Donald J. Farrelly, Jr.

DJF/ tlp
Enclosures

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TI 0011046

Share the power of our resources.

DUPONT

MATERIAL SAFETY DATA SHEET

E. I. DUPONT DE NEMOURS & CO
POLYMER PRODUCTS DEPARTMENT
ELECTRONICS DEPARTMENT
1007 MARKET STREET
WILMINGTON, DE 19898

TELEPHONE NUMBERS
MEDICAL EMERGENCY 800-441-3637
PRODUCT INFORMATION 800-441-7515
TRANSPORTATION EMERGENCY 800-424-9300

MATERIAL IDENTIFICATION

PRODUCT NAME	Kapton* Polyimide Film, coated types F, FN, XP, ZN <
CHEMICAL NAME	Aromatic Polyimide plus up to 1 % dimethyl acetamide and a polyfluorocarbon coating.
CAS REGISTRY NUMBER	NA
TSCA INVENTORY STATUS	All reportable ingredients are listed in the TSCA Chemical Substance Inventory. <
DOT HAZARD CLASS	Not regulated
SHIPPING NAME	NA
PREPARER	C. B. Stouffer DATE September 27, 1989 <

HAZARDOUS COMPONENTS

MATERIAL	Dimethyl acetamide
CAS NO.	127-19-5
CONCENTRATION %	Up to 1%
OSHA PEL	10 ppm (skin)* <
ACGIH TLV	10 ppm (skin)*
DUPONT AEL	10 ppm (skin)*

*The "skin" notation serves as a reminder that exposure can result through skin absorption as well as through inhalation, and that appropriate precautions should be taken to prevent both types of exposure.

SUBSTANCES PRESENT AT A CONCENTRATION OF 0.1% OR MORE CLASSIFIED AS A CARCINOGEN BY IARC, NTP OR OSHA: None

PHYSICAL/CHEMICAL DATA

APPEARANCE	Transparent film, light amber color
ODOR	None
MELTING POINT	None
SOLUBILITY IN WATER	Insoluble
VOLATILE CONTENT	1% max
SPECIFIC GRAVITY	>1.4

TI 0011047

FIRE AND EXPLOSION HAZARD DATA

FLASH IGNITION TEMPERATURE NA

UNUSUAL FIRE, EXPLOSION HAZARDS Chars but does not burn. Static charge may build up during handling of Kapton® film.

HAZARDOUS COMBUSTION PRODUCTS Hydrogen fluoride, carbon monoxide, carbonyl fluoride.

SPECIAL FIRE FIGHTING INSTRUCTIONS Wear self-contained breathing apparatus and clothing to protect from hydrogen fluoride, which react with water to form hydroflurlc acid. Wear Neoprene gloves when handling refuse from a fire involving fluorocarbon resins.

EXTINGUISHING MEDIA Water, carbon dioxide, foam, dry chemical.

HAZARDOUS REACTIVITY

CONDITIONS TO AVOID Temperatures above 260°C without adequate ventilation. Coated types of Kapton® will burn in an atmosphere of 95% oxygen.

MATERIALS TO AVOID Alkali metal and interhalogen compounds.

HAZARDOUS DECOMPOSITION PRODUCTS Above 260°C coated types of Kapton® can evolve toxic gaseous materials such as hydrogen fluoride and perfluoroolefins. Major off-gases are carbon monoxide and carbon dioxide.

HEALTH HAZARD DATA

Read "Safety in Handling and Use" Bulletin E-72084 before using Kapton®. Avoid contamination of tobacco products.

ACUTE OR IMMEDIATE EFFECTS: ROUTES OF ENTRY AND SYMPTOMS

INGESTION Not a probable route of exposure.

SKIN No irritation expected. Less than 1 ppm dimethyl acetamide was extracted from film by distilled water at 40°C for 4 hours.

EYE Not a probable route of exposure. Mechanical irritation.

INHALATION Vapors and fumes liberated above 260°C or from smoking tobacco or cigarettes contaminated with coated types of Kapton® film may cause influenza type symptoms (polymer fume fever) with chills fever and sore throat, which may not occur until several hours after after exposure, and pass within 36-48 hours, even without treatment.

Inhalation is not a probable route of exposure for film. For the polymer from which this film is made, du Pont recommends treating polymer dust as a nuisance particulate, and has established an AEL of 10 mg/m^3 total dust, the same as the TLV for nuisance particulates.

EMERGENCY FIRST AID
- If exposed to fumes from overheating or combustion, move to fresh air. Consult a physician if symptoms persist.
- For prolonged skin contact, wash with soap and water. In case of skin irritation, consult a physician.
- Flush eyes with plenty of water. Consult a physician if symptoms persist.

CHRONIC EFFECTS None known.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE None known.

PROTECTION INFORMATION

EYE Safety glasses recommended.

SKIN Gloves recommended.

VENTILATION Local exhaust for operation above 200°C.

RESPIRATOR Not required for normal processing.

DISPOSAL

SPILL, LEAK OR RELEASE Sweep up to avoid slipping hazard.

WASTE DISPOSAL Landfill or incinerate in compliance with federal, state, and local regulations. Incinerator should be equipped with scrubber to remove acidic hydrogen fluoride from off-gases.

AQUATIC TOXICITY Insoluble

STORAGE CONDITIONS Store away from flammable materials.

The information in this Material Safety Data Sheet relates only to the specific material (s) designated herein and does not relate to use in combination with any other material or in any process.

NA = Not applicable
NE = Not established
AEL = Du Pont Company's Acceptable Exposure Limit
> = New or revised information in this section when ">" is in left margin

TI 0011049

SECTION 313 SUPPLIER NOTIFICATION

This product contains no known toxic chemicals subject to the reporting requirements of section 313 of the Emergency Planning and Community Right-To-Know Act of 1986 and of 40 CFR 372.

STATE RIGHT TO KNOW LAWS

No substances on the state hazardous substances list, for the states indicated below, are used in the manufacture of products on this Material Safety Data Sheet, with the exceptions indicated. While we do not specifically analyze these products, or the raw materials used in their manufacture, for substances on various state hazardous substances lists, to the best of our knowledge the products on this Material Safety Data Sheet contain no such substances except for those specifically listed below:

SUBSTANCES ON THE PENNSYLVANIA HAZARDOUS SUBSTANCES LIST PRESENT AT A CONCENTRATION OF 1% OR MORE:
Dimethyl acetamide (1% maximum)

SUBSTANCES ON THE PENNSYLVANIA SPECIAL HAZARDOUS SUBSTANCES LIST PRESENT AT A CONCENTRATION OF 0.01% OR MORE: None known.

NON-HAZARDOUS INGREDIENTS PRESENT AT A CONCENTRATION OF 3% OR MORE REQUIRED TO BE LISTED BY PENSYLVANIA:

	CAS No.
Polyimide film	25038-81-7
Polyfluorocarbon coating	25067-11-2 or 26655-00-5 or 25038-71-5.

WARNING: SUBSTANCES KNOWN TO THE STATE OF CALIFORNIA TO CAUSE CANCER: None known.

WARNING: SUBSTANCES KNOWN TO THE STATE OF CALIFORNIA TO CAUSE BIRTH DEFECTS OR OTHER REPRODUCTIVE HARM: None known.

SUBSTANCES ON THE NEW JERSEY WORKPLACE HAZARDOUS SUBSTANCE LIST PRESENT AT A CONCENTRATION OF 1% OR MORE (0.1% FOR SUBSTANCES IDENTIFIED AS CARCINOGENS, MUTAGENS OR TERATOGENS):
Dimethyl acetamide (1% maximum).

Kapton

POLYIMIDE FILM

GENERAL SPECIFICATIONS BULLETIN GS-87-4

GENERAL

INTRODUCTION

The Electronics Department of the Du Pont Company manufactures and sells a variety of high quality plastic film products.

These specifications describe the values and tolerances for film properties and characteristics of "Kapton" polyimide film. Where necessary for thorough understanding, test methods and procedures have been included.

Any aspects of the specifications requiring further interpretation or clarification should be discussed with representatives of the Du Pont Electronics Department.

Types of Kapton® Polyimide Film

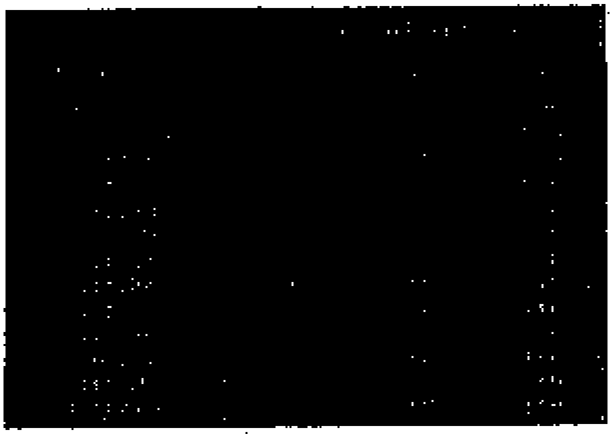
Du Pont makes three types of "Kapton" polyimide film, Type HN, Type FN and Type VN.

Type HN Film

"Kapton" Type HN is a tough aromatic polyimide film, exhibiting an excellent balance of physical, chemical and electrical properties over a wide temperature range, particularly at unusually high temperatures. Chemically, its polyimide polymer make up is the result of a polycondensation reaction between pyromellitic dianhydride and 4,4'-diaminodiphenylether. "Kapton" HN is available in 30, 50, 100, 200, 300 and 500 gauges.

Type FN Film

"Kapton" Type FN film is a heat sealable grade which retains the unique balance of properties that "Kapton" Type HN possesses over a wide temperature range. This is achieved by combining Type HN "Kapton" and Teflon® FEP fluorocarbon resin together in a composite structure. Listed below are those combinations commercially available at this time. Other combinations are available. Consult your Electronics Department marketing representative for further information.



