

EA02025

TEXAS INSTRUMENTS, INC.'S

09/10/03 LETTER TO ODI

REQUEST 10

BOX 13

PART A – G

PART E

Kapton

POLYIMIDE FILM

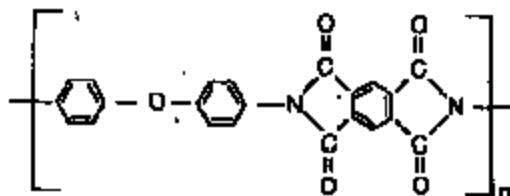
safe handling

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

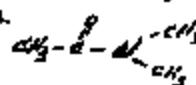
KAPTON Type H and Type V exhibits no melting point or softening point. A one-mil thick film has a zero-strength temperature of 815°C (1500°F). Zero-strength is measured as the

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 166 days exposure to boiling water. The film retained 85% 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 CFR 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 85% 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. & Tm. Off.

TI-NHTSA 018152

Kapton

POLYIMIDE FILM

Technical Information Bulletin

ADHESION TO KAPTON®

KAPTON® polyimide film, made only by DuPont, 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 TEFLO™ 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-87824, "Industry Specifications Bulletin PC-85-2." For flexible printed circuit applications the trade specification IPC-FC-221/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-72087, "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 bulletin. Specific requirements for copper laminates produced as substrates for flexible printed circuits are outlined in trade specifications:

- USA: IPC-FC-241
- British: BS-4564
- 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, butyl-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, film 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 I

Adhesive Type	Lamination Temperatures °F (°C)	Maximum Operating Temperature °F (°C)
Fluorocarbons	550-600 (280-315)	to 600 (280)
Polyimides	500-700 (280-370)	to 850 (345)
Epoxy	73-450 (-23-230)	to 600 (315)
Pressure Sensitive Silicones	73-300 (-23-150)	to 600 (280)
Rubber-Phenolics	300-400 (150-205)	to 500 (280)
Acrylics	350-375 (175-190)	to 550 (280)
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. 8) 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 vertical burning test for thin films. The oxygen index is 37% for 100 H film (ASTM 2803).

IV. HANDLING PRACTICES

- Safe handling of Type H and V KAPTON polyimide 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 mesh, 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.

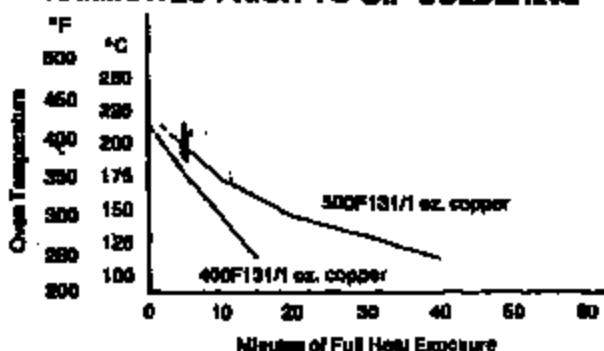
REFERENCES

1. J. T. Milek, "Polyimide Plastics: A State-of-the-Art Report," Electronic Properties Information Center, S-8, October 1, 1985, Air Force Systems Command, Contract AF33 (615)-2480, Project 7381; Task 738103.
2. C. E. Snod, A. L. Endley, S. V. Abrama, C. E. W. M. Edwards, and K. L. Oliver, *J. Poly. Sci. Polym. Chem. Ed.*, 23(4), 1373-90 (1985).

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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 8 lbs. per linear 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-Butylal	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 linear 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 8 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.

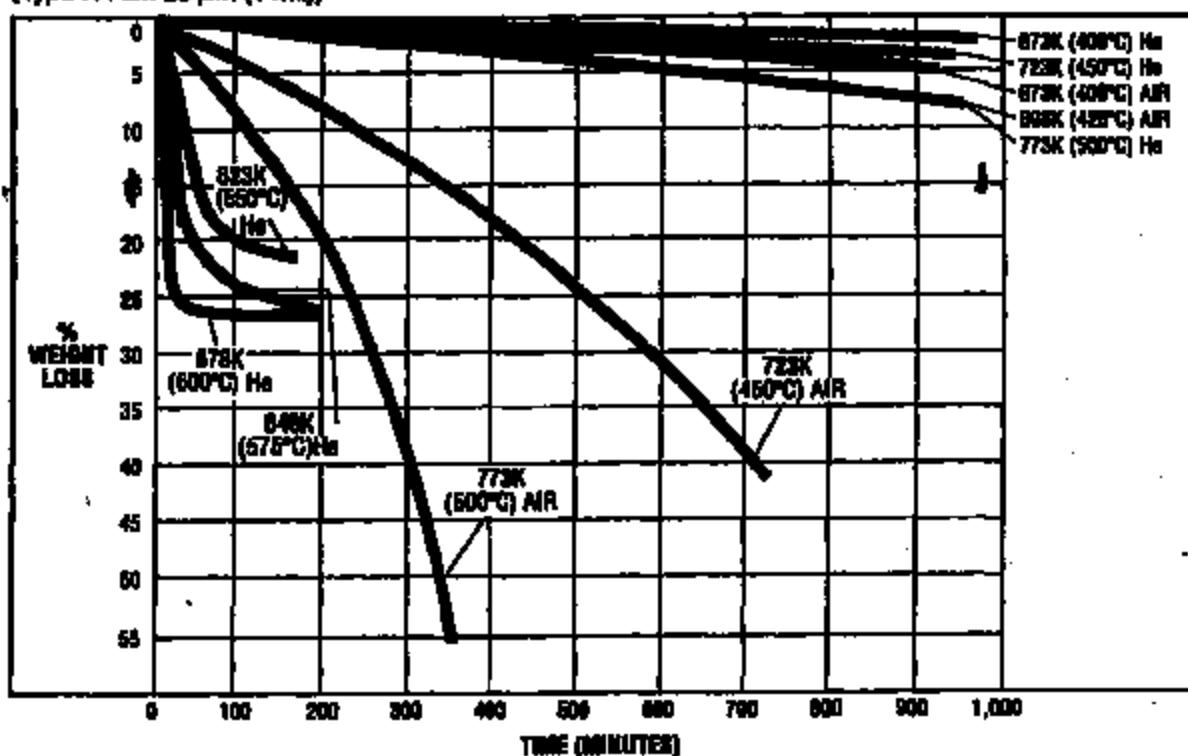
When higher adhesion levels are required for a given adhesive system, the range of the peel strength values for the laminate may usually be reduced if the surface of the film is mechanically or chemically abraded, light pumice scrubbing or caustic etching. Caution must be exercised with any such treatment 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 adhesibility 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 butylal and phenolic nitrile. Improvement over standard film averaged from 40% to 87% for these adhesive types.

ISOTHERMAL WEIGHT LOSS

(Type H Film 25 μ m (1 mil))



3. N. A. Androva, M. I. Bessonov, L. A. Lalus, and A. P. Pudakov, "Polyimides — A New Class of Thermally Stable Polymers," *Progress In Mats. Sci. Series*, Vol. VII, Technomic Publ. Co., Stamford, Conn., 1970, p. 79-88.
4. 1968 Listing of Plastic Materials, etc., P. 10, March 1968, National Sanitation Foundation.
5. General Electric Co. Res. Lab., Research of Dielectric Materials, Rept. WML-TDR-64-57, May 1964, DOC AD-602 438, NASA N64-26305.
6. R. F. Stabler and L. L. Lewis, "KAPTON Polyimide Film — A New Insulation for Aerospace Wire and Cable," Paper presented at Soc. of Aerospace Materials and Process Engineers Meeting, San Francisco, May 29, 1965.

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Kapton® Polyimide Film

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KAPTON® Polyimide Film Technical Bulletin

Suppliers of Adhesives to
the Electronics Industry

DuPont
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High Performance Substrates
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September 1988

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○ Assembly Systems Inc., Providence, RI	(401) 351-6184
○ Bacon Industries Inc., Watertown, MA	(617) 926-8550
○ Beaulieu Div. (Eckhart Corp.) Middletown, MA	(507) 777-0100
○ Comp Inc., Glens, NY	(716) 372-0660
○ Crest Products Co., Santa Ana, CA	(714) 540-9087
Delphi, John C. Co., Monmouth Junction, NJ	(201) 399-2203
● Dow Corning Corp., Midland, MI	(517) 496-4006
● Epoxy Technology Inc., Billerica, MA	(508) 657-3805
○ Fentech Inc., Ashland, MA	(508) 821-2000
○ Formulated Resins Inc., Greenville, RI	(401) 949-3080
○ GE/Silicon Products Div., Waterford, NY	(518) 237-3330
● E. F. Goodrich Adhesives Div., Akron, OH	(216) 374-3000
○ Hardman Inc., Belleville, NJ	(201) 751-3000
Hydrol Division, City of Industry, CA	(619) 969-6511
Isochem Products Co., Lincoln, HI	(401) 723-2100
● Loctite Corp., Newington, CT	(203) 246-1223
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○ Onsetta Electronic Mfg. Inc., Meadville, PA	(814) 298-2125
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Shell, Houston, TX	(713) 495-7275
○ Sympatex Inc., Montrose, CA	(318) 249-7810
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○ Thermoast Plastics Inc., Indianapolis, IN	(317) 259-4161
○ Tri-Con Inc., Medford, MA	(617) 291-5550
Vigor Co., New York, NY	(212) 807-3845
○ Whittaker (Dayton Chemicals Div.) West Alexandria, OH	(513) 839-4612

This list is believed to be complete as of the date of publication. There may be others not known
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KAPTON® Polyimide Film

Technical Bulletin

Suppliers of Adhesives to the Electronics Industry

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September 1989

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55-11-446-3711
Fax: 55-11-446-3602

Mexico
DuPont, S.A. de C.V.
Homero 205-10
Col. Chapultepec Morales
Mexico, D.F. 11870
52-5-260-2608
Fax: 52-5-260-2645

Venezuela
DuPont de Venezuela C.A.
Apartado Del Exco 81862
Caracas 1080-A, Venezuela
58-2-62-6022
Fax: 58-2-62-6442

Europe
DuPont de Nemours International S.A.
P.O. Box 60
2, chemin du Pavillon
CH-1218 Le Grand-Saconnex
Geneva, Switzerland
41 (22) 717-5111
Fax: 41 (22) 717-5100

Asia Pacific
Japan
DuPont Japan Ltd.
DuPont Tower, Shin-Nihon Building
10-1, Toranomon 2-chome
Minato-ku, Tokyo
100 Japan
81-3-3625-6511
Fax: 81-3-3224-6863

ASEAN
DuPont Singapore PTE Ltd.
1 Maritime Square
07-01, World Trade Centre
Singapore 0408
65-273-2244
Fax: 65-272-6066

Australia
DuPont (Australia) Ltd.
Northgate Gardens
168 Walker Street
North Sydney, NSW 2060
Australia
61-2-823-6111
Fax: 61-2-829-7217

Hong Kong/China
DuPont Asia Pacific Ltd.
1122 New World Office Bldg
East Wing
Salisbury Road, Kowloon
Hong Kong
852-724-6345
Fax: 852-724-4495

Korea
DuPont Korea Ltd.
9th Floor, Kyobo Bldg.
1, Chongno 1-Ka, Chongno-Ku
Seoul 110-714, Korea
82-2-721-5114
Fax: 82-2-732-6330

Taiwan
DuPont Taiwan Ltd.
13th Floor, Hung Kuo Building
187 Tun Hwa North Road
Taipei, Taiwan 10300, R.O.C.
886-2-712-1888
Fax: 886-2-712-0444

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DuPont Electronics



TI-NHTSA 018164

DD/NHTSA No. 3
84221



MATERIAL SAFETY DATA SHEET

IDENTIFICATION

NAME
HFC-134a

FORMULA
CH3FCF3

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

PERCENT VOLATILE BY VOLUME
100

LIQUID DENSITY
1.21 g/cc @ 25°C (77°F)

VAPOR PRESSURE
96 psig @ 25°C (77°F)

VAPOR DENSITY (AIR = 1)
3.18

SOLUBILITY IN WATER
0.15% by wt at 25°C (77°F) & 14.7 psia

FORM
Liquefied Gas

APPEARANCE
Clear

COLOR
Colorless

ODOR
Slight Ethereal

E-94938 Date: 4/88

TI-NHTSA 01B165

The data on this Material Safety Data Sheet applies only to the specific material designated above and does not extend in any way to combinations with any other material or in any product.

NHTSA No. 3
80282

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.

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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.

TI-NHTSA 018167

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.

TI-NHTSA 018168

TI-NHTSA 018169

DDV/NHTSA No. 3
6424



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

NFPA - 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

TI-NHTSA 018170

12/90 DR-34A

DuPont Electronics

DuPont Company
Berkeley Mill Plaza
P.O. Box 30000
Wilmington, Delaware 19899-0000

Dear Customer:

Thank you for calling Du Pont. Enclosed please find the literature you requested on Kapton®. 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.
Donald J. Farrelly, Jr.

DJP/ tlp
Enclosures

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TI-NHTSA 018171



MATERIAL SAFETY DATA SHEET

E. I. DU PONT DE NEMOURS & CO
POLYMER PRODUCTS DEPARTMENT
ELECTRONICS DEPARTMENT
1407 MARKET STREET
WILMINGTON, DE 19802

TELEPHONE NUMBERS
MEDICAL EMERGENCY 800-441-3437
PRODUCT INFORMATION 800-441-7616
TRANSPORTATION EMERGENCY 800-424-5300

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. Stooffer
	DATE September 27, 1988

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-NHTSA 018172

FIRE AND EXPLOSION HAZARD DATA

FLASH IGNITION TEMPERATURE NA

UNUSUAL FIRE, EXPLOSION HAZARDS Char 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 hydrofluoric 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 93% 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/m³ 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

NB = Not established

AEL = DuPont Company's Acceptable Exposure Limit

> = New or revised information in this section when ">" is in left margin

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 PENNSYLVANIA:

	CAS No.
Polyimide film	25038-61-7
Polyfluorocarbon coating	25067-11-2 or 26635-00-5 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).

TI-NHTSA 01B175

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 600 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

these combinations commercially available at this time. Other combinations are available. Consult your Electronics Department marketing representative for further information.

Base Film	Resin	Gauge	Base Film	Resin	Gauge
HN	FEP	30	HN	FEP	50
HN	FEP	50	HN	FEP	100
HN	FEP	100	HN	FEP	200
HN	FEP	200	HN	FEP	300
HN	FEP	300	HN	FEP	600
HN	Teflon	30	HN	Teflon	50
HN	Teflon	50	HN	Teflon	100
HN	Teflon	100	HN	Teflon	200
HN	Teflon	200	HN	Teflon	300
HN	Teflon	300	HN	Teflon	600

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 (MF) in addition to the items covered by this specifications bulletin. Written confirmation is available with each delivery upon request.



TI-NHTSA 018176

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.