Type VN Film

"Kapton" Type VN is the same tough polyimide film as Type HN Film, exhibiting an excellent balance of physical, chemical and electrical properties over a wide temperature range, with superior dimensional stability at elevated temperatures. This product is available in 100, 200, 300 and 500 gauges.

Certification

"Kapton" is certified to meet the requirements of the military specification MIL-P-46112 B (MR) in addition to the items covered by this specifications bulletin. Written confirmation is available with each delivery upon request.

DU PONT

TI 0011051

DD/NHTSA No. 3
00103

Kapton
POLYIMIDE FILM

GENERAL SPECIFICATIONS BULLETIN GS-87-4

GENERAL

INTRODUCTION

The Electronics Department of the Du Pont Company manufactures and sells a variety of high quality plastic film products.

These specifications describe the values and tolerances for film properties and characteristics of "Kapton" polyimide film. Where necessary for thorough understanding, test methods and procedures have been included.

Any aspects of the specifications requiring further interpretation or clarification should be discussed with representatives of the Du Pont Electronics Department.

Types of Kapton® Polyimide Film

Du Pont makes three types of "Kapton" polyimide film, Type HN, Type FN and Type VN.

Type HN Film

"Kapton" Type HN is a tough aromatic polyimide film, exhibiting an excellent balance of physical, chemical and electrical properties over a wide temperature range, particularly at unusually high temperatures. Chemically, its polyimide polymer make up is the result of a polycondensation reaction between pyromellitic dianhydride and 4,4'-diaminodiphenyl-ether. "Kapton" HN is available in 30, 50, 100, 200, 300 and 500 gauges.

Type FN Film

"Kapton" Type FN film is a heat sealable grade which retains the unique balance of properties that "Kapton" Type HN possesses over a wide temperature range. This is achieved by combining Type HN "Kapton" and Teflon® FEP fluorocarbon resin together in a composite structure. Listed below are those combinations commercially available at this time. Other combinations are available. Consult your Electronics Department marketing representative for further information.

[illegible]

Type VN Film

"Kapton" Type VN is the same tough polyimide film as Type HN Film, exhibiting an excellent balance of physical, chemical and electrical properties over a wide temperature range, with superior dimensional stability at elevated temperatures. This product is available in 100, 200, 300 and 500 gauges.

Certification

"Kapton" is certified to meet the requirements of the military specification MIL-P-46112 B (MR) in addition to the items covered by this specifications bulletin. Written confirmation is available with each delivery upon request.

DU PONT

PROPERTIES OF TYPE HN FILM

MECHANICAL

ELECTRICAL

*1 hour for 30 and 60 gauge film.

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 criterion of failure. "Kapton" is routinely tested at the manufacturing site in the following manner:

Sheets of film 8½" × 11" are freely suspended in an oven at 400°C. The temperature of the oven is monitored with a thermocouple to insure a temperature accuracy of ±2°C. Sheets are removed after 2 hours* and tested on an Instron Tensile Tester as described above under "Elongation." The elongation (at 23.5°C.) of the film should not be less than 10% after this aging at 400°C. This conforms to the "Elongation after Aging at 400°C." test (paragraph

4,4,5) and "Elongation, percent, after 2 hour 400°C." requirement (Table 1) of MIL-P-46112 B (MR).

Underwriters Laboratories Inc. lists a thermal index of 200°C.–220°C. (depending on gauge and type) for mechanical properties and 220°C.–240°C. (depending on gauge and type) for electrical properties under their file no. E39505 for "Kapton" polyimide film.

*1 hour for 30 & 50 gauge film.

PROPERTIES OF TYPE FN FILM

A. Heat Seal Strength

1. Film to Film Seals

The heat seal peel strength between the coated and uncoated side of one side coated Kapton® polyimide film or the coated to coated side of one or two side coated "Kapton" is measured in the following manner: Seals are made in a jaw sealer at 350°C., 20 psi, 20 sec. dwell time. After cooling, the seals are cut to 1" wide strips using a Thwing-Albert JDC sample cutter or equivalent. The strength of the seal is measured with an Instron type tensile tester. Seal strength is defined as the peak instantaneous strength occurring in each seal. Five specimen values are averaged.

The minimum peel strength between the coated sides of one or two side coated "Kapton" polyimide film will be 600 gms./inch except for 120FN616 which will be 450 gms./in. The minimum peel strength between the coated and uncoated side of one side coated "Kapton" will be 450 gms./inch.

2. Film to Copper Seals for 120FN616 Film

The ability of 120FN616 film to adhere to copper is measured by using the same heat seal peel strength technique as described above.

The peel strength obtained when 120FN616 is sealed to the untreated side of ¼ oz. GT copper foil (1 mil) will be a minimum of 250 gms./in.

3. As-Received Strength (Cold peel) of Bonds Between the Type HN "Kapton" and "Teflon" Layers

The bond between the Type HN "Kapton" and Teflon® fluorocarbon resin layers on all type FN products except 120FN616 will have a minimum peel strength of 225 gms./in. as measured using an Instron type tensile tester and a 180° peel.

B. Dielectric Strength

[illegible]

PROPERTIES OF TYPE VN FILM

MECHANICAL

[illegible]

[illegible]

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 criterion of failure. "Kapton" is routinely tested at the manufacturing site in the following manner.

Sheets of film 8½" × 11" are freely suspended in an oven at 400°C. The temperature of the oven is monitored with a thermocouple to insure a temperature accuracy of ±2°C. Sheets are removed after 2 hours and tested on an Instron Tensile Tester as described above under "Elongation." The elongation (at 23.5°C.) of the film should not be less than 10% after this aging at 400°C. This conforms to the "Elongation after Aging at 400°C." test (paragraph 4,4,5) and "Elongation, percent, after 2 hour 400°C." requirement (Table 1) of MIL-P-46112 B(MR).

Underwriters Laboratories Inc. lists a thermal index of 200°C.–220°C. (depending on gauge and type) for mechanical properties and 220°C.–240°C. (depending on gauge and type) for electrical properties under their file no. E39505 for "Kapton" polyimide film.

GENERAL

A. MATERIAL

Type HN and Type VN Film—A polyimide polymer in the form of a film.

Type FN Film—A combination of Kapton® polyimide film Type HN with Teflon® FEP fluorocarbon resin on one or both sides.

B. UNIFORMITY

Material shall be uniform in composition and free from defects which impair serviceability and/or appearance in proven applications.

C. CORES

Cores shall be of sufficient strength to prevent collapsing on handling. Standard core I.D.'s are 3" and 6" with the following specifications: 3" I.D. is 3.032" ± 0.006", 6" I.D. is 6.028" ± 0.010". Core material will be plastic for 3" I.D. cores less than ⅝" wide. Core material will be fibre for 3" I.D. cores wider than ⅝" and 6" I.D. cores. A split 3" I.D. fibre core is standard for all universal rolls. Core width for universal wind is 2⅞".

If these cores are not suitable, further information on other options may be obtained from your Electronics Department marketing representative.

D. WIDTH TOLERANCE

The maximum variation in film width from that specified on the order shall be as follows:

Slit Width Range	Tolerance
⅞" or less Universal only	± 7 mils
1" or less	± 15 mils
1¹⁄₁₆"–4"	± 30 mils
4¹⁄₁₆" or wider	± 60 mils

E. ROLL TYPES

"Kapton" film is supplied in two types of rolls, pad and universal wind. Available film widths and roll O.D.'s are specified on the next page.

TI 0011054

[redacted]

(1) 3" x 6" pad roll is available in widths up to ½" only in 100HN, 200HN, 300HN, 500HN, 120FN616, 200FN011, [illegible], [illegible], 300FN021, [illegible].
* O.D. Tolerance is ± [illegible]" for pads and ± [illegible]" for universal.
* Type HN, FN and VN films in pads are supplied in width increments of [illegible]". Most films are supplied in width increments of [illegible]" in widths [illegible]" to [illegible]".

* All universal rolls are available in [illegible]" width increments with [illegible]" maximum widths. The minimum width is [illegible]" for 3" x 6" (I.D. x O.D.); the minimum width is [illegible]" for [illegible]" x [illegible]", and 3" x 12" (I.D. x O.D.).

Specifications for pad rolls are:

1. Core width will be film width + ⅛", − 0".
2. Core edges shall not project more than 1/16" beyond roll face on either side.
3. Core shall not be recessed on either side.
4. The outside and starting ends of the film shall be fastened in such a manner as to prevent unwinding.
5. "Dishing" or "cupping" may not exceed 1/16" measured with a straight edge across the diameter of the roll.

Specifications for the universal rolls are:

1. The difference between the length of projecting core on each side shall not exceed 3/16".
2. Film shall not project from the main body of the roll more than ⅛".
3. The outside and starting ends of the film shall be fastened in such a manner as to prevent unwinding.
4. Roll face depression, the difference between the highest and lowest points unstressed, shall not exceed 3/16".
5. Width of traverse is 1¼", − ¼", + ⅛".

F. SPLICES

1. Description

Three types of splice are available.

1. Mylar® polyester film based yellow tape splice (standard).
2. Kapton® polyimide film based splice (special requirements only).
3. Heat seal splice (Type FN) in width, 12" or less.

Splices will be sufficiently smooth and wrinkle-free so as not to distort adjacent layers of film and approximately centered to ± ¼".

Tape splices are standard on all gauges of "HN" and "VN" film and also on all gauges of "FN" film more than 12" wide.

Tape splices are made as follows. A butt splice with film ends covered on both sides of the film with splice tape. For films less than 0.002" thick a 1" wide pressure sensitive tape is used. For films 0.002" thick and greater a 2" wide pressure sensitive tape will be used.

Heat seal splices are made as follows. On all films but 250FN029 the splice is an overlap splice a minimum of ⅝" long. On 250FN029 a butt splice is made using 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 put-ups and pad put-ups for two side FEP structures. Pad put-ups of one side 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 a universal put-up and on the bottom as it unwinds from a pad.

2. Maximum Splices per Slit Roll

The minimum average footage between splices for most rolls is shown in Table I. To calculate the maximum number of splices in a roll divide the nominal feet per roll by the minimum average length between splices and subtract one.

3. Splice Placement

Table I shows the minimum length between splices and from the beginning and end of a roll, for most "Kapton" rolls. No splice is allowed, however, once a roll has reached the minimum O.D.

TABLE I

MINIMUM AVERAGE SPLICE FREE LENGTH (FEET)

[redacted]

NOTES:
[1] To 60" wide for 30HN, 62" wide for 50HN
[2] To 60" wide
[3] To 6" wide
[4] To 18" wide. For widths greater than 18" to the maximum, the minimum average footage will be one half that shown in the table.
[5] ¼" to ½" wide

MINIMUM LENGTH BETWEEN SPLICES OR BEGINNING AND END OF A ROLL (FEET)

[redacted]

G. AVERAGE THICKNESS TOLERANCES (UNIT WEIGHT)

[redacted]

*Applies to Type VN films also.

[redacted]

Test Method and Sampling Procedure

Weigh test specimens equal to the width of slit roll and not less than ½ meter long to the nearest 0.10 gram on a torsion balance.

To confirm average thickness tolerances, obtain a sample consisting of a minimum of one specimen from each of several randomly selected slit rolls as follows:

Slit Roll Width	Minimum Number of Slit Rolls to be Sampled
Under 6"	25 ÷ slit roll width (in.)
6" and Over	4

TI 0011056

H. MICROMETER THICKNESS

Thickness tolerances are based on a statistical analysis of routine process control data.

[redacted]

*Applies to Type VN films also.

[redacted]

Test Method

Make the following measurements to confirm that film from a single slit roll meets the micrometer tolerances:

1. Measure in accordance with ASTM-D-374-79, Method A or C.
2. Obtain the average of 10 randomly selected readings from a minimum area of 12 square inches. Recheck before rejecting any slit roll. Abnormal readings may occasionally result from dust particles or spot surface imperfections. Discard such readings as they will adversely affect the accuracy of measurements designated to indicate general sheet thickness.

Gauge Depression

To reduce web handling difficulties which would occur if film representing thickness extremes were shipped in the same roll, a gauge depression standard is applied.

Roll depression is the difference in diameter between the hardest and softest part of the roll or the difference between the undepressed and depressed (finger pressure) diameter at the softest part, whichever is greater.

Table II lists the maximum allowable depression for most pad rolls. There is no gauge depression standard for universal wind since that roll is limited to a maximum of ⅛" wide.

TABLE II

KAPTON® POLYIMIDE FILM GAUGE DEPRESSION STANDARDS—PAD ROLLS
(Maximum allowable depression in 1/32" increments)

[redacted]

TI 0011057

Kapton

POLYIMIDE FILM

GENERAL
SPECIFICATIONS
BULLETIN GS-87-4

GENERAL

INTRODUCTION

The Electronics Department of the Du Pont Company manufactures and sells a variety of high quality plastic film products.

These specifications describe the values and tolerances for film properties and characteristics of "Kapton" polyimide film. Where necessary for thorough understanding, test methods and procedures have been included.

Any aspects of the specifications requiring further interpretation or clarification should be discussed with representatives of the Du Pont Electronics Department.

Types of Kapton® Polyimide Film

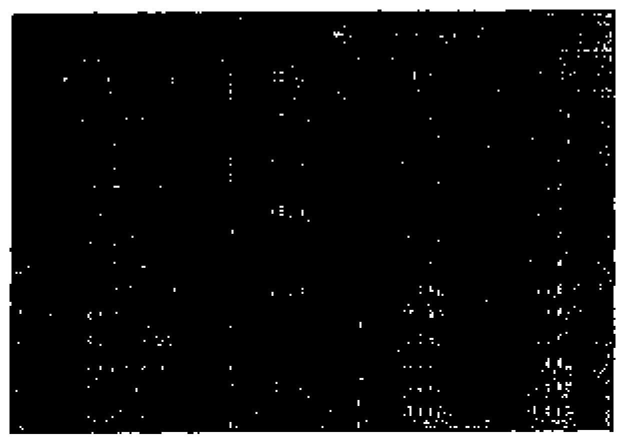
Du Pont makes three types of "Kapton" polyimide film, Type HN, Type FN and Type VN.

Type HN Film

"Kapton" Type HN is a tough aromatic polyimide film, exhibiting an excellent balance of physical, chemical and electrical properties over a wide temperature range, particularly at unusually high temperatures. Chemically, its polyimide polymer make up is the result of a polycondensation reaction between pyromellitic dianhydride and 4,4'-diaminodiphenylether. "Kapton" HN is available in 30, 50, 100, 200, 300 and 500 gauges.

Type FN Film

"Kapton" Type FN film is a heat sealable grade which retains the unique balance of properties that "Kapton" Type HN possesses over a wide temperature range. This is achieved by combining Type HN "Kapton" and Teflon® FEP fluorocarbon resin together in a composite structure. Listed below are those combinations commercially available at this time. Other combinations are available. Consult your Electronics Department marketing representative for further information.



Type VN Film

"Kapton" Type VN is the same tough polyimide film as Type HN Film, exhibiting an excellent balance of physical, chemical and electrical properties over a wide temperature range, with superior dimensional stability at elevated temperatures. This product is available in 100, 200, 300 and 500 gauges.

Certification

"Kapton" is certified to meet the requirements of the military specification MIL-P-46112 B (MR) in addition to the items covered by this specifications bulletin. Written confirmation is available with each delivery upon request.

DU PONT

71 0041063

Kapton

POLYIMIDE FILM

GENERAL SPECIFICATIONS BULLETIN GS-87-4

GENERAL

INTRODUCTION

The Electronics Department of the Du Pont Company manufactures and sells a variety of high quality plastic film products.

These specifications describe the values and tolerances for film properties and characteristics of "Kapton" polyimide film. Where necessary for thorough understanding, test methods and procedures have been included.

Any aspects of the specifications requiring further interpretation or clarification should be discussed with representatives of the Du Pont Electronics Department.

Types of Kapton® Polyimide Film

Du Pont makes three types of "Kapton" polyimide film, Type HN, Type FN and Type VN.

Type HN Film

"Kapton" Type HN is a tough aromatic polyimide film, exhibiting an excellent balance of physical, chemical and electrical properties over a wide temperature range, particularly at unusually high temperatures. Chemically, its polyimide polymer make up is the result of a polycondensation reaction between pyromellitic dianhydride and 4,4'-diaminodiphenylether. "Kapton" HN is available in 30, 50, 100, 200, 300 and 500 gauges.

Type FN Film

"Kapton" Type FN film is a heat sealable grade which retains the unique balance of properties that "Kapton" Type HN possesses over a wide temperature range. This is achieved by combining Type HN "Kapton" and Teflon® FEP fluorocarbon resin together in a composite structure. Listed below are those combinations commercially available at this time. Other combinations are available. Consult your Electronics Department marketing representative for further information.

Type VN Film

"Kapton" Type VN is the same tough polyimide film as Type HN Film, exhibiting an excellent balance of physical, chemical and electrical properties over a wide temperature range, with superior dimensional stability at elevated temperatures. This product is available in 100, 200, 300 and 500 gauges.

Certification

"Kapton" is certified to meet the requirements of the military specification MIL-P-46112 B (MR) in addition to the items covered by this specifications bulletin. Written confirmation is available with each delivery upon request.

DU PONT

TI 0041008

PROPERTIES OF TYPE HN FILM

MECHANICAL

ELECTRICAL

*1 hour for 30 and [illegible] gauge film.

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 criterion of failure. "Kapton" is routinely tested at the manufacturing site in the following manner:

Sheets of film 8½" × 11" are freely suspended in an oven at 400°C. The temperature of the oven is monitored with a thermocouple to insure a temperature accuracy of ±2°C. Sheets are removed after 2 hours* and tested on an Instron Tensile Tester as described above under "Elongation." The elongation (at 23.5°C.) of the film should not be less than 10% after this aging at 400°C. This conforms to the "Elongation after Aging at 400°C." test (paragraph

4,4,5) and "Elongation, percent, after 2 hour 400°C.*" requirement (Table 1) of MIL-P-46112 B (MR).

Underwriters Laboratories Inc. lists a thermal index of 200°C.–220°C. (depending on gauge and type) for mechanical properties and 220°C.-240°C. (depending on gauge and type) for electrical properties under their file no. E39505 for "Kapton" polyimide film.

*1 hour for 30 & 60 gauge film.

PROPERTIES OF TYPE FN FILM

A. Heat Seal Strength

1. Film to Film Seals

The heat seal peel strength between the coated and uncoated side of one side coated Kapton® polyimide film or the coated to coated side of one or two side coated "Kapton" is measured in the following manner: Seals are made in a jaw sealer at 350°C., 20 psi, 20 sec. dwell time. After cooling, the seals are cut to 1" wide strips using a Thwing-Albert JDC sample cutter or equivalent. The strength of the seal is measured with an Instron type tensile tester. Seal strength is defined as the peak instantaneous strength occurring in each seal. Five specimen values are averaged.