Base Film	Resin	Gauge	Thickness	Color	Temp. Rating	Dielectric Strength	Dielectric Constant	Dielectric Absorpt.	Insulation Resist.	Volume Resist.	Electrolytic Conduct.	Water Abs.	Shelf Life
HN	FEP	30	0.00030	White	260° F	1000 V/Mil	4.5	0.000001	10 ¹² ohms	10 ¹⁴ ohm-cm	10 ⁻¹⁰ mho/cm	0.001%	1 year
HN	FEP	50	0.00050	White	260° F	1000 V/Mil	4.5	0.000001	10 ¹² ohms	10 ¹⁴ ohm-cm	10 ⁻¹⁰ mho/cm	0.001%	1 year
HN	FEP	100	0.00100	White	260° F	1000 V/Mil	4.5	0.000001	10 ¹² ohms	10 ¹⁴ ohm-cm	10 ⁻¹⁰ mho/cm	0.001%	1 year
HN	FEP	200	0.00200	White	260° F	1000 V/Mil	4.5	0.000001	10 ¹² ohms	10 ¹⁴ ohm-cm	10 ⁻¹⁰ mho/cm	0.001%	1 year
HN	FEP	300	0.00300	White	260° F	1000 V/Mil	4.5	0.000001	10 ¹² ohms	10 ¹⁴ ohm-cm	10 ⁻¹⁰ mho/cm	0.001%	1 year
HN	FEP	500	0.00500	White	260° F	1000 V/Mil	4.5	0.000001	10 ¹² ohms	10 ¹⁴ ohm-cm	10 ⁻¹⁰ mho/cm	0.001%	1 year

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.



TI-NHTSA 018177

PROPERTIES OF TYPE HN FILM

MECHANICAL

Category	Approximate Number				
	White	Black	Asian	Other	Total
White, non-Hispanic	1,000	100	100	100	1,300
Black, non-Hispanic	100	1,000	100	100	1,300
Asian, non-Hispanic	100	100	1,000	100	1,300
Hispanic	100	100	100	1,000	1,300
Other	100	100	100	100	1,300
Total	1,300	1,300	1,300	1,300	5,200

ELECTRICAL

and the other two were not. The first was a small, dark, irregularly shaped mass, which had been partially dissolved by the acid. The second was a larger, more rounded mass, which had been partially dissolved by the acid. The third was a small, dark, irregularly shaped mass, which had been partially dissolved by the acid.

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" 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 $\pm 2^{\circ}\text{C}$. 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

1 hour for 30 and 60 gauge filters

4,4,5) and "Elongation, percent, after 2 hour 400°C." requirement (Table 1) of MIL-P-48112 B (MR).

Underwriters Laboratories Inc. lists a thermal index of 200°C.-220°C. (depending on gauge and type) for mechanical properties and 230°C.-240°C. (depending on gauge and type) for electrical properties under their file no. E39605 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 sides 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 800 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 $\frac{1}{2}$ 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

Thickness	Dielectric Strength Volts/Mil
0.0005	1000
0.0010	1000
0.0015	1000
0.0020	1000
0.0025	1000
0.0030	1000
0.0035	1000
0.0040	1000
0.0045	1000
0.0050	1000
0.0060	1000
0.0070	1000
0.0080	1000
0.0090	1000
0.0100	1000
0.0125	1000
0.0150	1000
0.0175	1000
0.0200	1000
0.0250	1000
0.0300	1000
0.0350	1000
0.0400	1000
0.0450	1000
0.0500	1000
0.0600	1000
0.0700	1000
0.0800	1000
0.0900	1000
0.1000	1000
0.1250	1000
0.1500	1000
0.1750	1000
0.2000	1000
0.2500	1000
0.3000	1000
0.3500	1000
0.4000	1000
0.4500	1000
0.5000	1000
0.6000	1000
0.7000	1000
0.8000	1000
0.9000	1000
1.0000	1000
1.2500	1000
1.5000	1000
1.7500	1000
2.0000	1000
2.5000	1000
3.0000	1000
3.5000	1000
4.0000	1000
4.5000	1000
5.0000	1000
6.0000	1000
7.0000	1000
8.0000	1000
9.0000	1000
10.0000	1000
12.5000	1000
15.0000	1000
17.5000	1000
20.0000	1000
25.0000	1000
30.0000	1000
35.0000	1000
40.0000	1000
45.0000	1000
50.0000	1000
60.0000	1000
70.0000	1000
80.0000	1000
90.0000	1000
100.0000	1000
125.0000	1000
150.0000	1000
175.0000	1000
200.0000	1000
250.0000	1000
300.0000	1000
350.0000	1000
400.0000	1000
450.0000	1000
500.0000	1000
600.0000	1000
700.0000	1000
800.0000	1000
900.0000	1000
1000.0000	1000
1250.0000	1000
1500.0000	1000
1750.0000	1000
2000.0000	1000
2500.0000	1000
3000.0000	1000
3500.0000	1000
4000.0000	1000
4500.0000	1000
5000.0000	1000
6000.0000	1000
7000.0000	1000
8000.0000	1000
9000.0000	1000
10000.0000	1000
12500.0000	1000
15000.0000	1000
17500.0000	1000
20000.0000	1000
25000.0000	1000
30000.0000	1000
35000.0000	1000
40000.0000	1000
45000.0000	1000
50000.0000	1000
60000.0000	1000
70000.0000	1000
80000.0000	1000
90000.0000	1000
100000.0000	1000
125000.0000	1000
150000.0000	1000
175000.0000	1000
200000.0000	1000
250000.0000	1000
300000.0000	1000
350000.0000	1000
400000.0000	1000
450000.0000	1000
500000.0000	1000
600000.0000	1000
700000.0000	1000
800000.0000	1000
900000.0000	1000
1000000.0000	1000
1250000.0000	1000
1500000.0000	1000
1750000.0000	1000
2000000.0000	1000
2500000.0000	1000
3000000.0000	1000
3500000.0000	1000
4000000.0000	1000
4500000.0000	1000
5000000.0000	1000
6000000.0000	1000
7000000.0000	1000
8000000.0000	1000
9000000.0000	1000
10000000.0000	1000
12500000.0000	1000
15000000.0000	1000
17500000.0000	1000
20000000.0000	1000
25000000.0000	1000
30000000.0000	1000
35000000.0000	1000
40000000.0000	1000
45000000.0000	1000
50000000.0000	1000
60000000.0000	1000
70000000.0000	1000
80000000.0000	1000
90000000.0000	1000
100000000.0000	1000
125000000.0000	1000
150000000.0000	1000
175000000.0000	1000
200000000.0000	1000
250000000.0000	1000
300000000.0000	1000
350000000.0000	1000
400000000.0000	1000
450000000.0000	1000
500000000.0000	1000
600000000.0000	1000
700000000.0000	1000
800000000.0000	1000
900000000.0000	1000
1000000000.0000	1000
1250000000.0000	1000
1500000000.0000	1000
1750000000.0000	1000
2000000000.0000	1000
2500000000.0000	1000
3000000000.0000	1000
3500000000.0000	1000
4000000000.0000	1000
4500000000.0000	1000
5000000000.0000	1000
6000000000.0000	1000
7000000000.0000	1000
8000000000.0000	1000
9000000000.0000	1000
10000000000.0000	1000
12500000000.0000	1000
15000000000.0000	1000
17500000000.0000	1000
20000000000.0000	1000
25000000000.0000	1000
30000000000.0000	1000
35000000000.0000	1000
40000000000.0000	1000
45000000000.0000	1000
50000000000.0000	1000
60000000000.0000	1000
70000000000.0000	1000
80000000000.0000	1000
90000000000.0000	1000
100000000000.0000	1000
125000000000.0000	1000
150000000000.0000	1000
175000000000.0000	1000
200000000000.0000	1000
250000000000.0000	1000
300000000000.0000	1000
350000000000.0000	1000
400000000000.0000	1000
450000000000.0000	1000
500000000000.0000	1000
600000000000.0000	1000
700000000000.0000	1000
800000000000.0000	1000
900000000000.0000	1000
1000000000000.0000	1000
1250000000000.0000	1000
1500000000000.0000	1000
1750000000000.0000	1000
2000000000000.0000	1000
2500000000000.0000	1000
3000000000000.0000	1000
3500000000000.0000	1000
4000000000000.0000	1000
4500000000000.0000	1000
5000000000000.0000	1000
6000000000000.0000	1000
7000000000000.0000	1000
8000000000000.0000	1000
9000000000000.0000	1000
10000000000000.0000	1000
12500000000000.0000	1000
15000000000000.0000	1000
17500000000000.0000	1000
20000000000000.0000	1000
25000000000000.0000	1000
30000000000000.0000	1000
35000000000000.0000	1000
40000000000000.0000	1000
45000000000000.0000	1000
50000000000000.0000	1000
60000000000000.0000	1000
70000000000000.0000	1000
80000000000000.0000	1000
90000000000000.0000	1000
100000000000000.0000	1000
125000000000000.0000	1000
150000000000000.0000	1000
175000000000000.0000	1000
200000000000000.0000	1000
250000000000000.0000	1000
300000000000000.0000	1000
350000000000000.0000	1000
400000000000000.0000	1000
450000000000000.0000	1000
500000000000000.0000	1000
600000000000000.0000	1000
700000000000000.0000	1000
800000000000000.0000	1000
900000000000000.0000	1000
1000000000000000.0000	1000
1250000000000000.0000	1000
1500000000000000.0000	1000
1750000000000000.0000	1000
2000000000000000.0000	1000
2500000000000000.0000	1000
3000000000000000.0000	1000
3500000000000000.0000	1000
4000000000000000.0000	1000
4500000000000000.0000	1000
5000000000000000.0000	1000
6000000000000000.0000	1000
7000000000000000.0000	1000
8000000000000000.0000	1000
9000000000000000.0000	1000
10000000000000000.0000	1000
12500000000000000.0000	1000
15000000000000000.0000	1000
17500000000000000.0000	1000
20000000000000000.0000	1000
25000000000000000.0000	1000
30000000000000000.0000	1000
35000000000000000.0000	1000
40000000000000000.0000	1000
45000000000000000.0000	1000
50000000000000000.0000	1000
60000000000000000.0000	1000
70000000000000000.0000	1000
80000000000000000.0000	1000
90000000000000000.0000	1000
100000000000000000.0000	1000
125000000000000000.0000	1000
150000000000000000.0000	1000
175000000000000000.0000	1000
200000000000000000.0000	1000
250000000000000000.0000	1000
300000000000000000.0000	1000
350000000000000000.0000	1000
400000000000000000.0000	1000
450000000000000000.0000	1000
500000000000000000.0000	1000
600000000000000000.0000	1000
700000000000000000.0000	1000
800000000000000000.0000	1000
900000000000000000.0000	1000
1000000000000000000.0000	1000
1250000000000000000.0000	1000
1500000000000000000.0000	1000
1750000000000000000.0000	1000
2000000000000000000.0000	1000
2500000000000000000.0000	1

ELECTRICAL

Test Item	Spec. Ref.	Test Method	Test Result	Comments
Dielectric Strength	MIL-E-4000, Sec. 10.1	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 1 minute, no breakdown.
Dielectric Absorption	MIL-E-4000, Sec. 10.1	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 1 minute, no absorption.
Dielectric Constant	MIL-E-4000, Sec. 10.1	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 1 minute, no absorption.
Dielectric Loss Factor	MIL-E-4000, Sec. 10.1	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 1 minute, no absorption.
Dielectric Breakdown Voltage	MIL-E-4000, Sec. 10.1	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 1 minute, no breakdown.
Dielectric Strength, 2 hr. 400°C	MIL-P-46112 B(MP)	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 2 hours, 400°C, no breakdown.
Dielectric Strength, 2 hr. 220°C	MIL-P-46112 B(MP)	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 2 hours, 220°C, no breakdown.
Dielectric Strength, 2 hr. 200°C	MIL-P-46112 B(MP)	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 2 hours, 200°C, no breakdown.
Dielectric Strength, 2 hr. 175°C	MIL-P-46112 B(MP)	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 2 hours, 175°C, no breakdown.
Dielectric Strength, 2 hr. 150°C	MIL-P-46112 B(MP)	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 2 hours, 150°C, no breakdown.
Dielectric Strength, 2 hr. 125°C	MIL-P-46112 B(MP)	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 2 hours, 125°C, no breakdown.
Dielectric Strength, 2 hr. 100°C	MIL-P-46112 B(MP)	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 2 hours, 100°C, no breakdown.
Dielectric Strength, 2 hr. 75°C	MIL-P-46112 B(MP)	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 2 hours, 75°C, no breakdown.
Dielectric Strength, 2 hr. 50°C	MIL-P-46112 B(MP)	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 2 hours, 50°C, no breakdown.
Dielectric Strength, 2 hr. 25°C	MIL-P-46112 B(MP)	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 2 hours, 25°C, no breakdown.
Dielectric Strength, 2 hr. 0°C	MIL-P-46112 B(MP)	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 2 hours, 0°C, no breakdown.
Dielectric Strength, 2 hr. -25°C	MIL-P-46112 B(MP)	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 2 hours, -25°C, no breakdown.
Dielectric Strength, 2 hr. -50°C	MIL-P-46112 B(MP)	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 2 hours, -50°C, no breakdown.
Dielectric Strength, 2 hr. -75°C	MIL-P-46112 B(MP)	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 2 hours, -75°C, no breakdown.
Dielectric Strength, 2 hr. -100°C	MIL-P-46112 B(MP)	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 2 hours, -100°C, no breakdown.
Dielectric Strength, 2 hr. -125°C	MIL-P-46112 B(MP)	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 2 hours, -125°C, no breakdown.
Dielectric Strength, 2 hr. -150°C	MIL-P-46112 B(MP)	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 2 hours, -150°C, no breakdown.
Dielectric Strength, 2 hr. -175°C	MIL-P-46112 B(MP)	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 2 hours, -175°C, no breakdown.
Dielectric Strength, 2 hr. -200°C	MIL-P-46112 B(MP)	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 2 hours, -200°C, no breakdown.
Dielectric Strength, 2 hr. -220°C	MIL-P-46112 B(MP)	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 2 hours, -220°C, no breakdown.
Dielectric Strength, 2 hr. -240°C	MIL-P-46112 B(MP)	ASTM D-149	1000 VAC	Tested at 1000 VAC, 60 Hz, 2 hours, -240°C, no breakdown.

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" 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.B) and "Elongation, percent, after 2 hour 400°C." requirement (Table 1) of MIL-P-46112 B(MP).

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. E38505 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" ± 0.008", 6" I.D. is 6.028" ± 0.010". Core material will be plastic for 3" I.D. cores less than ½" wide. Core material will be fibre for 3" I.D. cores

wider than ½" 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:

Width Range	Tolerance
½" or less Universal only	± 7 mils
1" or less	± 15 mils
1½"-4"	± 30 mils
4½" 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.