The minimum peel strength between the coated sides of one or two side coated "Kapton" polyimide film will be 600 gms./inch except for 120FN616 which will be 450 gms./in. The minimum peel strength between the coated and uncoated side of one side coated "Kapton" will be 450 gms./inch.

2. Film to Copper Seals for 120FN616 Film

The ability of 120FN616 film to adhere to copper is measured by using the same heat seal peel strength technique as described above.

The peel strength obtained when 120FN616 is sealed to the untreated side of 3/4 oz. GT copper foil (1 mil) will be a minimum of 250 gms./in.

3. As-Received Strength (Cold peel) of Bonds Between the Type HN "Kapton" and "Teflon" Layers

The bond between the Type HN "Kapton" and Teflon® fluorocarbon resin layers on all type FN products except 120FN616 will have a minimum peel strength of 225 gms./in. as measured using an Instron type tensile tester and a 180° peel.

B. Dielectric Strength

[redacted]

PROPERTIES OF TYPE VN FILM

MECHANICAL

[redacted]

TI 0011060

DD/NHTSA No. 3
00304

ELECTRICAL

[redacted]

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 criterion of failure. "Kapton" is routinely tested at the manufacturing site in the following manner.

Sheets of film 8½" × 11" are freely suspended in an oven at 400°C. The temperature of the oven is monitored with a thermocouple to insure a temperature accuracy of ±2°C. Sheets are removed after 2 hours and tested on an Instron Tensile Tester as described above under "Elongation." The elongation (at 23.5°C.) of the film should not be less than 10% after this aging at 400°C. This conforms to the "Elongation after Aging at 400°C." test (paragraph 4,4,5) and "Elongation, percent, after 2 hour 400°C." requirement (Table 1) of MIL-P-46112 B(MR).

Underwriters Laboratories Inc. lists a thermal index of 200°C.-220°C. (depending on gauge and type) for mechanical properties and 220°C.-240°C. (depending on gauge and type) for electrical properties under their file no. E39505 for "Kapton" polyimide film.

GENERAL

A. MATERIAL

Type HN and Type VN Film—A polyimide polymer in the form of a film.

Type FN Film—A combination of Kapton® polyimide film Type HN with Teflon® FEP fluorocarbon resin on one or both sides.

B. UNIFORMITY

Material shall be uniform in composition and free from defects which impair serviceability and/or appearance in proven applications.

C. CORES

Cores shall be of sufficient strength to prevent collapsing on handling. Standard core I.D.'s are 3" and 6" with the following specifications: 3" I.D. is 3.032" ± 0.006", 6" I.D. is 6.028" ± 0.010". Core material will be plastic for 3" I.D. cores less than 5/8" wide. Core material will be fibre for 3" I.D. cores wider than 5/8" and 6" I.D. cores. A split 3" I.D. fibre core is standard for all universal rolls. Core width for universal wind is 2¾".

If these cores are not suitable, further information on other options may be obtained from your Electronics Department marketing representative.

D. WIDTH TOLERANCE

The maximum variation in film width from that specified on the order shall be as follows:

Slit Width Range	Tolerance
5/8" or less Universal only	± 7 mils
1" or less	± 15 mils
1 1/16"–4"	± 30 mils
4 1/16" or wider	± 60 mils

E. ROLL TYPES

"Kapton" film is supplied in two types of rolls, pad and universal wind. Available film widths and roll O.D.'s are specified on the next page.

TI 0011061

[redacted]

(1) 3" x 6" pad roll is available in widths up to [illegible] only in 100HN, 200HN, 300HN, 500HN, [illegible]
* O.D. Tolerance is ± [illegible] for pads and ± [illegible] for universal.
* Type HN, FN and VN films in pads are supplied in width increments of [illegible]. [illegible]
* All universal rolls are available in [illegible] width increments with [illegible] maximum widths. The minimum width is [illegible] for 3" x 6" (I.D. x O.D.); the minimum width is [illegible] for 3" x [illegible], and 3" x 12" (I.D. x O.D.).

Specifications for pad rolls are:

1. Core width will be film width + 1/8", − 0".
2. Core edges shall not project more than 1/16" beyond roll face on either side.
3. Core shall not be recessed on either side.
4. The outside and starting ends of the film shall be fastened in such a manner as to prevent unwinding.
5. "Dishing" or "cupping" may not exceed 1/32" measured with a straight edge across the diameter of the roll.

Specifications for the universal rolls are:

1. The difference between the length of projecting core on each side shall not exceed 1/16".
2. Film shall not project from the main body of the roll more than 1/8".
3. The outside and starting ends of the film shall be fastened in such a manner as to prevent unwinding.
4. Roll face depression, the difference between the highest and lowest points unstressed, shall not exceed 3/16".
5. Width of traverse is 1 3/4", − 1/4", + 1/8".

F. SPLICES

1. Description

Three types of splice are available.

1. Mylar® polyester film based yellow tape splice (standard).
2. Kapton® polyimide film based splice (special requirements only).
3. Heat seal splice (Type FN) in width, 12" or less.

Splices will be sufficiently smooth and wrinkle-free so as not to distort adjacent layers of film and approximately centered to ± 1/4".

Tape splices are standard on all gauges of "HN" and "VN" film and also on all gauges of "FN" film more than 12" wide.

Tape splices are made as follows. A butt splice with film ends covered on both sides of the film with splice tape. For films less than 0.002" thick a 1" wide pressure sensitive tape is used. For films 0.002" thick and greater a 2" wide pressure sensitive tape will be used.

Heat seal splices are made as follows. On all films but 250FN029 the splice is an overlap splice a minimum of 1/8" long. On 250FN029 a butt splice is made using 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 put-ups and pad put-ups for two side FEP structures. Pad put-ups of one side 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 a universal put-up and on the bottom as it unwinds from a pad.

2. Maximum Splices per Slit Roll

The minimum average footage between splices for most rolls is shown in Table I. To calculate the maximum number of splices in a roll divide the nominal feet per roll by the minimum average length between splices and subtract one.

TI 0011062

3. Splice Placement

Table I shows the minimum length between splices and from the beginning and end of a roll, for most "Kapton" rolls. No splice is allowed, however, once a roll has reached the minimum O.D.

TABLE I

MINIMUM AVERAGE SPLICE FREE LENGTH (FEET)

[redacted]

NOTES: [1] To [illegible]" wide for 30HN, [illegible]" wide for 50HN
[2] To 90" wide
[3] To 6" wide
[4] To 18" wide. For widths greater than 18" to the maximum, the minimum average footage will be one half that shown in the table.
[5] [illegible]" to [illegible]" wide

MINIMUM LENGTH BETWEEN SPLICES OR BEGINNING AND END OF A ROLL (FEET)

[redacted]

G. AVERAGE THICKNESS TOLERANCES (UNIT WEIGHT)

[redacted]

*Applies to Type VN films also.

[redacted]

Test Method and Sampling Procedure

Weigh test specimens equal to the width of slit roll and not less than ½ meter long to the nearest 0.10 gram on a torsion balance.

To confirm average thickness tolerances, obtain a sample consisting of a minimum of one specimen from each of several randomly selected slit rolls as follows:

Slit Roll Width	Minimum Number of Slit Rolls to be Sampled
Under 6"	25 ÷ slit roll width (in.)
6" and Over	4

TI 0011063

H. MICROMETER THICKNESS

Thickness tolerances are based on a statistical analysis of routine process control data.

[redacted]

*Applies to Type VN films also.

[redacted]

Test Method

Make the following measurements to confirm that film from a single slit roll meets the micrometer tolerances:

1. Measure in accordance with ASTM-D-374-79, Method A or C.
2. Obtain the average of 10 randomly selected readings from a minimum area of 12 square inches. Recheck before rejecting any slit roll. Abnormal readings may occasionally result from dust particles or spot surface imperfections. Discard such readings as they will adversely affect the accuracy of measurements designated to indicate general sheet thickness.

Gauge Depression

To reduce web handling difficulties which would occur if film representing thickness extremes were shipped in the same roll, a gauge depression standard is applied.

Roll depression is the difference in diameter between the hardest and softest part of the roll or the difference between the undepressed and depressed (finger pressure) diameter at the softest part, whichever is greater.

Table II lists the maximum allowable depression for most pad rolls. There is no gauge depression standard for universal wind since that roll is limited to a maximum of ¼" wide.

TABLE II

KAPTON® POLYIMIDE FILM GAUGE DEPRESSION STANDARDS—PAD ROLLS
(Maximum allowable depression in 1⁄32" increments)

[redacted]

TI 0011064

Kapton

POLYIMIDE FILM

ADHESION TO KAPTON®

KAPTON® polyimide film, made only by Du Pont, is available in three basic film types. Type H KAPTON is 100% polyimide film. Type F is coated on one or both sides with a TEFLON® FEP fluorocarbon adhesive and Type V is a plain polyimide film having superior dimensional stability properties. Typical property information for KAPTON is found in Bulletin E-72087, "Summary of Properties." Specifications are found in Bulletin E-57824, "Industry Specifications Bulletin FC-85-2." For flexible printed circuit applications the trade specification IPC-FC-231/Sheet 1, applies to KAPTON.

ADHESIVE SELECTION

For some applications KAPTON must be bonded to other materials, such as copper foil, which requires the use of an adhesive. Optimum adhesion results are usually obtained from commercially coated KAPTON which is available from a variety of suppliers such as those listed in Bulletin E-72091, "Suppliers of Adhesive Coatings on KAPTON." This listing represents most of those companies offering coated KAPTON but should not be regarded as a complete listing. Detailed information on the use of these adhesive coated products can be obtained from the supplier's bulletins. Specific requirements for copper laminates produced as substrates for flexible printed circuits are outlined in trade specifications:

- USA: IPC-FC-241
- British: BS-4584
- German: DIN-40802

When commercially coated film is not suitable for an application, most vendors offer a dry film form of their adhesives for use as a bonding film in laminations. However, better adhesion is normally obtained from commercial solution coatings than from the dry bonding film. The dry film adhesive does have the advantage that it can be cut to shapes which cover only that portion of the polyimide film where adhesion is desired.