(15.3" x 6" pad roll is available in widths up to 1/4" only in 220FN, 220HN, 220VN,
220NA, 220PN01, 220PN02, 220PN03, 220PN021, 220PN022.

* G.D. Tolerance is ± 1/4" for pads and ± 1/8" for universal.

* Type HN, PN and VN films in pads are supplied in width increments of 1/4".
Mark lines are supplied in width increments of 1/4" in widths 1/4" to 2".

* All universal rolls are available in 1/4" width increments with 1/8" maximum widths. The minimum width is 1/4" for 2" x 6" (D.O. x 0.5); the maximum width is 1/4" for 3" x 12", and 1" x 12" (D.O. x 0.3).

Specifications for pad rolls are:

1. Core width will be film width + 1/4", - 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 1/16".
2. Film shall not project from the main body of the roll more than 1/4".
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 1/16".
5. Width of traverse is 1 1/4", - 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.

Splines 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 HNs but 250FN029 the splice is an overlap splice a minimum of 1/4" long. On 250FN029 a butt splice is made using 120FN816 as the joining tape applied on the FEP surfaces.

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 120FN816 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 Sift 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)

Slit Roll Width (in.)	Minimum Average Splice Free Length (Feet)	
	To 12" wide	To 18" wide
12	12	12
14	14	14
16	16	16
18	18	18
20	20	20
22	22	22
24	24	24
26	26	26
28	28	28
30	30	30
32	32	32
34	34	34
36	36	36
38	38	38
40	40	40
42	42	42
44	44	44
46	46	46
48	48	48
50	50	50
52	52	52
54	54	54
56	56	56
58	58	58
60	60	60
62	62	62
64	64	64
66	66	66
68	68	68
70	70	70
72	72	72
74	74	74
76	76	76
78	78	78
80	80	80
82	82	82
84	84	84
86	86	86
88	88	88
90	90	90
92	92	92
94	94	94
96	96	96
98	98	98
100	100	100

NOTES: * To 12" wide for 30HN, 62" wide for 60HN

* To 62" wide

* To 6" wide

* To 18" wide. For widths greater than 18" to the maximum, the minimum average footage will be one half that shown in the table.

* 1/2 in 1/4" wide

MINIMUM LENGTH BETWEEN SPLICES OR BEGINNING AND END OF A ROLL (FEET)

Slit Roll Width (in.)	Minimum Length Between Splices or Beginning and End of a Roll (Feet)	
	To 12" wide	To 18" wide
12	12	12
14	14	14
16	16	16
18	18	18
20	20	20
22	22	22
24	24	24
26	26	26
28	28	28
30	30	30
32	32	32
34	34	34
36	36	36
38	38	38
40	40	40
42	42	42
44	44	44
46	46	46
48	48	48
50	50	50
52	52	52
54	54	54
56	56	56
58	58	58
60	60	60
62	62	62
64	64	64
66	66	66
68	68	68
70	70	70
72	72	72
74	74	74
76	76	76
78	78	78
80	80	80
82	82	82
84	84	84
86	86	86
88	88	88
90	90	90
92	92	92
94	94	94
96	96	96
98	98	98

G. AVERAGE THICKNESS TOLERANCES (UNIT WEIGHT)

Slit Roll Width (in.)	Average Thickness Tolerances (Unit Weight)	
	Under 12"	Over 12"
12	± .005	± .005
14	± .005	± .005
16	± .005	± .005
18	± .005	± .005
20	± .005	± .005
22	± .005	± .005
24	± .005	± .005
26	± .005	± .005
28	± .005	± .005
30	± .005	± .005
32	± .005	± .005
34	± .005	± .005
36	± .005	± .005
38	± .005	± .005
40	± .005	± .005
42	± .005	± .005
44	± .005	± .005
46	± .005	± .005
48	± .005	± .005
50	± .005	± .005
52	± .005	± .005
54	± .005	± .005
56	± .005	± .005
58	± .005	± .005
60	± .005	± .005
62	± .005	± .005
64	± .005	± .005
66	± .005	± .005
68	± .005	± .005
70	± .005	± .005
72	± .005	± .005
74	± .005	± .005
76	± .005	± .005
78	± .005	± .005
80	± .005	± .005
82	± .005	± .005
84	± .005	± .005
86	± .005	± .005
88	± .005	± .005
90	± .005	± .005
92	± .005	± .005
94	± .005	± .005
96	± .005	± .005
98	± .005	± .005

* Applies to Type VH film sizes.

Slit Roll Width (in.)	Average Thickness Tolerances (Unit Weight)	
	Under 12"	Over 12"
12	± .005	± .005
14	± .005	± .005
16	± .005	± .005
18	± .005	± .005
20	± .005	± .005
22	± .005	± .005
24	± .005	± .005
26	± .005	± .005
28	± .005	± .005
30	± .005	± .005
32	± .005	± .005
34	± .005	± .005
36	± .005	± .005
38	± .005	± .005
40	± .005	± .005
42	± .005	± .005
44	± .005	± .005
46	± .005	± .005
48	± .005	± .005
50	± .005	± .005
52	± .005	± .005
54	± .005	± .005
56	± .005	± .005
58	± .005	± .005
60	± .005	± .005
62	± .005	± .005
64	± .005	± .005
66	± .005	± .005
68	± .005	± .005
70	± .005	± .005
72	± .005	± .005
74	± .005	± .005
76	± .005	± .005
78	± .005	± .005
80	± .005	± .005
82	± .005	± .005
84	± .005	± .005
86	± .005	± .005
88	± .005	± .005
90	± .005	± .005
92	± .005	± .005
94	± .005	± .005
96	± .005	± .005
98	± .005	± .005

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 12"	25 + slit roll width (in.)
12" and Over	4

H. MICROMETER THICKNESS

Thickness tolerances are based on a statistical analysis of routine process control data.

Thickness (inches)	Deviation (inches)	Thickness (mm)	Deviation (mm)
0.0000	+0.0000	0.0000	+0.0000
0.0005	+0.0000	0.0127	+0.0000
0.0010	+0.0000	0.0254	+0.0000
0.0015	+0.0000	0.0381	+0.0000
0.0020	+0.0000	0.0508	+0.0000
0.0025	+0.0000	0.0635	+0.0000
0.0030	+0.0000	0.0762	+0.0000
0.0035	+0.0000	0.0889	+0.0000
0.0040	+0.0000	0.1016	+0.0000
0.0045	+0.0000	0.1143	+0.0000
0.0050	+0.0000	0.1270	+0.0000
0.0055	+0.0000	0.1397	+0.0000
0.0060	+0.0000	0.1524	+0.0000
0.0065	+0.0000	0.1651	+0.0000
0.0070	+0.0000	0.1778	+0.0000
0.0075	+0.0000	0.1905	+0.0000
0.0080	+0.0000	0.2032	+0.0000
0.0085	+0.0000	0.2159	+0.0000
0.0090	+0.0000	0.2286	+0.0000
0.0095	+0.0000	0.2413	+0.0000
0.0100	+0.0000	0.2540	+0.0000
0.0105	+0.0000	0.2667	+0.0000
0.0110	+0.0000	0.2794	+0.0000
0.0115	+0.0000	0.2921	+0.0000
0.0120	+0.0000	0.3048	+0.0000
0.0125	+0.0000	0.3175	+0.0000
0.0130	+0.0000	0.3302	+0.0000
0.0135	+0.0000	0.3429	+0.0000
0.0140	+0.0000	0.3556	+0.0000
0.0145	+0.0000	0.3683	+0.0000
0.0150	+0.0000	0.3810	+0.0000
0.0155	+0.0000	0.3937	+0.0000
0.0160	+0.0000	0.4064	+0.0000
0.0165	+0.0000	0.4191	+0.0000
0.0170	+0.0000	0.4318	+0.0000
0.0175	+0.0000	0.4445	+0.0000
0.0180	+0.0000	0.4572	+0.0000
0.0185	+0.0000	0.4700	+0.0000
0.0190	+0.0000	0.4827	+0.0000
0.0195	+0.0000	0.4954	+0.0000
0.0200	+0.0000	0.5081	+0.0000
0.0205	+0.0000	0.5208	+0.0000
0.0210	+0.0000	0.5335	+0.0000
0.0215	+0.0000	0.5462	+0.0000
0.0220	+0.0000	0.5589	+0.0000
0.0225	+0.0000	0.5716	+0.0000
0.0230	+0.0000	0.5843	+0.0000
0.0235	+0.0000	0.5970	+0.0000
0.0240	+0.0000	0.6097	+0.0000
0.0245	+0.0000	0.6224	+0.0000
0.0250	+0.0000	0.6351	+0.0000
0.0255	+0.0000	0.6478	+0.0000
0.0260	+0.0000	0.6605	+0.0000
0.0265	+0.0000	0.6732	+0.0000
0.0270	+0.0000	0.6859	+0.0000
0.0275	+0.0000	0.6986	+0.0000
0.0280	+0.0000	0.7113	+0.0000
0.0285	+0.0000	0.7240	+0.0000
0.0290	+0.0000	0.7367	+0.0000
0.0295	+0.0000	0.7494	+0.0000
0.0300	+0.0000	0.7621	+0.0000
0.0305	+0.0000	0.7748	+0.0000
0.0310	+0.0000	0.7875	+0.0000
0.0315	+0.0000	0.8002	+0.0000
0.0320	+0.0000	0.8129	+0.0000
0.0325	+0.0000	0.8256	+0.0000
0.0330	+0.0000	0.8383	+0.0000
0.0335	+0.0000	0.8510	+0.0000
0.0340	+0.0000	0.8637	+0.0000
0.0345	+0.0000	0.8764	+0.0000
0.0350	+0.0000	0.8891	+0.0000
0.0355	+0.0000	0.9018	+0.0000
0.0360	+0.0000	0.9145	+0.0000
0.0365	+0.0000	0.9272	+0.0000
0.0370	+0.0000	0.9400	+0.0000
0.0375	+0.0000	0.9527	+0.0000
0.0380	+0.0000	0.9654	+0.0000
0.0385	+0.0000	0.9781	+0.0000
0.0390	+0.0000	0.9908	+0.0000
0.0395	+0.0000	1.0035	+0.0000
0.0400	+0.0000	1.0162	+0.0000
0.0405	+0.0000	1.0289	+0.0000
0.0410	+0.0000	1.0416	+0.0000
0.0415	+0.0000	1.0543	+0.0000
0.0420	+0.0000	1.0670	+0.0000
0.0425	+0.0000	1.0797	+0.0000
0.0430	+0.0000	1.0924	+0.0000
0.0435	+0.0000	1.1051	+0.0000
0.0440	+0.0000	1.1178	+0.0000
0.0445	+0.0000	1.1305	+0.0000
0.0450	+0.0000	1.1432	+0.0000
0.0455	+0.0000	1.1559	+0.0000
0.0460	+0.0000	1.1686	+0.0000
0.0465	+0.0000	1.1813	+0.0000
0.0470	+0.0000	1.1940	+0.0000
0.0475	+0.0000	1.2067	+0.0000
0.0480	+0.0000	1.2194	+0.0000
0.0485	+0.0000	1.2321	+0.0000
0.0490	+0.0000	1.2448	+0.0000
0.0495	+0.0000	1.2575	+0.0000
0.0500	+0.0000	1.2702	+0.0000
0.0505	+0.0000	1.2829	+0.0000
0.0510	+0.0000	1.2956	+0.0000
0.0515	+0.0000	1.3083	+0.0000
0.0520	+0.0000	1.3210	+0.0000
0.0525	+0.0000	1.3337	+0.0000
0.0530	+0.0000	1.3464	+0.0000
0.0535	+0.0000	1.3591	+0.0000
0.0540	+0.0000	1.3718	+0.0000
0.0545	+0.0000	1.3845	+0.0000
0.0550	+0.0000	1.3972	+0.0000
0.0555	+0.0000	1.4100	+0.0000
0.0560	+0.0000	1.4227	+0.0000
0.0565	+0.0000	1.4354	+0.0000
0.0570	+0.0000	1.4481	+0.0000
0.0575	+0.0000	1.4608	+0.0000
0.0580	+0.0000	1.4735	+0.0000
0.0585	+0.0000	1.4862	+0.0000
0.0590	+0.0000	1.5000	+0.0000
0.0595	+0.0000	1.5127	+0.0000
0.0600	+0.0000	1.5254	+0.0000
0.0605	+0.0000	1.5381	+0.0000
0.0610	+0.0000	1.5508	+0.0000
0.0615	+0.0000	1.5635	+0.0000
0.0620	+0.0000	1.5762	+0.0000
0.0625	+0.0000	1.5889	+0.0000
0.0630	+0.0000	1.6016	+0.0000
0.0635	+0.0000	1.6143	+0.0000
0.0640	+0.0000	1.6270	+0.0000
0.0645	+0.0000	1.6397	+0.0000
0.0650	+0.0000	1.6524	+0.0000
0.0655	+0.0000	1.6651	+0.0000
0.0660	+0.0000	1.6778	+0.0000
0.0665	+0.0000	1.6905	+0.0000
0.0670	+0.0000	1.7032	+0.0000
0.0675	+0.0000	1.7159	+0.0000
0.0680	+0.0000	1.7286	+0.0000
0.0685	+0.0000	1.7413	+0.0000
0.0690	+0.0000	1.7540	+0.0000
0.0695	+0.0000	1.7667	+0.0000
0.0700	+0.0000	1.7794	+0.0000
0.0705	+0.0000	1.7921	+0.0000
0.0710	+0.0000	1.8048	+0.0000
0.0715	+0.0000	1.8175	+0.0000
0.0720	+0.0000	1.8302	+0.0000
0.0725	+0.0000	1.8429	+0.0000
0.0730	+0.0000	1.8556	+0.0000
0.0735	+0.0000	1.8683	+0.0000
0.0740	+0.0000	1.8810	+0.0000
0.0745	+0.0000	1.8937	+0.0000
0.0750	+0.0000	1.9064	+0.0000
0.0755	+0.0000	1.9191	+0.0000
0.0760	+0.0000	1.9318	+0.0000
0.0765	+0.0000	1.9445	+0.0000
0.0770	+0.0000	1.9572	+0.0000
0.0775	+0.0000	1.9700	+0.0000
0.0780	+0.0000	1.9827	+0.0000
0.0785	+0.0000	1.9954	+0.0000
0.0790	+0.0000	2.0081	+0.0000
0.0795	+0.0000	2.0208	+0.0000
0.0800	+0.0000	2.0335	+0.0000
0.0805	+0.0000	2.0462	+0.0000
0.0810	+0.0000	2.0589	+0.0000
0.0815	+0.0000	2.0716	+0.0000
0.0820	+0.0000	2.0843	+0.0000
0.0825	+0.0000	2.0970	+0.0000
0.0830	+0.0000	2.1100	+0.0000
0.0835	+0.0000	2.1227	+0.0000
0.0840	+0.0000	2.1354	+0.0000
0.0845	+0.0000	2.1481	+0.0000
0.0850	+0.0000	2.1608	+0.0000
0.0855	+0.0000	2.1735	+0.0000
0.0860	+0.0000	2.1862	+0.0000
0.0865	+0.0000	2.1989	+0.0000
0.0870	+0.0000	2.2116	+0.0000
0.0875	+0.0000	2.2243	+0.0000
0.0880	+0.0000	2.2370	+0.0000
0.0885	+0.0000	2.2500	+0.0000
0.0890	+0.0000	2.2627	+0.0000
0.0895	+0.0000	2.2754	+0.0000
0.0900	+0.0000	2.2881	+0.0000
0.0905	+0.0000	2.3008	+0.0000
0.0910	+0.0000	2.3135	+0.0000
0.0915	+0.0000	2.3262	+0.0000
0.0920	+0.0000	2.3389	+0.0000
0.0925	+0.0000	2.3516	+0.0000
0.0930	+0.0000	2.3643	+0.0000
0.0935	+0.0000	2.3770	+0.0000
0.0940	+0.0000	2.3900	+0.0000
0.0945	+0.0000	2.4027	+0.0000
0.0950	+0.0000	2.4154	+0.0000
0.0955	+0.0000	2.4281	+0.0000
0.0960	+0.0000	2.4408	+0.0000
0.0965	+0.0000	2.4535	+0.0000
0.0970	+0.0000	2.4662	+0.0000
0.0975	+0.0000	2.4789	+0.0000
0.0980	+0.0000	2.4916	+0.0000
0.0985	+0.0000	2.5043	+0.0000
0.0990	+0.0000	2.5170	+0.0000
0.0995	+0.0000	2.5300	+0.0000
0.1000	+0.0000	2.5427	+0.0000
0.1005	+0.0000	2.5554	+0.0000
0.1010	+0.0000	2.5681	+0.0000
0.1015	+0.0000	2.5808	+0.0000
0.1020	+0.0000	2.5935	+0.0000
0.1025	+0.0000	2.6062	+0.0000
0.1030	+0.0000	2.6189	+0.0000
0.1035	+0.0000	2.6316	+0.0000
0.1040	+0.0000	2.6443	+0.0000
0.1045	+0.0000	2.6570	+0.0000
0.1050	+0.0000	2.6700	+0.0000
0.1055	+0.0000	2.6827	+0.0000
0.1060	+0.0000	2.6954	+0.0000
0.1065	+0.0000	2.7081	+0.0000
0.1070	+0.0000	2.7208	+0.0000
0.1075	+0.0000	2.7335	+0.0000
0.1080	+0.0000	2.7462	+0.0000
0.1085	+0.0000	2.7589	+0.0000
0.1090	+0.0000	2.7716	+0.0000
0.1095	+0.0000	2.7843	+0.0000
0.1100	+0.0000	2.7970	+0.0000
0.1105	+0.0000	2.8100	+0.0000
0.1110	+0.0000	2.8227	+0.0000
0.1115	+0.0000	2.8354	+0.0000
0.1120	+0.0000	2.8481	+0.0000
0.1125	+0.0000	2.8608	+0.0000
0.1130	+0.0000	2.8735	+0.0000
0.1135	+0.0000	2.8862	+0.0000
0.1140	+0.0000</		