If neither commercially coated polyimide film nor adhesive bonding film is suitable for the application, the remaining option is for the user to apply a solution adhesive. Some generic classes of adhesives which bond KAPTON include acrylics, epoxies, butyral-phenolics, polyesters, silicones, urethanes, fluorocarbons and blends of these materials.

Selection of an adhesive is usually dependent on the properties required of the adhesive and the demands of the application. Property considerations are the thermal rating, chemical resistance, fill and flow characteristics, flexibility, peel strength, flammability, moisture resistance and insulation resistance. Also to be considered is the ease of processing, lamination temperature and whether the lamination is to be made in continuous roll equipment or in a platen press.

ADHESIVE PROPERTIES

Adhesives used with KAPTON Type H are usually a modified version of the generic adhesive family (e.g., modified-epoxy). These formulations are proprietary to the suppliers of coated KAPTON and require specific processing conditions to achieve the maximum bond strength. Always use the supplier's recommended lamination conditions for the specific adhesive you select.

Listed in Table I are several adhesive types along with information on typical lamination temperatures and maximum operating temperatures (short term exposure). When using an epoxy adhesive, anhydride curing agents are preferred. If an amine curing agent must be used, avoid an excess of curing agent as the free alkaline materials can degrade the polyimide.

TABLE 1

Adhesive Types	Lamination Temperatures °F (°C)	Maximum Operating Temperature °F (°C)
Fluorocarbons	550-600 (290-315)	to 500 (260)
Polyimides	500-700 (260-370)	to 650 (345)
Epoxies	73-450 (23-230)	to 600 (315)
Pressure Sensitive		
Silicones	73-300 (23-150)	to 500 (260)
Rubber-Phenolics	300-400 (150-205)	to 500 (260)
Acrylics	350-375 (175-190)	to 550 (290)
Polyesters	275-300 (135-150)	to 220 (105)

Solution forms of most of the adhesives above are available from suppliers of adhesives to the electronics industry. Listings of suppliers can be found in buyer's guides for electronic products. Bulletin E-74149, "Suppliers of Adhesives to the Electronics Industry," provides a representative listing of adhesive suppliers who can be consulted with for specific adhesive needs.

DU PONT

TI 0011065

PACKAGING AND MARKING

A. PACKAGING

"Kapton" shall be adequately packed to prevent loss of contents or damage during shipment.

All film will be wrapped with a non-fibrous material.

B. MARKING

"Kapton" is identified as follows to allow complete traceability back to the raw materials and processing conditions:

[redacted]

(a) Affixed to the core on all cores, 2½" wide and over. Included with the package on all cores less than 2½" wide.
(b) Inside diameter of core and nominal outside diameter of roll.
(c) Available for up to 12 characters.

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TI 0011036

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TI 0011068

Kapton

for innovative solutions to extreme-temperature, design engineering problems.

DD/NHTSA No. 3
00313

KAPTON® a versatile space-age material with down-to-earth applications.

The space shuttle's solar array; the Lunar Excursion Module; miniaturized electronic components; more efficient oil well pump motors; reliable flexible circuits; thin, lightweight electrical heaters; precise electrothermal fuel level sensors; high-temperature electrical insulation. For the past twenty years, KAPTON has contributed to the innovative design and commercial success of a wide variety of new and improved products. The reason KAPTON was selected for such demanding applications is its unique *combination* of outstanding mechanical, electrical and chemical properties *and* its ability to retain these properties over a wide range of temperatures where other engineering materials do not function.

KAPTON has proved itself as *the* material of choice in applications that involve very high or low operating temperatures.

Designers are finding that the application potential for this unique industrial material has barely been tapped.

A variety of new application possibilities for KAPTON are now being explored by Du Pont and its customers, including semiconductor pads and microprocessor chip carriers. However, a number of uses for KAPTON are well established. Some examples from the electrical and electronics industries are: field coil insulation; substrates for flexible printed circuits; motor and generator armature slot liners; magnet wire insulation; transformer and capacitor insulation; magnetic recording and pressure-sensitive tapes and tubing; and wire and cable insulation.

Three types of KAPTON are commercially available.

- KAPTON Type H is an all-purpose, all-polyimide film that has been used successfully in applications reaching temperatures as low as −269°C and as high as 400°C. Type H film can be laminated, metallized, diecut, slit, formed, or adhesive-coated. It is available as 0.3, 0.5, 1, 2, 3, and 5 mil film.
- KAPTON Type V is an all-purpose, all-polyimide film with all of the properties of Type H film, plus *superior dimensional stability*. It is available in 1, 2, 3, and 5 mil thickness.
- KAPTON Type F is a Type H film coated on one or both sides with TEFLON® FEP fluoropolymer resin to impart *heat sealability*, provide a moisture barrier, and enhance chemical resistance. It is available in a variety of constructions.

One of the important benefits of KAPTON polyimide film is its ability to be bonded, laminated, coated, and otherwise converted to fulfill a broad range of high-performance operating requirements. This outstanding versatility — and the fact that all three types share the same unique balance of properties inherent in the basic material — allows KAPTON to be *custom-tailored* to fit an almost endless variety of applications.

Armed with 20 years' experience with a high-quality material and backed by the considerable resources of the Du Pont Company, we are committed to remaining the world leader in the manufacture and diversification of polyimide films. In response to the needs of our customers and their interest in films that can insulate or conduct electricity, heat shrinkable films, pigmented films, heat conductive films and new adhesive systems, we are making a significant investment in research, development and equipment — aimed at delivering higher quality, improved productivity and better end use products, to our customers.

When sufficient business potential exists, our resources can be made available for the joint development of custom-tailored products and programs to fulfill your most stringent design requirements — during the Eighties and beyond.

TI 0011070

KAPTON® a versatile space-age material with down-to-earth applications.

The space shuttle's solar array; the Lunar Excursion Module; miniaturized electronic components; more efficient oil well pump motors; reliable flexible circuits; thin, lightweight electrical heaters; precise electrothermal fuel level sensors; high-temperature electrical insulation. For the past twenty years, KAPTON has contributed to the innovative design and commercial success of a wide variety of new and improved products. The reason KAPTON was selected for such demanding applications is its unique *combination* of outstanding mechanical, electrical and chemical properties *and* its ability to retain these properties over a wide range of temperatures where other engineering materials do not function.

KAPTON has proved itself as *the* material of choice in applications that involve very high or low operating temperatures.

Designers are finding that the application potential for this unique industrial material has barely been tapped.

A variety of new application possibilities for KAPTON are now being explored by Du Pont and its customers, including semiconductor pads and microprocessor chip carriers. However, a number of uses for KAPTON are well established. Some examples from the electrical and electronics industries are: field coil insulation; substrates for flexible printed circuits; motor and generator armature slot liners; magnet wire insulation; transformer and capacitor insulation; magnetic recording and pressure-sensitive tapes and tubing; and wire and cable insulation.

Three types of KAPTON are commercially available.

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- KAPTON Type V is an all-purpose, all-polyimide film with all of the properties of Type H film, plus *superior dimensional stability.* It is available in 1, 2, 3, and 5 mil thickness.
- KAPTON Type F is a Type H film coated on one or both sides with TEFLON® FEP fluoropolymer resin to impart *heat sealability,* provide a moisture barrier, and enhance chemical resistance. It is available in a variety of constructions.

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TI 0011070

Form 417 Rev.3F

Inland Fisher Guide - Impact Test Facility

Request for Testing

Test No. 95-IFG-7110 Run No. SD 17384 ITF Tech. D. Brown Test Date 12 DE 95

Submitted By George Pahson Phone # 6-2730 Date 11/27/95 Use NA where Not Applicable

George Pahson

Type of Test Static Deployment

ONE Occupant Defined Per Sheet

One Or Two Occupant Test

Buck ID. ______ Pulse No. ______

Occupant Location

Occupant Type

ATD # I-______

Occupant Position ______

Body Line Dimensions Head ___/___ Hip ___/___ Knee ___/___ Ankle ___/___

INSTRUMENT DESCRIPTION AND IDENTIFICATION

Channels Required Serial Number

SIR Csh Pres-1 TM160 ______

SIR Csh Pres-2 TM160 ______

SIR Csh Pres-3 TM160 ______

-----End of List------

Timing light Generator TM202 ITC Pin Number ______

		Test Plan	Process Plan
KinetioSystems HTM8 3000 TM381	1-		
KinetioSystems HTM8 3000 TM381	2-		
KinetioSystems HTM8 3000 TM381	3-		
KinetioSystems HTM8 3000 TM381	4-		
KinetioSystems HTM8 3000 TM381	5-		
KinetioSystems HTM8 3000 TM381	6-		

Dial Indicators TM199 ______

Firing Controls TM390 Dr V ___ Dr C ___ Resistance ______

Volt Ohm Meter TM### Ps V ___ Ps C ___ Resistance 2.08Ω

Firing Controls TM390p Dr Dial ______ Pas Dial 645

Compressed Gas Timer 1 ___ Timer 2 ___ Timer 3 ___ Timer 4 ___

Accumulator Pres. Tank 1 ___ Tank 2 ___ Tank 3 ___

Tank# ___ Volume ___ UTT106-102 ______

Conditioning Chamber ______

Temperature Indicator TM254- 509-7

Thermometer TM251 ______

Tank Test Stand TM374 ______

Air/Nitrogen Purge Gauge TM369-25 ______

35mm Film Roll Number 0669

Additional Instruments ______

TM 509-4 Ohm Meter

Technician Comments ______

G.M. CONFIDENTIAL

KAPTON®offers inherent heat and flame resistance and excellent thermal performance.

For all of its outstanding properties, KAPTON is probably best known for its ability to "take the heat." With a UL-94 rating of V-O for flammability — the best possible — KAPTON polyimide film will not sustain or propagate flame. Nor will it melt, drip or produce any significant smoke when exposed to flame.

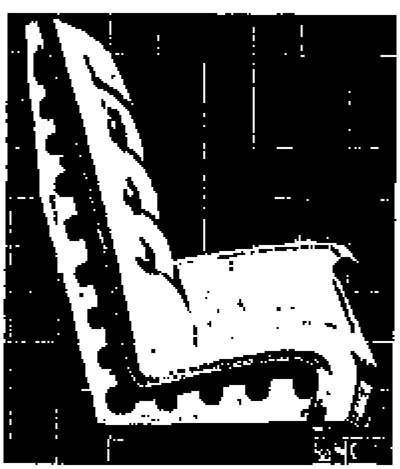
Rated at 240°C for continuous service, KAPTON can still function after exposure to temperatures up to 400°C for brief periods. Best of all — it retains its high dielectric strength even at elevated temperatures — 2,500 volts/mil at 300°C.

These outstanding thermal properties provide significant advantages to the designer. Insulation thickness on the windings of large coils for motors can be significantly reduced in size; flexible circuits can be wave-soldered without distortion; and, when used in combination with inorganic insulating tapes, high-performance cables will continue to operate in direct exposure to flame.

KAPTON polyimide film is compatible with a number of high-temperature impregnating varnishes used in modern electrical equipment manufacture — including polyimides, esterimides, epoxies, silicones, amides-imides, and organo-silicones. Magnet wire made with certain combinations of polyimide film and varnishes has a IEEE #57 thermal stability rating of 260°C.

But flame and heat resistance aren't the only thermal advantages of KAPTON. It also performs very well at the other end of the temperature scale. KAPTON film retains its flexibility at -269°C without embrittlement or significant loss of other properties.

Keeping people and equipment warm is a natural for KAPTON. As a strong, lightweight, flexible laminated sheet, it can be used to insulate and protect embedded heater wires for such diverse applications as car seat or ski-lift chair heaters, aircraft wing deicers, engine warmers, hot trays and electric blankets.



7. A strip of KAPTON Type H film is positioned over the pins in this IC socket to prevent wicking during wave soldering. The strip also provides a dielectric barrier between the leads and printed circuit.

8. A steel mill now gets 3,000 extra horsepower from the same size motor thanks to KAPTON as the coil insulation. The motor manufacturer reports that insulated windings of KAPTON last as much as 50 times longer at the 200°C rated operating temperature versus those with previously used insulations.

9. Used as insulation in rotor and stator windings, KAPTON reduced the weight of traction motors in the world's fastest train by 5%. It also helped reduce motor production costs and increased horsepower.

10. The low smoke properties of insulation of KAPTON permit its use as a cable jacket for plenum cable, eliminating the need for expensive metal conduit.

11. As a pin grid array, KAPTON allows insertion of *all* pins into a circuit board in a single, high-speed operation. Registration is perfect, and the need for expensive loading machinery is eliminated. KAPTON withstands the high temperatures of wave soldering and allows visual inspection of completed connections. After soldering, KAPTON can either be peeled away or left in place as additional support for pins during further processing and handling.

12. PC boards are identified for quality control and inventory purposes by bar code labels using an overlay of KAPTON. Since KAPTON can withstand the temperatures of wave soldering without significant shrinkage or distortion, it can be used for labeling on the *underside* of printed circuit boards where space is not at a premium.

TI 0011072

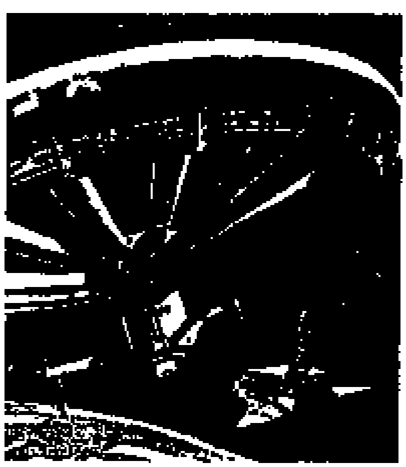
KAPTON® has superior strength, toughness, abrasion resistance and workability.

KAPTON polyimide film can solve a host of parts' performance problems that fibers, resins, metals, composites, glass, ceramics, mica or asbestos and conventional films cannot. The high tensile strength and initial tear resistance of KAPTON provide the mechanical durability necessary for many critical manufacturing operations, such as printed circuit processing and installation. Its exceptional toughness and resistance to cut-through and abrasion make it especially useful as insulation for aerospace communications wire and cable where it can be pulled through even the tightest routing.

Since the outside diameter of a wire or cable insulated with KAPTON is smaller than conventional wiring using extruded insulations, more cables can be run through a given size conduit or plenum. Stripping and termination are easier, too.

The strength, toughness, flexibility and wear resistance of KAPTON film are leading to greater numbers of non-electrical applications as well. Applications such as drive belts, pressure switch diaphragms, wear strips, washers, and seals.

As a material for use in space, KAPTON has virtually no limitations. Designers already envision huge inflatable structures that could be used for a variety of purposes, including space station repairs, energy-collection and transmission, and temporary protection of unassembled equipment components.



TI 0011074

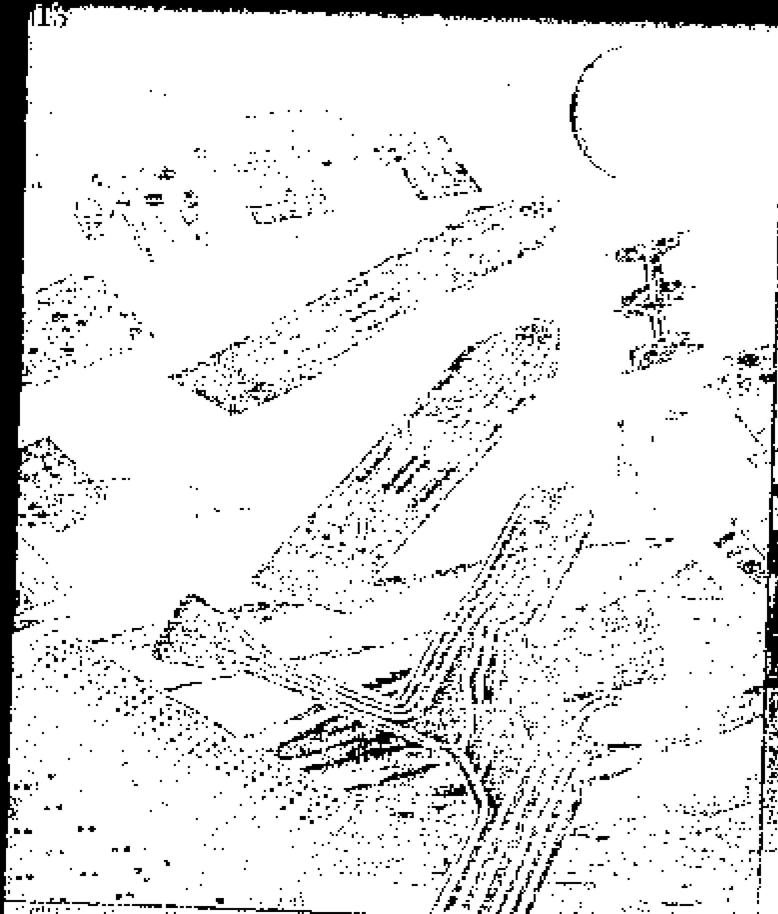
13. Flexible circuits of KAPTON can be bent, coiled, folded or twisted — and remain that way for the life of the product — without impairing circuit integrity while offering additional design freedom.

14. KAPTON protects plenum cables from damage by abrasion, kinking and snagging during installation when it is "fished" over sharp places in plenums and through ducting and conduit.

15. Automotive pressure sensing switches use KAPTON for the diaphragm because it is flexible, easily fabricated and withstands the dramatic temperature changes under the hood. KAPTON also resists most organic solvents, oils and greases.

16. KAPTON is an ideal material for tractor belts on high-speed computer printers. Because of its excellent toughness, dimensional stability and thermal properties, KAPTON stands up to the shock of abrupt start and stop operation and the heat of high-speed operation. The tractor belt teeth are injection molded directly into KAPTON film.