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.

Base Film	Resin	Gauge	Thickness	Color	Temperature Rating	Other
HN	FEP	30	0.00030	White	260° C. (500° F.)	
HN	FEP	50	0.00050	White	260° C. (500° F.)	
HN	FEP	100	0.00100	White	260° C. (500° F.)	
HN	FEP	200	0.00200	White	260° C. (500° F.)	
HN	FEP	300	0.00300	White	260° C. (500° F.)	
HN	FEP	500	0.00500	White	260° C. (500° F.)	
VN	FEP	100	0.00100	White	260° C. (500° F.)	
VN	FEP	200	0.00200	White	260° C. (500° F.)	
VN	FEP	300	0.00300	White	260° C. (500° F.)	
VN	FEP	500	0.00500	White	260° C. (500° F.)	

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.



TI-NHTSA 018184

GENERAL

INTRODUCTION

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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.

Base Film	Resin	Gauge	Thickness	Color	Notes
HN	FEP	30	0.00030	White	
HN	FEP	50	0.00050	White	
HN	FEP	100	0.00100	White	
HN	FEP	200	0.00200	White	
HN	FEP	300	0.00300	White	
HN	FEP	500	0.00500	White	
VN	FEP	100	0.00100	White	
VN	FEP	200	0.00200	White	
VN	FEP	300	0.00300	White	
VN	FEP	500	0.00500	White	

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.



TI-NHTSA 018186

PROPERTIES OF TYPE HN FILM

MECHANICAL

ELECTRICAL

the first time in the history of the world, the people of the United States have been compelled to make a choice between two political parties, each of which has a distinct and well-defined platform, and each of which has a definite and well-defined object in view. The people of the United States have been compelled to make a choice between two political parties, each of which has a distinct and well-defined platform, and each of which has a definite and well-defined object in view.

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 $8\frac{1}{2}'' \times 11''$ 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 $\pm 2^\circ\text{C}$. 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

11 hours for 30 and 40 meter DSD

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. E38505 for "Kapton" polyimide film.

*1 hour for 20 & 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 800 gms./inch except for 120FN816 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 120FN816 Film

The ability of 120FN816 film to adhere to copper is measured by using the same heat seal peel strength technique as described above.

The peel strength obtained when 120FN816 is sealed to the untreated side of $\frac{1}{4}$ oz. GT copper foil (1 mil) will be a minimum of 250 gms./in.

B. As-Received Strength (Cold Peel) of Bonds Between the Type HN "Kapton" and "Teflon" Layers

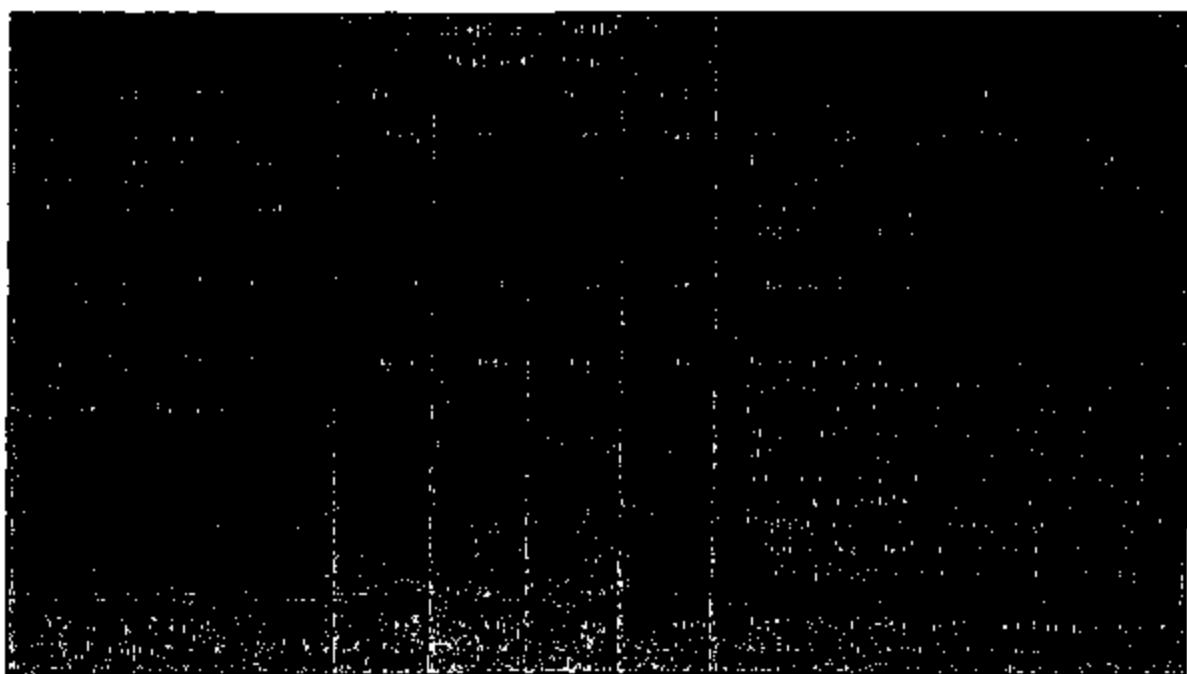
The bond between the Type HN "Kapton" and Teflon® Fluorocarbon resin layers on all type FN products except 120FN816 will have a minimum peel strength of 225 gms./in. as measured using an Instron type tensile tester and a 180° peel.

C. Dielectric Strength

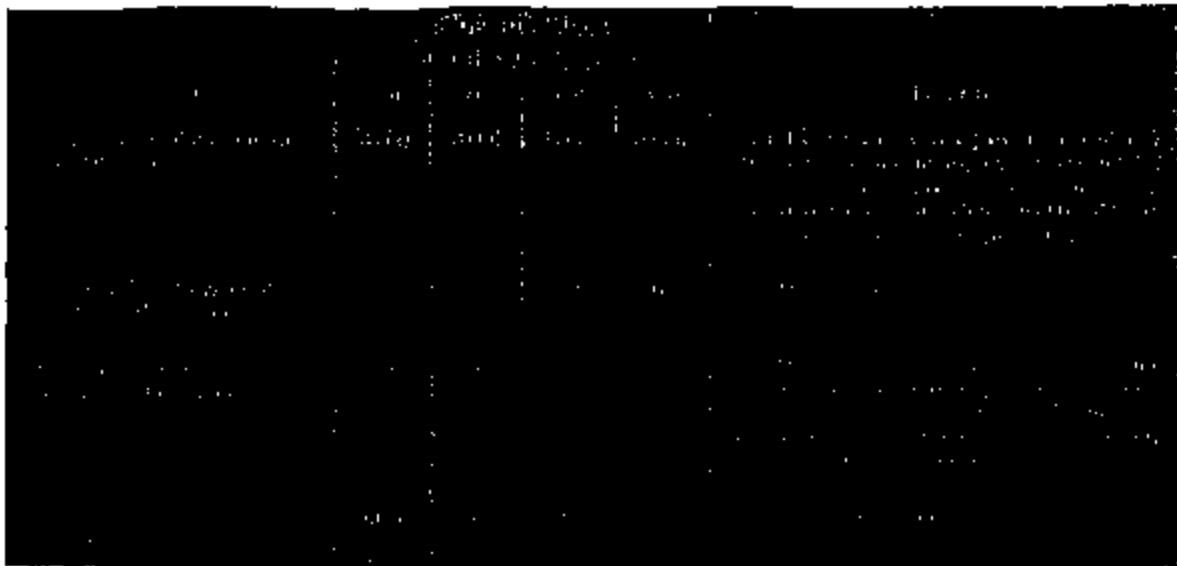


PROPERTIES OF TYPE VN FILM

MECHANICAL



ELECTRICAL



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" 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 $\pm 2^\circ\text{C}$. 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.B) 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. E38505 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

Core 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 $3.032^\circ \pm 0.008^\circ$, 6" I.D. is $6.028^\circ \pm 0.010^\circ$. Core material will be plastic for 3" I.D. cores less than $\frac{1}{2}$ " wide. Core material will be fibre for 3" I.D. cores

wider than $\frac{1}{2}$ " and 6" I.D. cores. A split 3" I.D. fibre core is standard for all universal rolls. Core width for universal wind is $2\frac{1}{4}$ ".

If these cores are not suitable, further information on other options may be obtained from your Electronics Department marketing representative.

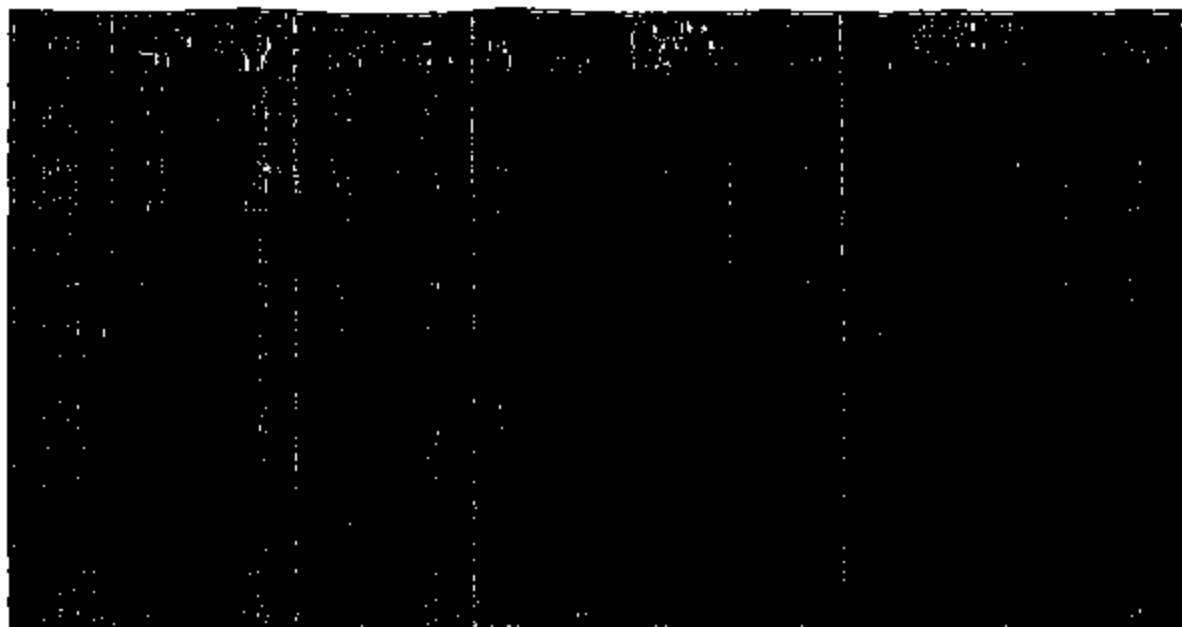
D. WIDTH TOLERANCE

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

SR# Width Range	Tolerance
1/2" or less Universal only	$\pm .7$ mils
1" or less	± 1.5 mils
1 1/2"-4"	± 3.0 mils
4 1/2" or wider	± 6.0 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.



(1) 2" x 6" pad roll is available in widths up to 14" only in 120HN1, 200HN1, 300HN1, 300HN4, 120FN019, 200FN019, 200FH019, 300FH019, 300FN019.

* O.D. Tolerance is $\pm \frac{1}{16}$ " for pads and $\pm \frac{1}{16}$ " for universal.

* Type HN, FN and VH films in pads are supplied in width increments of two. Most films are supplied in width increments of four in widths 4" to 24".

Specifications for pad rolls are:

1. Core width will be film width $\pm \frac{1}{16}$ ", -0".
2. Core edges shall not project more than $\frac{1}{16}$ " 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 $\frac{1}{16}$ " 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 $\frac{1}{16}$ ".
2. Film shall not project from the main body of the roll more than $\frac{1}{16}$ ".
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 $\frac{1}{16}$ ".
5. Width of traverse is $1\frac{3}{4}$ ", $- \frac{1}{16}$ ", $+ \frac{1}{16}$ ".

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.

* All universal rolls are available in 4" width (conformance with $\frac{1}{16}$ " maximum width). The minimum width is $\frac{1}{2}$ " for 2" x 6" O.D. x C.I.D. and minimum width is $\frac{1}{2}$ " for 3" x 6", and 3" x 12" O.D. x C.I.D..

Splines will be sufficiently smooth and wrinkle-free so as not to distort adjacent layers of film and approximately centered to $\pm \frac{1}{16}$ ".

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 $\frac{1}{2}$ " long. On 250FN029 a butt splice is made using 120FN018 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 120FN018 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 Silt 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 SPLICING FREE LENGTH (FEET)

Slit Roll Width	Minimum Average Splicing Free Length (Feet)
Up to 8"	12
Up to 10"	18
Up to 12"	24
Up to 14"	30
Up to 16"	36
Up to 18"	42
Up to 20"	48
Up to 22"	54
Up to 24"	60
Up to 26"	66
Up to 28"	72
Up to 30"	78
Up to 32"	84
Up to 34"	90
Up to 36"	96
Up to 38"	102
Up to 40"	108
Up to 42"	114
Up to 44"	120
Up to 46"	126
Up to 48"	132
Up to 50"	138
Up to 52"	144
Up to 54"	150
Up to 56"	156
Up to 58"	162
Up to 60"	168
Up to 62"	174
Up to 64"	180
Up to 66"	186
Up to 68"	192
Up to 70"	198
Up to 72"	204
Up to 74"	210
Up to 76"	216
Up to 78"	222
Up to 80"	228
Up to 82"	234
Up to 84"	240
Up to 86"	246
Up to 88"	252
Up to 90"	258
Up to 92"	264
Up to 94"	270
Up to 96"	276
Up to 98"	282
Up to 100"	288
Up to 102"	294
Up to 104"	300
Up to 106"	306
Up to 108"	312
Up to 110"	318
Up to 112"	324
Up to 114"	330
Up to 116"	336
Up to 118"	342
Up to 120"	348
Up to 122"	354
Up to 124"	360
Up to 126"	366
Up to 128"	372
Up to 130"	378
Up to 132"	384
Up to 134"	390
Up to 136"	396
Up to 138"	402
Up to 140"	408
Up to 142"	414
Up to 144"	420
Up to 146"	426
Up to 148"	432
Up to 150"	438
Up to 152"	444
Up to 154"	450
Up to 156"	456
Up to 158"	462
Up to 160"	468
Up to 162"	474
Up to 164"	480
Up to 166"	486
Up to 168"	492
Up to 170"	498
Up to 172"	504
Up to 174"	510
Up to 176"	516
Up to 178"	522
Up to 180"	528
Up to 182"	534
Up to 184"	540
Up to 186"	546
Up to 188"	552
Up to 190"	558
Up to 192"	564
Up to 194"	570
Up to 196"	576
Up to 198"	582
Up to 200"	588
Up to 202"	594
Up to 204"	600
Up to 206"	606
Up to 208"	612
Up to 210"	618
Up to 212"	624
Up to 214"	630
Up to 216"	636
Up to 218"	642
Up to 220"	648
Up to 222"	654
Up to 224"	660
Up to 226"	666
Up to 228"	672
Up to 230"	678
Up to 232"	684
Up to 234"	690
Up to 236"	696
Up to 238"	702
Up to 240"	708
Up to 242"	714
Up to 244"	720
Up to 246"	726
Up to 248"	732
Up to 250"	738
Up to 252"	744
Up to 254"	750
Up to 256"	756
Up to 258"	762
Up to 260"	768
Up to 262"	774
Up to 264"	780
Up to 266"	786
Up to 268"	792
Up to 270"	798
Up to 272"	804
Up to 274"	810
Up to 276"	816
Up to 278"	822
Up to 280"	828
Up to 282"	834
Up to 284"	840
Up to 286"	846
Up to 288"	852
Up to 290"	858
Up to 292"	864
Up to 294"	870
Up to 296"	876
Up to 298"	882
Up to 300"	888
Up to 302"	894
Up to 304"	900
Up to 306"	906
Up to 308"	912
Up to 310"	918
Up to 312"	924
Up to 314"	930
Up to 316"	936
Up to 318"	942
Up to 320"	948
Up to 322"	954
Up to 324"	960
Up to 326"	966
Up to 328"	972
Up to 330"	978
Up to 332"	984
Up to 334"	990
Up to 336"	996
Up to 338"	1002
Up to 340"	1008
Up to 342"	1014
Up to 344"	1020
Up to 346"	1026
Up to 348"	1032
Up to 350"	1038
Up to 352"	1044
Up to 354"	1050
Up to 356"	1056
Up to 358"	1062
Up to 360"	1068
Up to 362"	1074
Up to 364"	1080
Up to 366"	1086
Up to 368"	1092
Up to 370"	1098
Up to 372"	1104
Up to 374"	1110
Up to 376"	1116
Up to 378"	1122
Up to 380"	1128
Up to 382"	1134
Up to 384"	1140
Up to 386"	1146
Up to 388"	1152
Up to 390"	1158
Up to 392"	1164
Up to 394"	1170
Up to 396"	1176
Up to 398"	1182
Up to 400"	1188
Up to 402"	1194
Up to 404"	1200
Up to 406"	1206
Up to 408"	1212
Up to 410"	1218
Up to 412"	1224
Up to 414"	1230
Up to 416"	1236
Up to 418"	1242
Up to 420"	1248
Up to 422"	1254
Up to 424"	1260
Up to 426"	1266
Up to 428"	1272
Up to 430"	1278
Up to 432"	1284
Up to 434"	1290
Up to 436"	1296
Up to 438"	1302
Up to 440"	1308
Up to 442"	1314
Up to 444"	1320
Up to 446"	1326
Up to 448"	1332
Up to 450"	1338
Up to 452"	1344
Up to 454"	1350
Up to 456"	1356
Up to 458"	1362
Up to 460"	1368
Up to 462"	1374
Up to 464"	1380
Up to 466"	1386
Up to 468"	1392
Up to 470"	1398
Up to 472"	1404
Up to 474"	1410
Up to 476"	1416
Up to 478"	1422
Up to 480"	1428
Up to 482"	1434
Up to 484"	1440
Up to 486"	1446
Up to 488"	1452
Up to 490"	1458
Up to 492"	1464
Up to 494"	1470
Up to 496"	1476
Up to 498"	1482
Up to 500"	1488
Up to 502"	1494
Up to 504"	1500
Up to 506"	1506
Up to 508"	1512
Up to 510"	1518
Up to 512"	1524
Up to 514"	1530
Up to 516"	1536
Up to 518"	1542
Up to 520"	1548
Up to 522"	1554
Up to 524"	1560
Up to 526"	1566
Up to 528"	1572
Up to 530"	1578
Up to 532"	1584
Up to 534"	1590
Up to 536"	1596
Up to 538"	1602
Up to 540"	1608
Up to 542"	1614
Up to 544"	1620
Up to 546"	1626
Up to 548"	1632
Up to 550"	1638
Up to 552"	1644
Up to 554"	1650
Up to 556"	1656
Up to 558"	1662
Up to 560"	1668
Up to 562"	1674
Up to 564"	1680
Up to 566"	1686
Up to 568"	1692
Up to 570"	1698
Up to 572"	1704
Up to 574"	1710
Up to 576"	1716
Up to 578"	1722
Up to 580"	1728
Up to 582"	1734
Up to 584"	1740
Up to 586"	1746
Up to 588"	1752
Up to 590"	1758
Up to 592"	1764
Up to 594"	1770
Up to 596"	1776
Up to 598"	1782
Up to 600"	1788
Up to 602"	1794
Up to 604"	1800
Up to 606"	1806
Up to 608"	1812
Up to 610"	1818
Up to 612"	1824
Up to 614"	1830
Up to 616"	1836
Up to 618"	1842
Up to 620"	1848
Up to 622"	1854
Up to 624"	1860
Up to 626"	1866
Up to 628"	1872
Up to 630"	1878
Up to 632"	1884
Up to 634"	1890
Up to 636"	1896
Up to 638"	1902
Up to 640"	1908
Up to 642"	1914
Up to 644"	1920
Up to 646"	1926
Up to 648"	1932
Up to 650"	1938
Up to 652"	1944
Up to 654"	1950
Up to 656"	1956
Up to 658"	1962
Up to 660"	1968
Up to 662"	1974
Up to 664"	1980
Up to 666"	1986
Up to 668"	1992
Up to 670"	1998
Up to 672"	2004
Up to 674"	2010
Up to 676"	2016
Up to 678"	2022
Up to 680"	2028
Up to 682"	2034
Up to 684"	2040
Up to 686"	2046
Up to 688"	2052
Up to 690"	2058
Up to 692"	2064
Up to 694"	2070
Up to 696"	2076
Up to 698"	2082
Up to 700"	2088
Up to 702"	2094
Up to 704"	2100
Up to 706"	2106
Up to 708"	2112
Up to 710"	2118
Up to 712"	2124
Up to 714"	2130
Up to 716"	2136
Up to 718"	2142
Up to 720"	2148
Up to 722"	2154
Up to 724"	2160
Up to 726"	2166
Up to 728"	2172
Up to 730"	2178
Up to 732"	2184
Up to 734"	2190
Up to 736"	2196
Up to 738"	2202
Up to 740"	2208
Up to 742"	2214
Up to 744"	2220
Up to 746"	2226
Up to 748"	2232
Up to 750"	2238
Up to 752"	2244
Up to 754"	2250
Up to 756"	2256
Up to 758"	2262
Up to 760"	2268
Up to 762"	2274
Up to 764"	2280
Up to 766"	2286
Up to 768"	2292
Up to 770"	2298
Up to 772"	2304
Up to 774"	2310
Up to 776"	2316
Up to 778"	2322
Up to 780"	2328
Up to 782"	2334
Up to 784"	2340
Up to 786"	2346
Up to 788"	2352
Up to 790"	2358
Up to 792"	2364
Up to 794"	2370
Up to 796"	2376
Up to 798"	2382
Up to 800"	2388
Up to 802"	2394
Up to 804"	2400
Up to 806"	2406
Up to 808"	2412
Up to 810"	2418
Up to 812"	2424
Up to 814"	2430
Up to 816"	2436
Up to 818"	2442
Up to 820"	2448
Up to 822"	2454
Up to 824"	2460
Up to 826"	2466
Up to 828"	2472
Up to 830"	2478
Up to 832"	2484
Up to 834"	2490
Up to 836"	2496
Up to 838"	2502
Up to 840"	2508
Up to 842"	2514
Up to 844"	2520
Up to 846"	2526
Up to 848"	2532
Up to 850"	2538
Up to 852"	2544
Up to 854"	2550
Up to 856"	2556
Up to 858"	2562
Up to 860"	2568
Up to 862"	2574
Up to 864"	2580
Up to 866"	2586
Up to 868"	2592
Up to 870"	2598
Up to 872"	2604
Up to 874"	2610
Up to 876"	2616
Up to 878"	2622
Up to 880"	2628
Up to 882"	2634
Up to 884"	2640
Up to 886"	2646
Up to 888"	2652
Up to 890"	2658
Up to 892"	2664
Up to 894"	2670
Up to 896"	2676
Up to 898"	2682
Up to 900"	2688
Up to 902"	2694
Up to 904"	2700
Up to 906"	2706
Up to 908"	2712
Up to 910"	2718
Up to 912"	2724
Up to 914"	2730
Up to 916"	2736
Up to 918"	2742
Up to 920"	2748
Up to 922"	2754
Up to 924"	2760
Up to 926"	2766
Up to 928"	2772
Up to 930"	2778
Up to 932"	2784
Up to 934"	2790

H. MICROMETER THICKNESS

Thickness tolerances are based on a statistical analysis of routine process control data.



*Applies to Type VH films only.



TABLE II
KAPTON® POLYIMIDE FILM GAUGE DEPRESSION STANDARDS—PAD ROLLS
(Maximum allowable depression in $\frac{1}{16}$ " increments)

Pad Roll Width	Maximum Allowable Depression	
	1"	2"
1"	0.000	0.000
2"	0.000	0.000
3"	0.000	0.000
4"	0.000	0.000
5"	0.000	0.000
6"	0.000	0.000
7"	0.000	0.000
8"	0.000	0.000
9"	0.000	0.000
10"	0.000	0.000
12"	0.000	0.000
14"	0.000	0.000
16"	0.000	0.000
18"	0.000	0.000
20"	0.000	0.000
22"	0.000	0.000
24"	0.000	0.000
26"	0.000	0.000
28"	0.000	0.000
30"	0.000	0.000
32"	0.000	0.000
34"	0.000	0.000
36"	0.000	0.000
38"	0.000	0.000
40"	0.000	0.000
42"	0.000	0.000
44"	0.000	0.000
46"	0.000	0.000
48"	0.000	0.000
50"	0.000	0.000
52"	0.000	0.000
54"	0.000	0.000
56"	0.000	0.000
58"	0.000	0.000
60"	0.000	0.000
62"	0.000	0.000
64"	0.000	0.000
66"	0.000	0.000
68"	0.000	0.000
70"	0.000	0.000
72"	0.000	0.000
74"	0.000	0.000
76"	0.000	0.000
78"	0.000	0.000
80"	0.000	0.000
82"	0.000	0.000
84"	0.000	0.000
86"	0.000	0.000
88"	0.000	0.000
90"	0.000	0.000
92"	0.000	0.000
94"	0.000	0.000
96"	0.000	0.000
98"	0.000	0.000
100"	0.000	0.000

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 $\frac{1}{4}$ " wide.

Kapton

POLYIMIDE FILM

Technical Data Sheet - Adhesive Coatings

ADHESION TO KAPTON®

KAPTON® polyimide film, made only by DuPont, 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-72007, "Summary of Properties." Specifications are found in Bulletin E-87824, "Industry Specifications Bulletin FC-85-2." For flexible printed circuit applications the trade specification IPC-PC-221/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-72001, "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-PC-241
- British: BS-4884
- 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, butyl-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 I

Adhesive Type	Lamination Temperatures °F (°C)	Maximum Operating Temperature °F (°C)
Fluorocarbons	550-600 (280-315)	to 600 (280)
Polyimides	600-700 (280-370)	to 650 (345)
Epoxy	73-450 (-23-230)	to 600 (315)
Pressure Sensitive		
Silicones	73-300 (-23-150)	to 500 (280)
Rubber-Phenolics	300-400 (180-205)	to 600 (280)
Acrylics	350-375 (175-190)	to 550 (290)
Polyesters	275-300 (135-160)	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.