13



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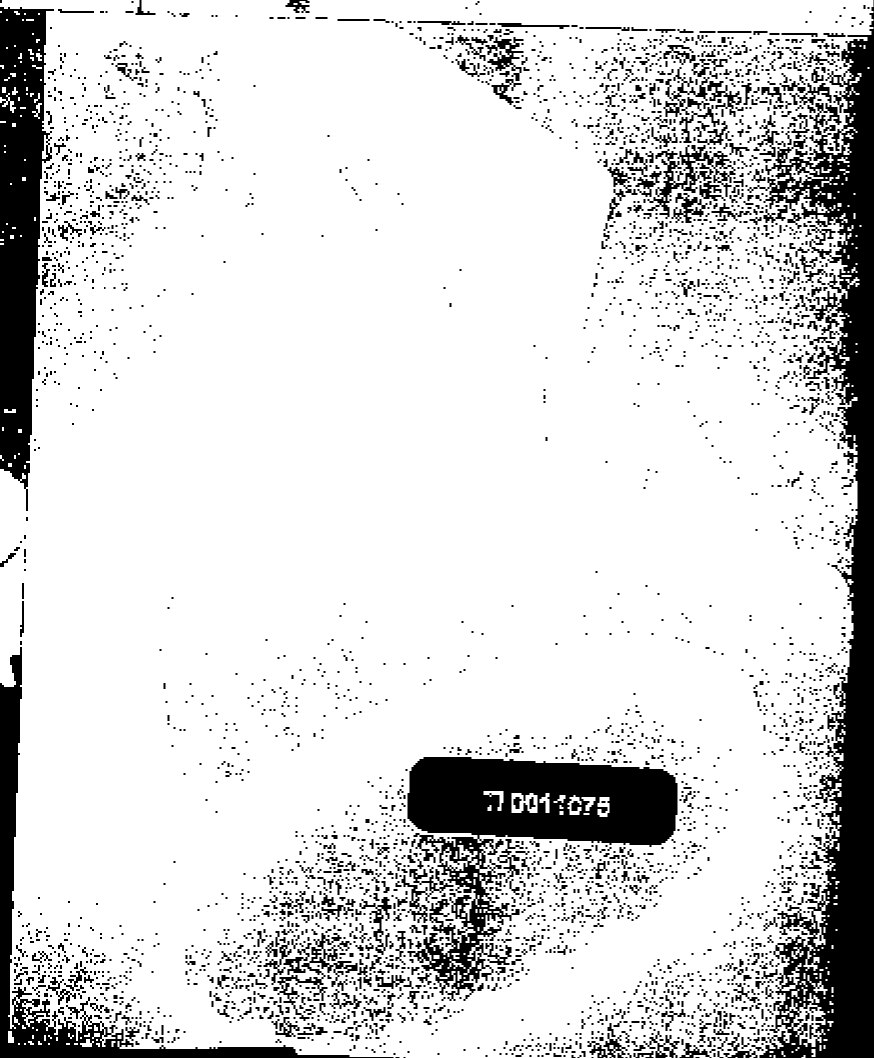


KAPTON® has outstanding electrical properties.

Next to its thermal properties, KAPTON polyimide film is selected by designers most frequently because of its excellent dielectric strength, dielectric constant, and dissipation factor. The dielectric strength of 1 mil KAPTON — 7,000 volts at room temperature (23°C) — is typically 2,500 volts even at an elevated temperature of 300°C. In fact, short-term exposure to temperatures as high as 400°C will not significantly affect the electrical properties of KAPTON.

The combination of high dielectric strength, thermal stability, uniform thickness and excellent mechanical properties allows designers of electrical equipment to specify thinner insulation on coils for transformer, generator or motor windings. This is very important because more conductors can be physically located within a given space, yielding greater power per unit. Or, if the power requirement is constant, the weight and dimensions of a given coil, stator or rotor can be substantially reduced.

In flexible circuits, the high dielectric constant of KAPTON and low dissipation factor combine to reduce signal loss to a minimum at relatively low operating voltages.

KAPTON film will play a major role in the world's largest linear particle accelerator. Proposed as the insulation for the research instrument's superconductive magnet wire, KAPTON is the only material — repeat, the only material — that can provide the extremely close tolerances, excellent dielectric strength and resistance to the liquid helium temperatures that are required for this unique application.

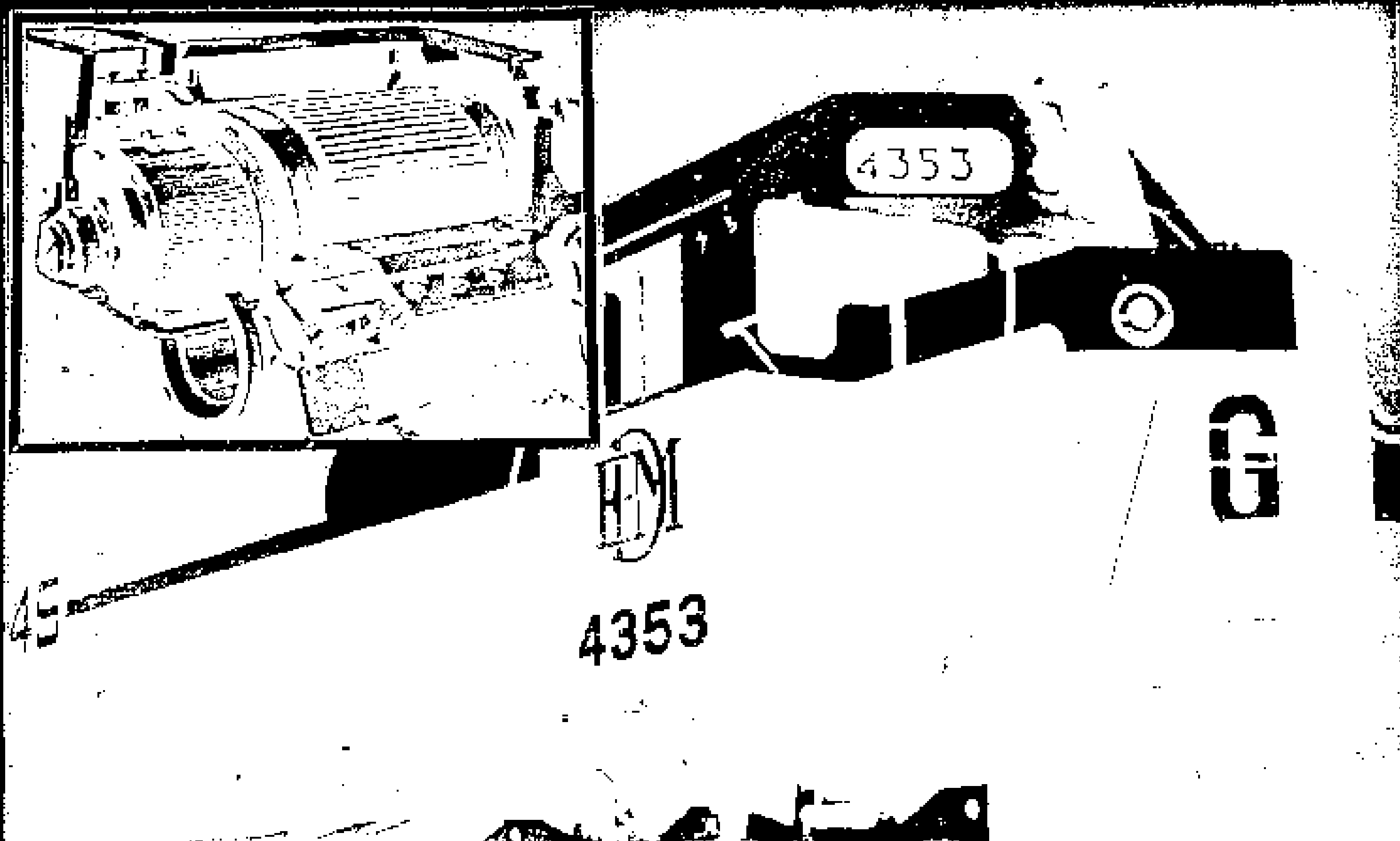
17. This electric locomotive, equipped with 3,000 volt DC traction motors, uses KAPTON Type F as an insulation on its motor windings. The KAPTON permitted an 8% increase in power over the conventional insulation material it replaced.

18. A thin, circular band of KAPTON provides outstanding electrical and thermal insulation for this high-frequency "super-tweeter" voice coil. KAPTON resists distortion at high operating temperatures, and is fully compatible with the epoxies, resins and paints used in speaker manufacture.

19. The elongation of KAPTON polyimide film is such that magnet wire insulated with KAPTON Type F sealable film can be easily bent to the desired shape without creating air gaps in the insulation, which could lead to dielectric failure or "hot spots".

20. By utilizing KAPTON on the coil winding of this electric utility line trap, the size and weight of the device can be reduced 30% — a significant advantage for substations in locations where real estate is at a premium.

TI 0011076



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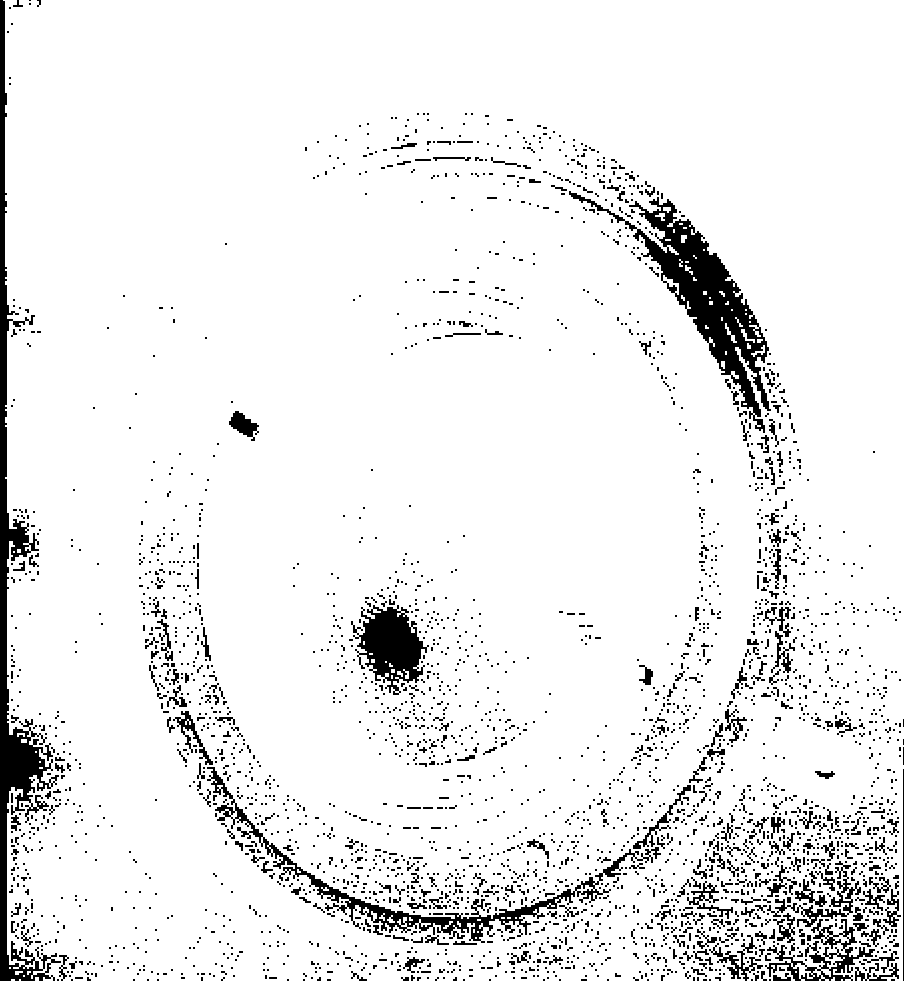