TI-NHTSA 018192

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:



- (b) Affixed to the cones on all cores, 2½" wide and over. Included with the package on all cores less than 2½" wide.
 (c) Inside diameter of core and nominal outside diameter of ret.
 (d) Available for use in 12 characters.

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Kapton

for innovative solutions to extreme-temperature,
design engineering problems.



TI-NHTSA 01B198

DYNATEX No. 3
04313



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 DuPont 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 elec-

tronics 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 TEFILON® 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 DuPont 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-NHTSA 018197

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 DuPont 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 elec-

tronics 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 TEFILON® 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 customized to fit an almost endless variety of applications.

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TI-NHTSA 018198

LINASER space shuttle took off at the top of the weightlessness, neither aches and fatigue, and
with full life, with the potential of permanent stay in space,
referred to as "the life of the organization" in the walls of the shuttle.

The design of the shuttle is very good, and the 177
cubic meter payload can be used for such
as the first stage of the space station or the second
stage of the space station.

In addition, the flight of the space shuttle
is not limited by the size of the cargo, but
by the weight of the cargo. Space equipment, it is planned
to be the flight of the first stage of the station or the second
stage of the space station.

The first stage of the space station is the first stage of the station
and the second stage of the space station, and the third stage of the station
is the third stage of the space station, and the fourth stage of the station
is the fourth stage of the space station, and the fifth stage of the station
is the fifth stage of the space station.

The flight of the space station is very good, and the
first stage of the space station is the first stage of the station
and the second stage of the space station, and the third stage of the station
is the third stage of the space station.

The second stage of the space station is the second stage of the station
and the third stage of the space station, and the fourth stage of the station
is the fourth stage of the space station.



TI-NHTSA 018199

DO-NHTSA No. 3
00316

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 complicated 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-NHTSA 018200

DIVNHTSA No. 3
00317



TI-NHTSA 018201

DOVETSA No. 3
0018

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 tensile 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.

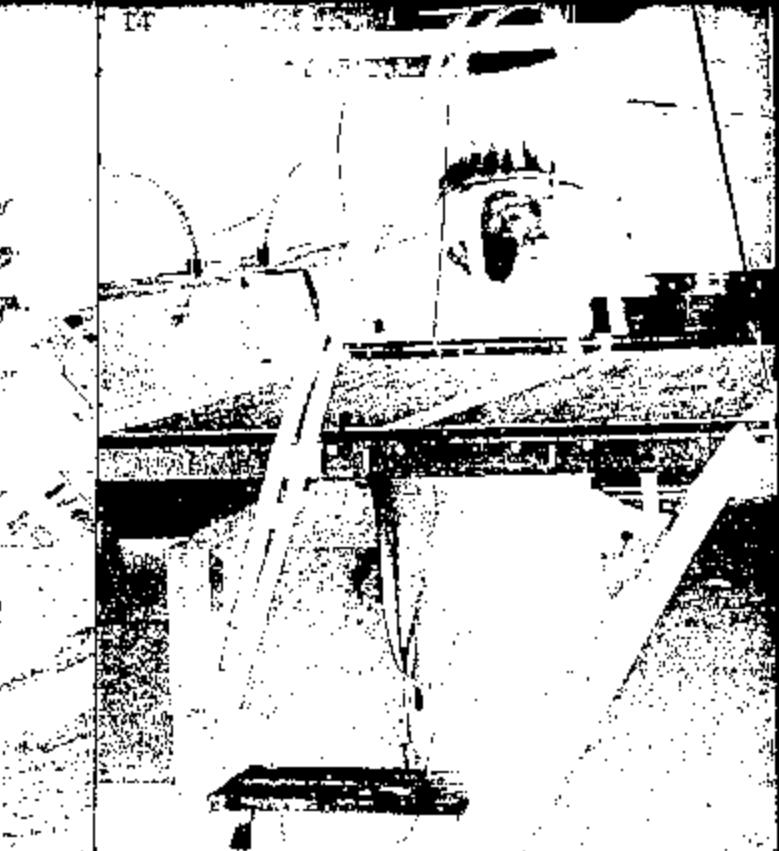
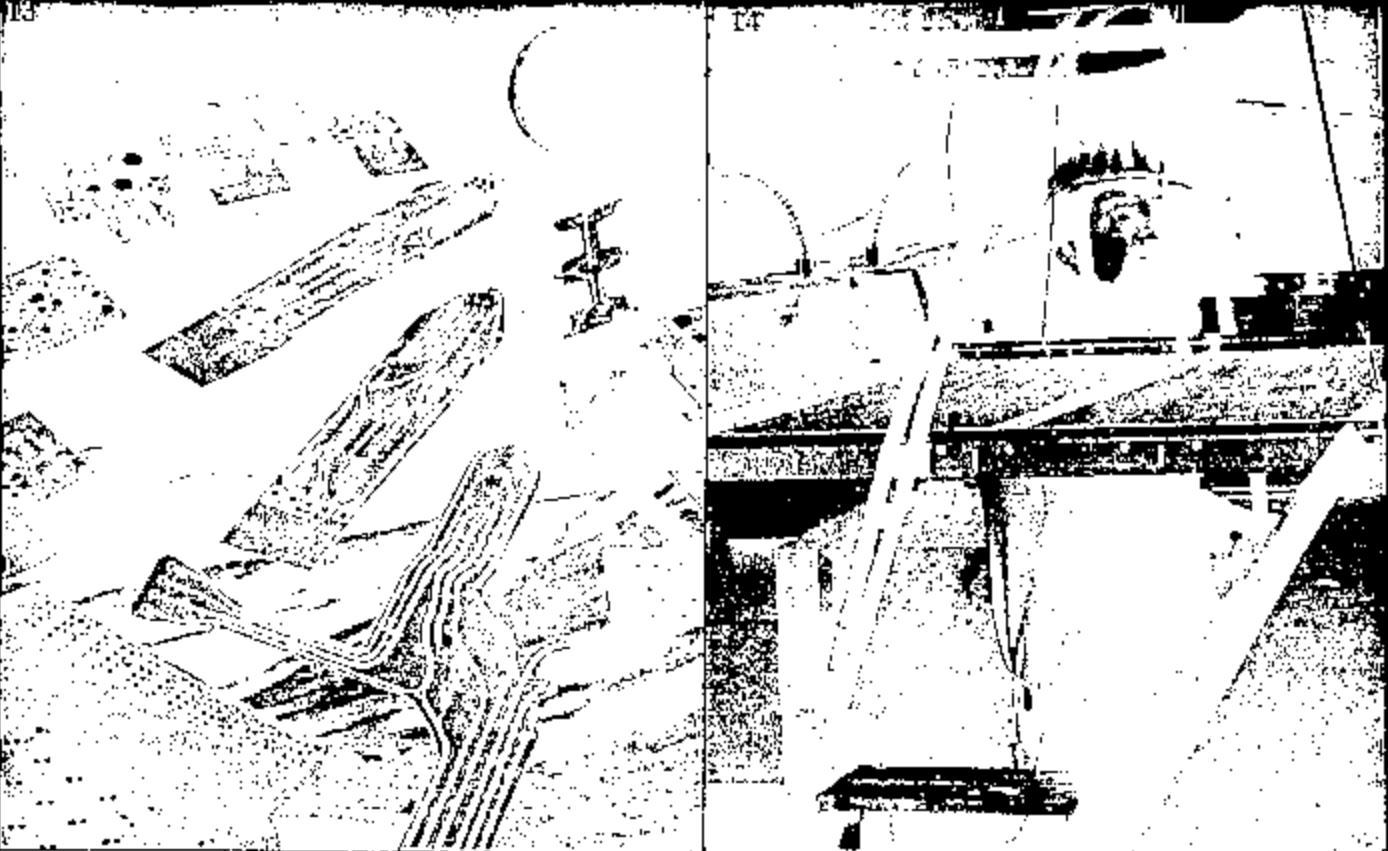


13. Flexible circuits of KAPTON can be bent, coiled, folded or twisted — and remain that way for the life of the product — without impairing circuit integrity while offering additional design freedom.

14. KAPTON protects plenum cables from damage by abrading, kinking and snapping during installation when it is "bashed" over sharp places in plenum 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.



DD/NHTSA No. 3
00329

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.



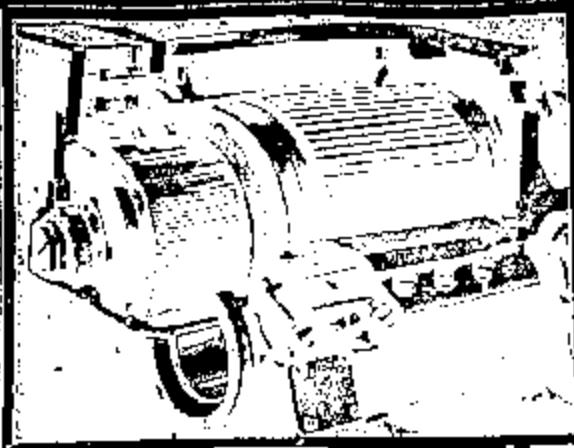
17. This electric locomotive, equipped with 3,000 volt DC traction motors, uses KAPTON Type F as an insulation on its motor windings. The KAPTON permitted an 8% increase in power over the conventional insulation material it replaced.

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.

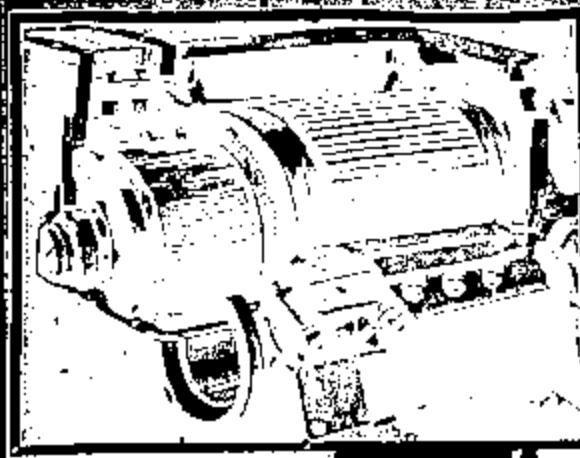
19. The elongation of KAPTON polyimide film is such that magnet wire insulated with KAPTON Type F sealable film can be easily bent to the desired shape without creating air gaps in the insulation, which could lead to dielectric failure or "hot spots".

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 substation in locations where real estate is at a premium.

TI-NHTSA 018204



NHTSA No. 3
06322



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TI-NHTSA 018206



DD/NHTSA No. 3
46323

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 10⁶ 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 etching 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.

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.

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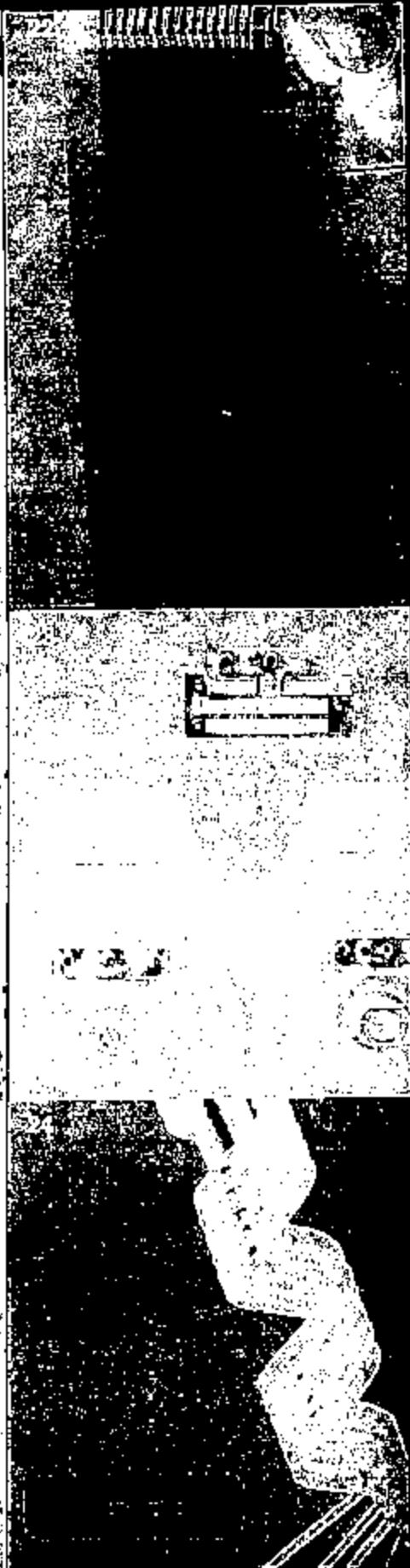
TI-NHTSA 018208

DD/NHTSA No. 3
00328



DDM-NHTSA No. 3
09326

TI-NHTSA 018209



Kapton®... only from Du Pont

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DDMHNTSA No. 3
66327

TI-NHTSA 018210

Kopto

POLYACRYLIC FILM



TI-NHTSA 018211

NHTSA No. 3
48180

Kapton®

Summary of Properties

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TI-NHTSA 018212



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 bi-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 temperature that makes KAPTON a unique industrial material.

DuPont 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 -250°C (-423°F) and as high as 400°C (752°F). Type HN film can be laminated, metallized, punched, foamed, or adhesive coated. It is available as 0.8, 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 TEPLOC™ FRP fluorocarbon resin to impart heat stability, 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 DuPont representative for specification purposes.

*Reg. U.S. Pat. Off.

TI-NHTSA 018213

PHYSICAL & THERMAL PROPERTIES

LEMPER: Temperatura de fusão (derretimento) para polímero. É o ponto em que o material se funde.
COP: Coeficiente de expansão linear. Relaciona a variação de temperatura com a variação de comprimento. É a razão entre a variação de comprimento e a variação de temperatura. O resultado é sempre positivo.
GAMA DE FUSÃO: Intervalo de temperatura entre o ponto de derretimento e o ponto de fundição. É a diferença entre a fusão (235°C) e o ponto de fundição (171°C).

INMETRA No. 3
MIR

TI-NHTSA 018214

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

PHYSICAL PROPERTIES

PHYSICAL PROPERTIES	TYPICAL VALUES		TEST METHOD
	20°C (68°F)	200°C (392°F)	
Ultimate Tensile (MD)	231	139	ASTM D-882-62, Method A ¹
Strength, MPa (psi)	(33,800)	(30,000)	
Yield Point (MD) at 3%, MPa (psi)	89 (13,000)	41 ° (6,000)	ASTM D-882-61
Stress to Produce (MD)	90	61	ASTM D-882-61
5% Elongation, MPa (psi)	(13,000)	(1,000)	
Ultimate Elongation (MD), %	72	63	ASTM D-882-61
Tensile Modulus, GPa (MD) (psi)	3.5 (370,000)	3.0 (300,000)	ASTM D-882-61
Impact Strength, Kgm/cm (ft-lb)	9 (20)		Du Pont Pneumatic Impact Test
Folding Endurance (MD), cycles	250,000		ASTM D-2176-65 (1982)
Tear Strength (MD) - Propagating (Kilobond), g	7		ASTM D-2823-67 (1978)
Tear Strength (MD) - Initial (Creased), g	720		ASTM D-2004-65 (1981)
Density, g/cm ³	1.43		ASTM D-1505-68 (1970)
Coefficient of Friction - Kinetic [Film-to-Film]	.48		ASTM D-1894-78
Coefficient of Friction - Static [Film-to-Film]	.58		ASTM D-1894-78
Refractive Index (Becke Line)	1.66		ASTM D-545-60 (1977)
Poisson's Ratio	.34		Avg. 3 Samples Elongated at 5%, 7%, 10%
Low Temperature Flex. Life (MD) - Machine Direction	Pass		IPC TM-650, Method 2.6.1A
Thickness (25 ± 5) µm (0.001 ± 0.0002 in) Expansion Factor (1") per Spec. Thickness (0") along direction due to the tensile strength and elongation measured at 100°C.			

THERMAL PROPERTIES

THERMAL PROPERTIES	TYPICAL VALUES	TEST CONDITION	TEST METHOD
Melting Point	NONE		ASTM E-784-61
Thermal Coefficient of Expansion	20 ppm/°C (11 ppm/°F)	-14 to 200°C (7 to 392°F)	ASTM D-696-78
Coefficient of Thermal Conductivity, W/m-K $\frac{W}{cm \cdot K} \times 10^3$	0.12	200°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 (24-05)
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-2853-77
Solder Flux	Pass		IPC TM-650, Method 2.4.13A
Smoke Generation	DM = less than 1	NBS Smoke Chamber	NFPA-285
Glass Transition Temperature (Tg)	A second order transition occurs in KAPTON between 300°C (560°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 μ m (1 mil)	50 μ m (2 mil)	75 μ m (3 mil)	125 μ m (5 mil)	
Ultimate Tensile Strength (MD), MPa Kpsi	231 (33,000)	234 (34,000)	231 (33,000)	231 (33,000)	ASTM D-638-63
Ultimate Elongation (MD), %	72	63	52	52	ASTM D-638-63
Tear Strength (MD) (Initial) Grams, g	720	1020	2051	4700	ASTM D-1004-66 (1961)
Tear Strength (MD) (Propagating) Elbowload, g	7	21	39	59	ASTM D-1022-67 (1970)
Folding Endurance (MT), K cycles	200	30	5	5	ASTM D-2176-68 (1968)
Density, g/cm ³	1.42	1.42	1.42	1.42	ASTM D-1505-68 (1970)
Flameability	94V-0	94V-0	94V-0	94V-0	UL94
Shrinkage, %	0.03	0.03	0.03	0.03	IPC TM-650 Method 2.2.4A
Limiting Oxygen Index, %	37	43	45	45	ASTM D-2857-77

KAPTON® Type FN Film

PROPERTIES OF FILM TYPES

PROPERTY	TYPICAL VALUES FOR FILM TYPE*		
	125FN016	150FN018	225FN025
Ultimate Tensile Strength (MD), MPa (psi)			
23°C (73°F)	207 (30,000)	182 (25,500)	303 (29,000)
200°C (392°F)	121 (17,500)	89 (13,000)	115 (17,000)
Yield Point at 3% (MD), MPa (psi)			
23°C (73°F)	21 (3,000)	49 (7,000)	56 (8,000)
200°C (392°F)	42 (6,000)	43 (6,000)	55 (8,000)
Stress at 5% Elongation (MD), MPa (psi)			
23°C (73°F)	79 (11,500)	65 (9,500)	76 (11,000)
200°C (392°F)	83 (12,000)	62 (8,000)	48 (7,000)
Ultimate Elongation (MD), %			
23°C (73°F)	76	70	65
200°C (392°F)	20	76	110
Tensile Modulus (MD), GPa (psi)			
23°C (73°F)	2.80 (415,000)	2.28 (320,000)	2.82 (380,000)
200°C (392°F)	1.62 (235,000)	1.14 (165,000)	1.28 (200,000)
Impact Strength at 23°C (73°F)			
Kg-cm (lb-in)	8 (.59)	7 (.51)	18 (1.18)
Tear Strength (MD) - Initial (Grams)			
g (lb)	1,200 (2.6)	1,175 (2.6)	1,515 (4.0)
Tear Strength (MD) - Propagating (Elbowload)			
g (lb)	8 (.12)	45 (.11)	66 (.13)
Weight % Polyimide	80	57	73
Weight % PTFE	20	43	27
Density, g/cm ³	1.53	1.57	1.57

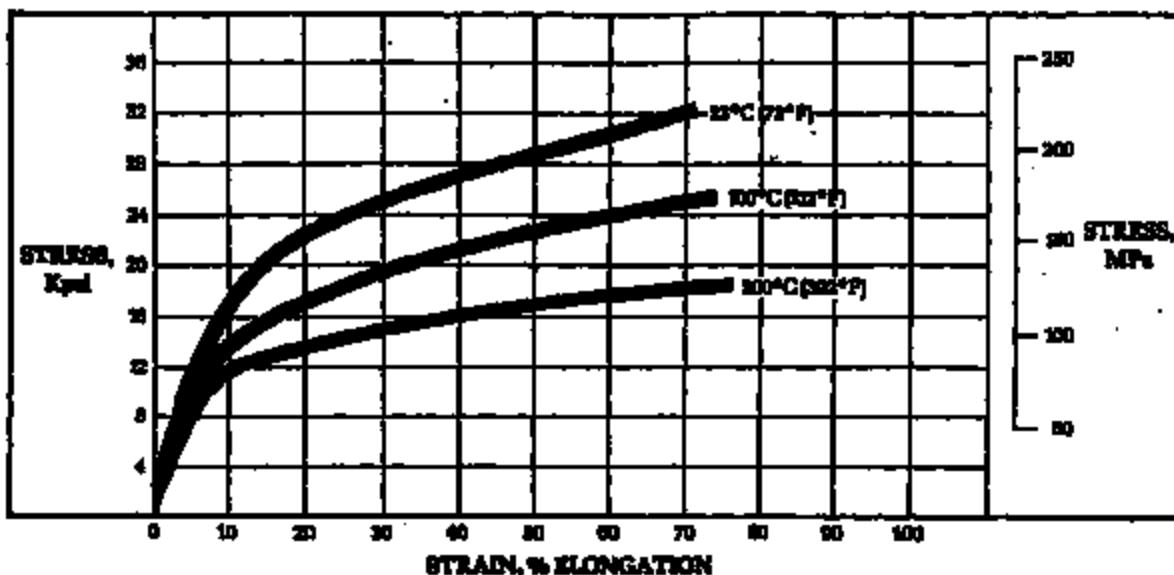
*Since a number of combinations of polyimide film and fluorocarbon coating add up to the same total gauge, it is necessary to distinguish among them. A three-digit system is used in which the middle digit represents the nominal thickness of the base KAPTON film in mils. The first and third digits represent the coating thickness of the TEFILON® PTFE fluorocarbon resin in mils. The symbol 8 is used to represent 25 μ m (.001 in) and 6 to represent 2.5 μ m (.010 in). Example 125FN016 is a 125-gauge structure consisting of a 25 μ m (.001 in) base film with a 2.5 μ m (.010 in) coating of TEFILON on each side. See page 24 for construction explanation.

MECHANICAL PROPERTIES

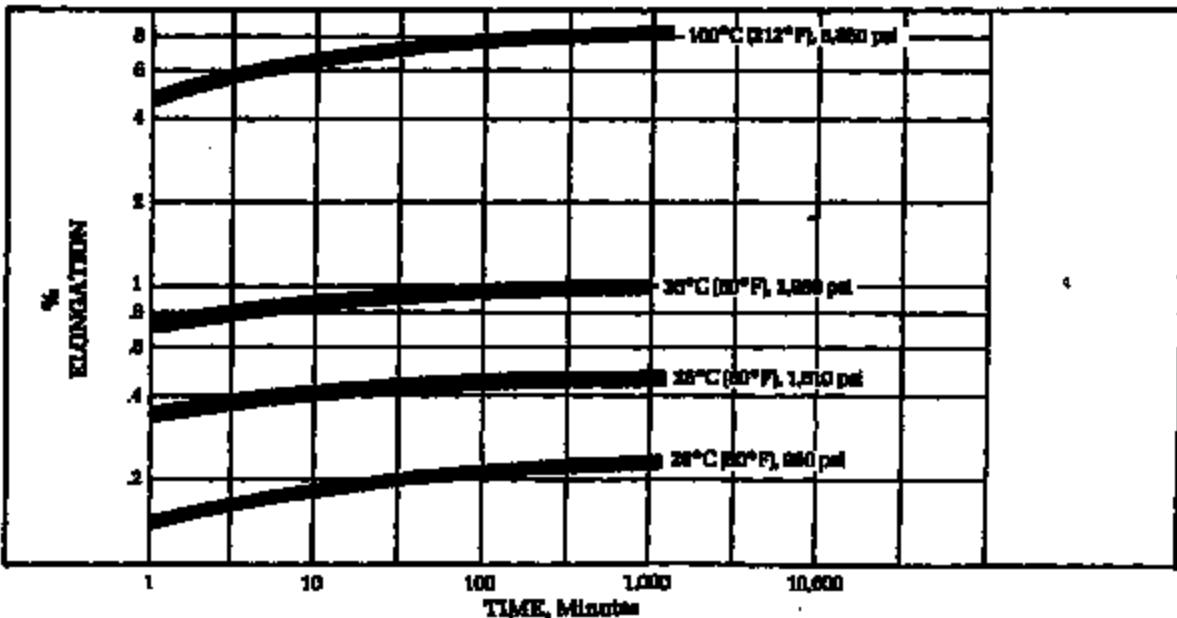
The usual values of tensile strength, tensile modulus, and ultimate elongation at various temperatures can be obtained from the typical stress-strain curves shown below. Such properties as tensile strength and modulus have an inverse relation with temperature, while elongation peaks to a maximum value at about 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, 26 µm (1 mil))



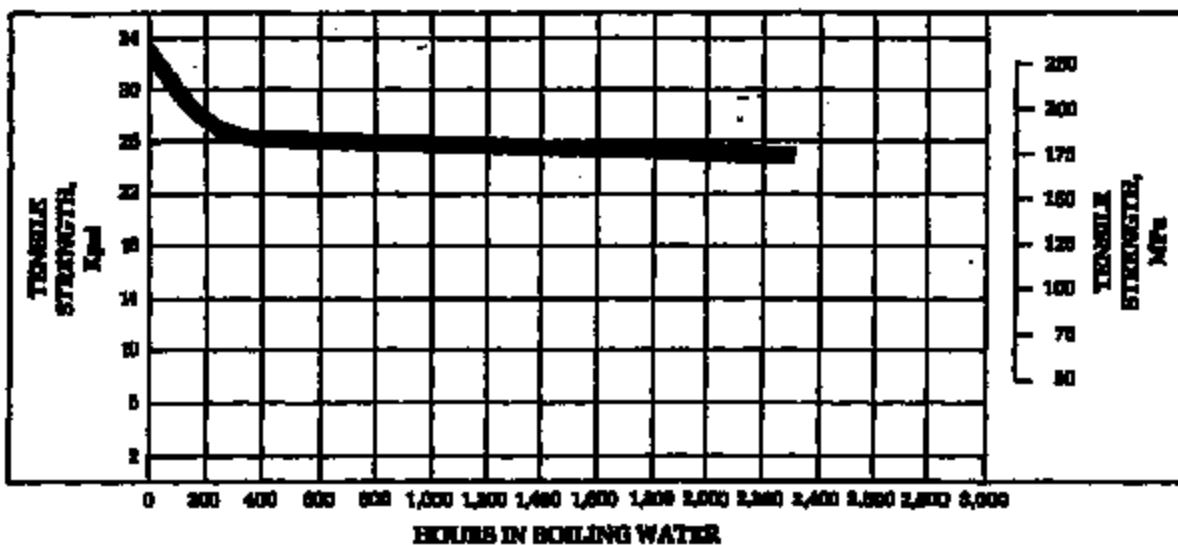
TENSILE CREEP PROPERTIES



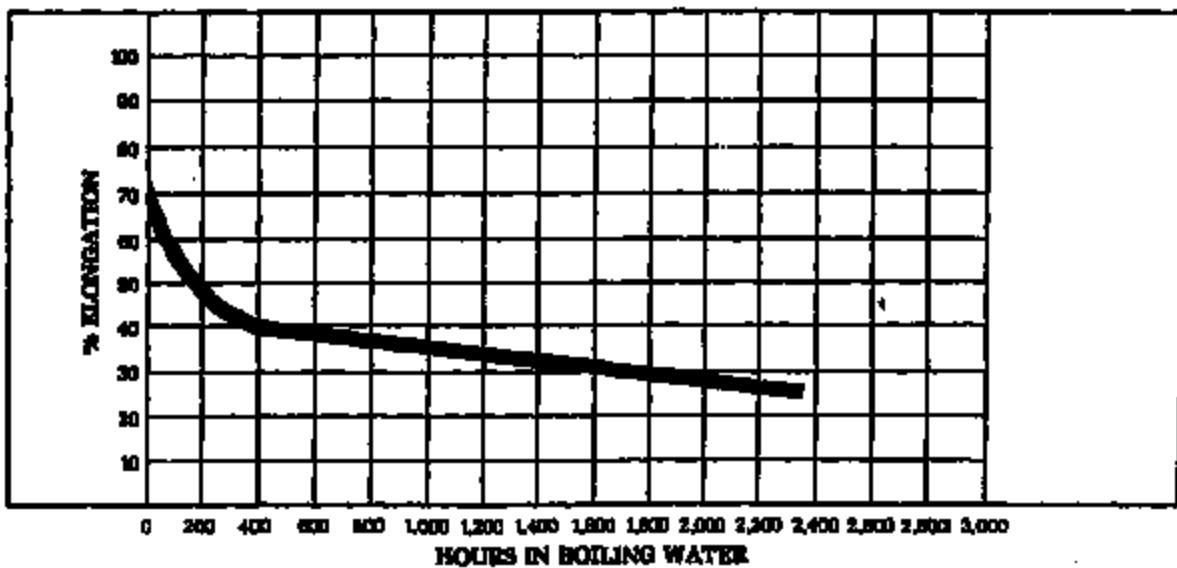
HYDROLYTIC STABILITY

KAPTON® polyimide film is made by a condensation reaction; therefore, its properties are affected by water. Although long-term exposure to boiling water, as shown in the curves below, will reduce the level of film properties, sufficient tensile and elongation remains 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))