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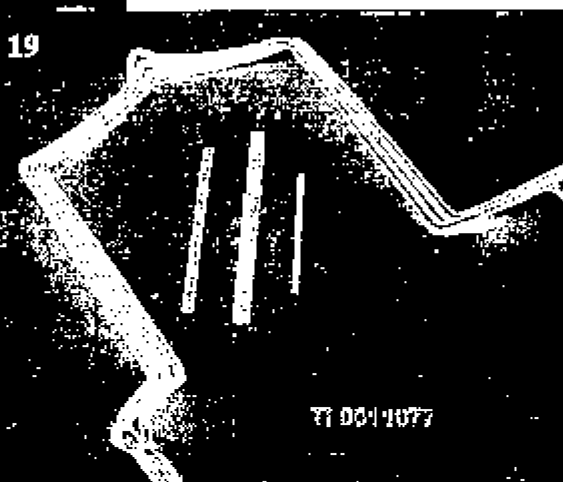

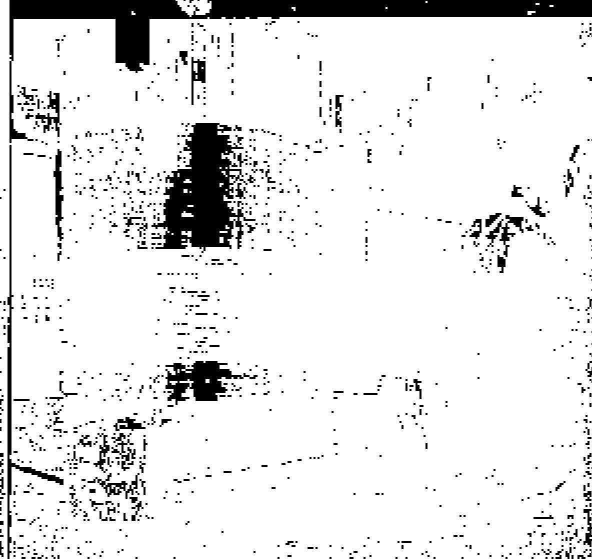

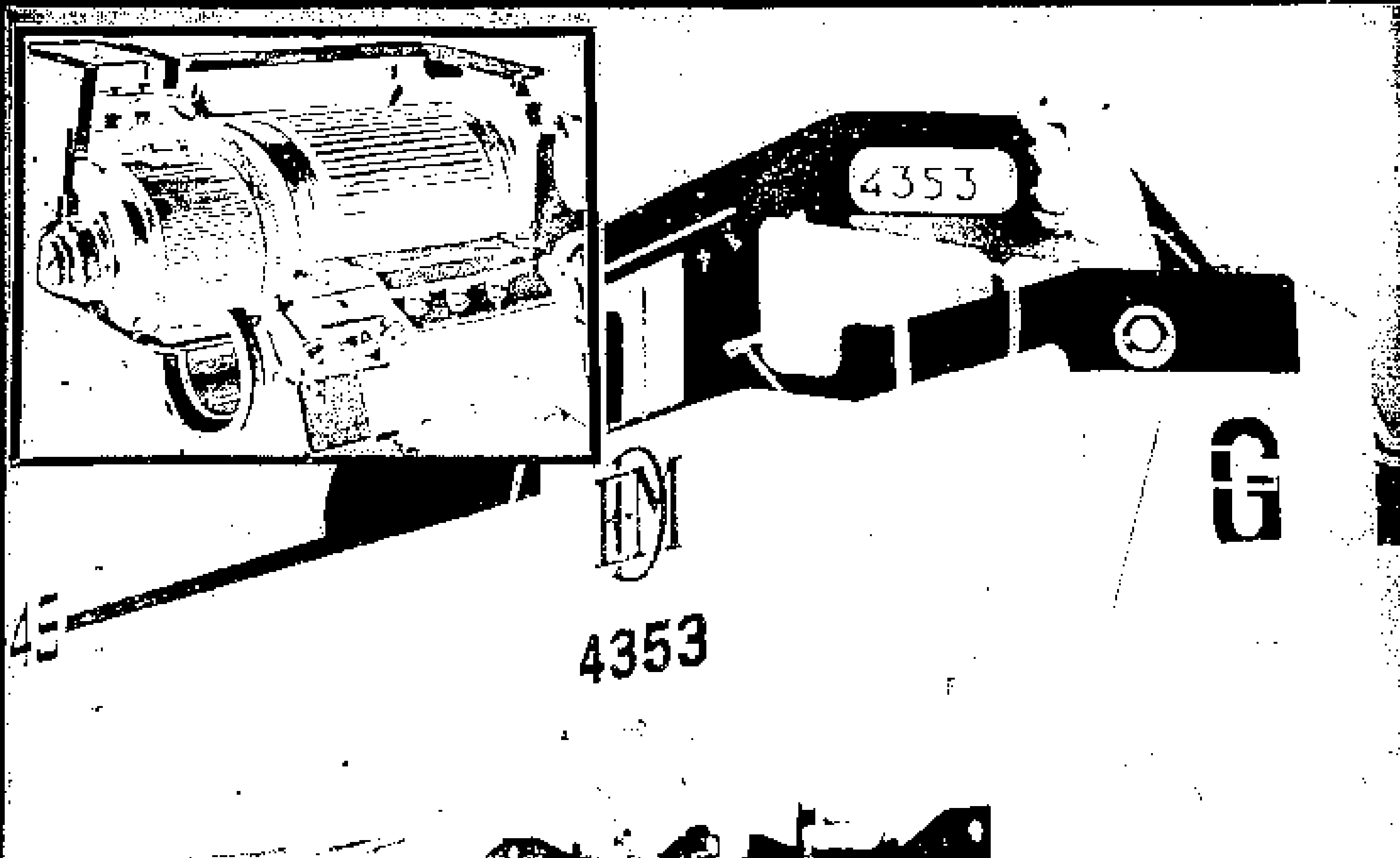

18

19

KAPTON® has outstanding resistance to most chemicals, solvents, lubricants and fuels.

KAPTON is an ideal material for use in demanding environments in which a combination of hostile elements such as chemicals, gasses, radiation and high temperature is present. No matter whether you're talking about the motor windings insulation in an oil well pump operating in a pit of gas and brine 20,000 feet below the surface of the earth, a protective layer for a liquid level sensor submerged in an organic solvent, or in a pressure switch in the cooling system of an automobile — KAPTON can take the punishment and still deliver reliable performance.

In flexible circuitry, conductors bonded between layers of KAPTON polyimide film are protected against chemicals, moisture, gasses and foreign materials so they can operate reliably in demanding environments. In military and industrial applications, KAPTON film remains tough and flexible even after exposure to 10^9 RADS of gamma radiation. And, although it is unaffected by most organic chemicals, solvents, fuels and lubricants, KAPTON can be dissolved by certain strong bases — a fact that printed circuit manufacturers use to advantage in the chemical milling of holes in printed circuits.

As mobile research vehicles brave the hostile environments of distant planets and traverse their rugged surfaces gathering samples and data, they will undoubtedly have the protection of KAPTON film. In applications ranging from wire and cable insulation to surface protection — from tractor belts to solar panels — KAPTON will make these robot explorers lighter, stronger, more resistant to chemicals, radiation and abrasion, and ultimately — more reliable.

21. This 2,300 VAC submersible oil well pump uses KAPTON polyimide film in the magnet wire and slot liner insulation system. Motors of this type often operate at depths of 20,000 feet or more in hostile, high-temperature environments which contain brine, petrochemicals and hydrogen sulfide. Manufacturers report a 50% improvement in service life using motors insulated with KAPTON.

22. Specialty conductors metallized between sheets of KAPTON comprise a highly reliable and accurate automotive electrothermal fuel level sensor developed in Germany by VDO. In addition to its outstanding thermal and dielectric properties, KAPTON can be directly immersed in a wide variety of fuels, including blended ethanol and methanol.

23. KAPTON is an ideal substrate for this CTS throttle position transducer. Not only is it resistant to automotive chemicals and lubricants; it can also withstand both high underhood temperatures, and cold winter mornings while still performing reliably.

24. Critical fuel lines of satellites in space are kept from freezing at ultra-low temperatures by heater cables insulated with KAPTON. Nickel-chromium heating elements are encapsulated in a sandwich of KAPTON which provides both superior dielectric properties and full protection against the thermal shock of extremely high and extremely low temperatures.

TI 0011078

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TI 0011078

Kapton ... only from Du Pont

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TI 0011060

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