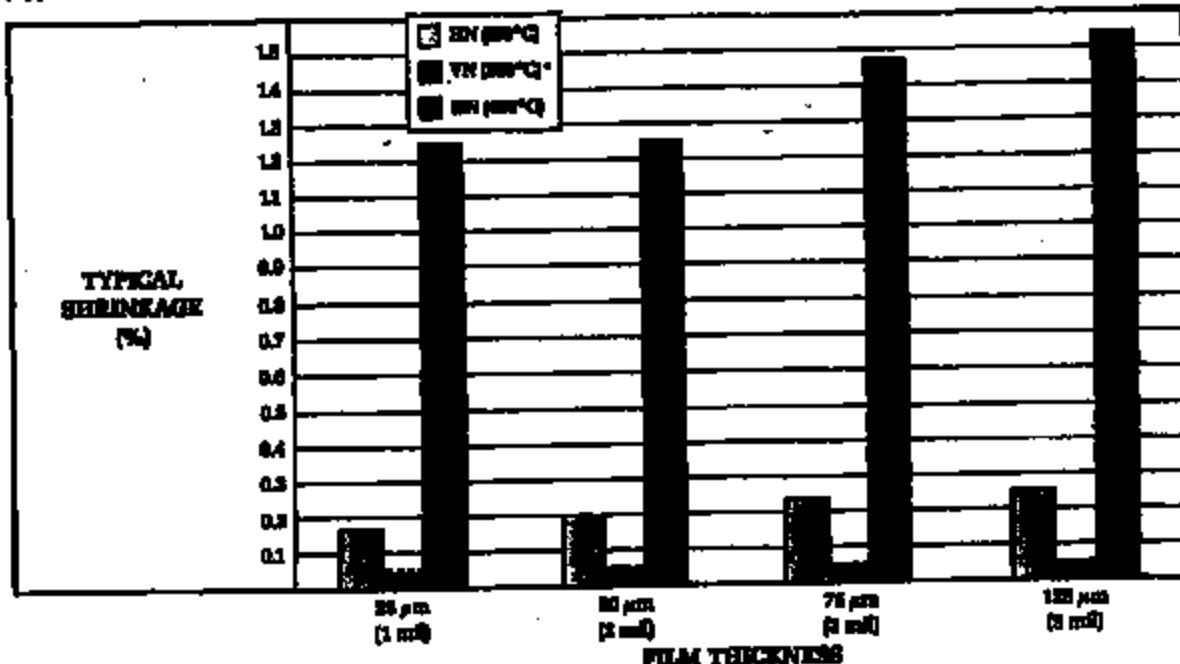
TI-NHTSA 018218

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 0.20% for all thicknesses.

THERMAL COEFFICIENT OF EXPANSION

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

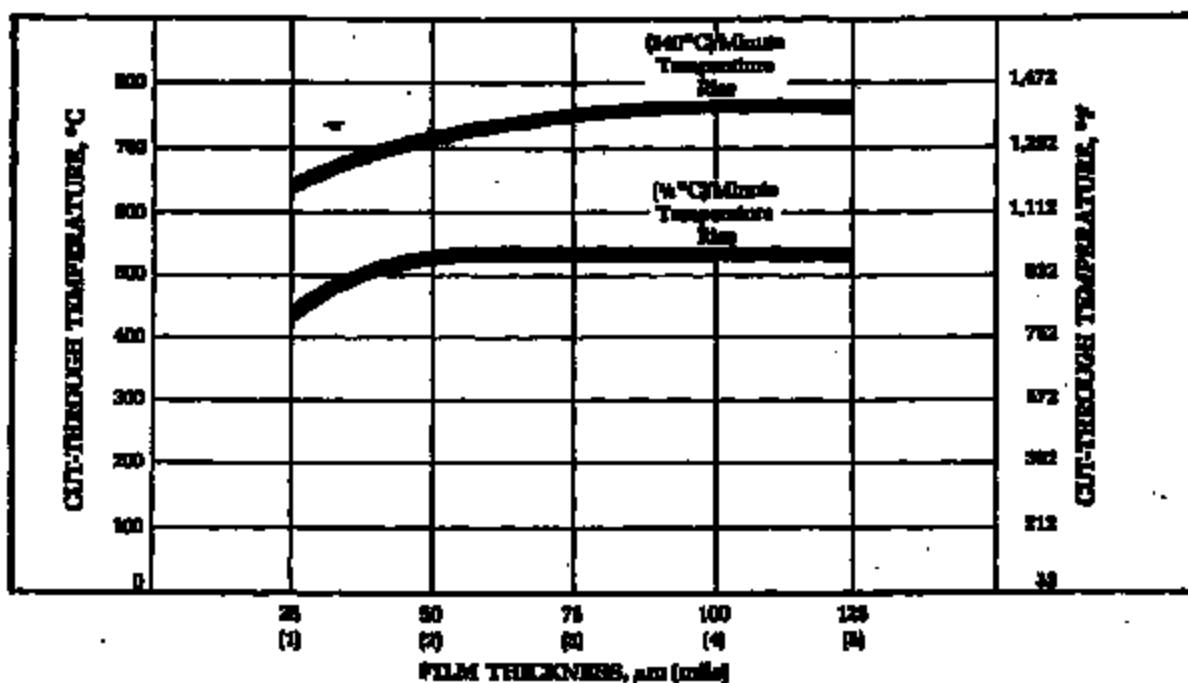
Temperature Range	ppm/°C
25-100°C (73-212°F)	15
100-200°C (212-392°F)	31
200-300°C (392-572°F)	45
300-400°C (572-752°F)	75
25-400°C (73-752°F)	48

TI-NHTSA 01B218

CUT-THROUGH RESISTANCE

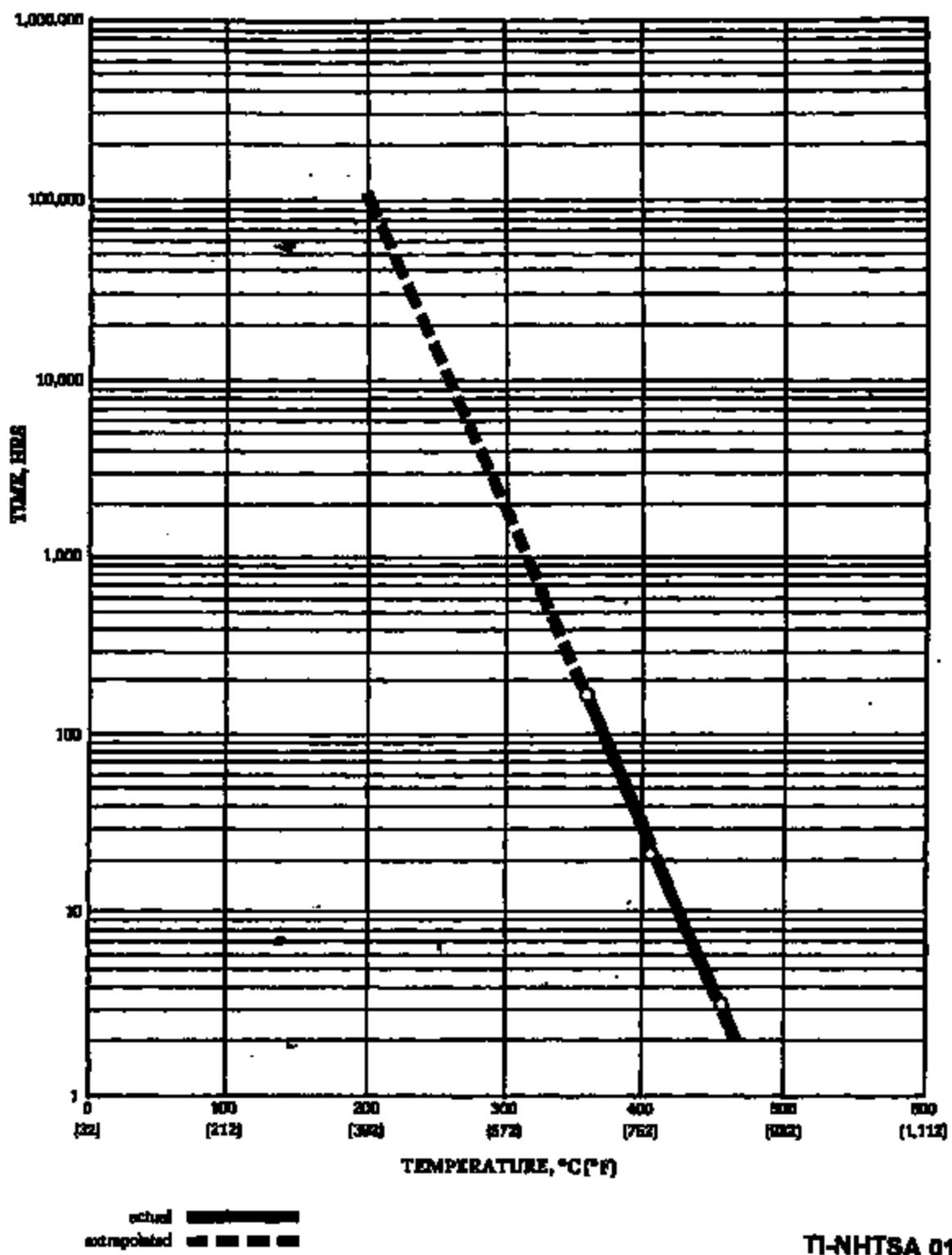
Most organic films exhibit a tendency to flow or thin out under high compressive stresses, especially at elevated temperatures. KAPTON® polyimide film possesses an extremely high resistance to such stresses. Test procedures described in ASTM D-376-60 have been adapted to flat film to provide the data below. Stress ranges from an infinitely high point load to 63 MPa (9,000 psi) at cut-through for a 25 μ m (1 mil) film.

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



TI-NHTSA 018220

RESISTANCE TO CUT-THROUGH VS. TEMPERATURE
(Type HN Film, 25 μ m (1 mil))



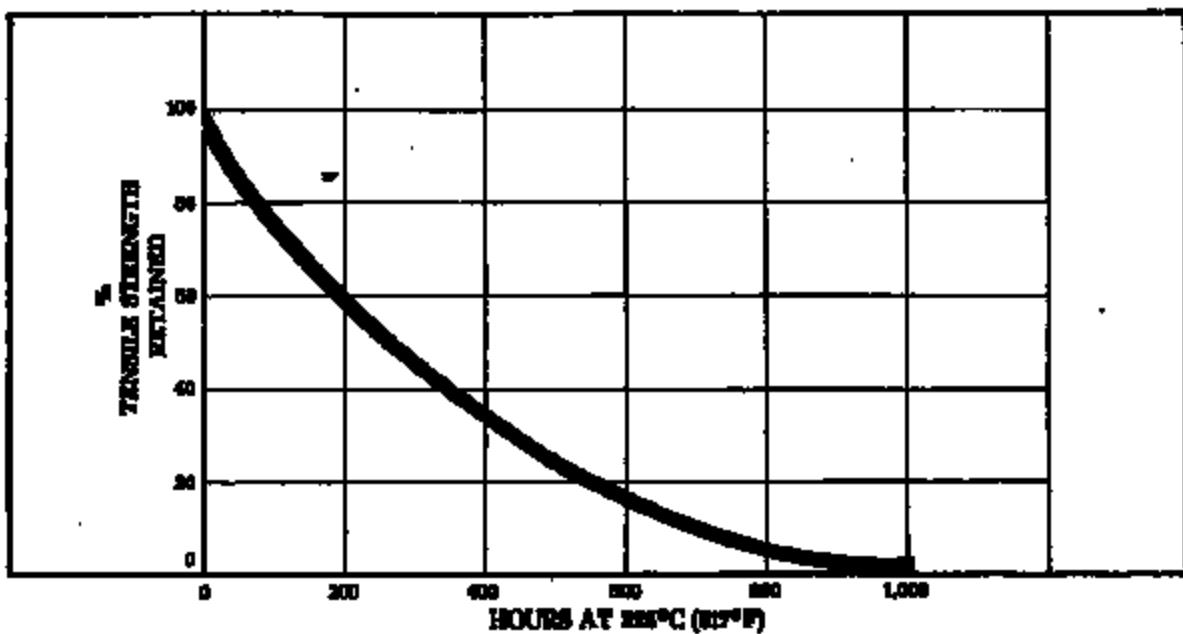
TI-NHTSA 018221

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 67 percent. The results are graphed below.

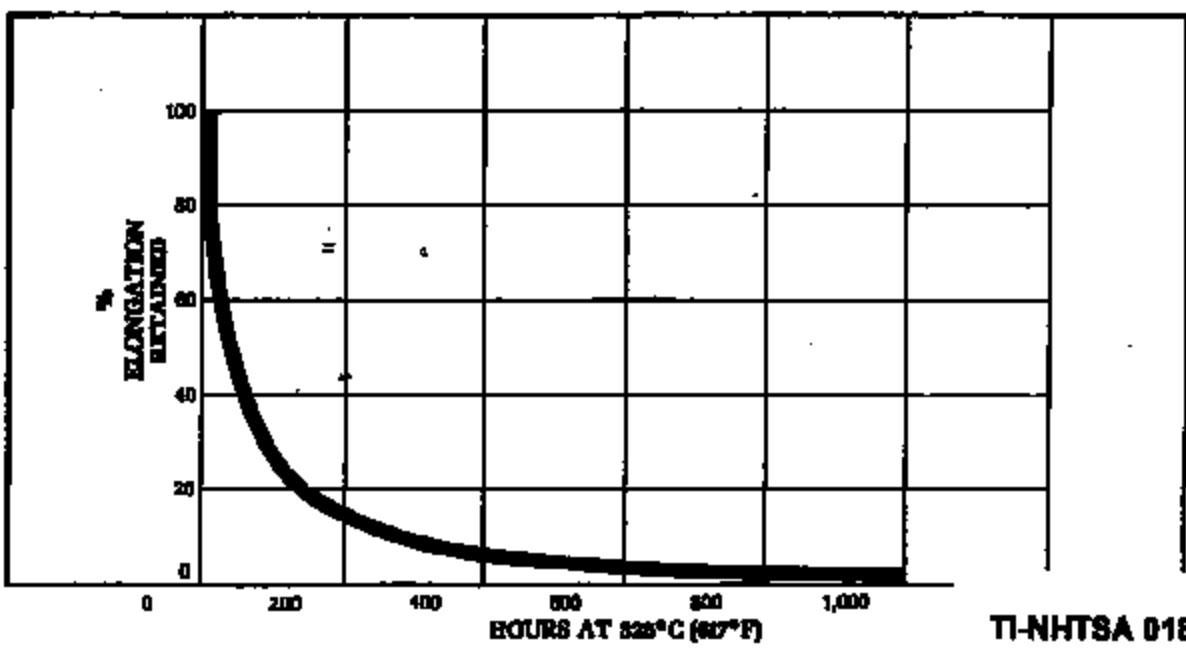
TENSILE STRENGTH VS. AGING IN AIR AT 325°C (617°F)

(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])



TI-NHTSA 018222

TIME REQUIRED FOR REDUCTION IN ULTIMATE ELONGATION FROM 70% TO 1%

(Type HN Film, 25 μ m (1 mil))

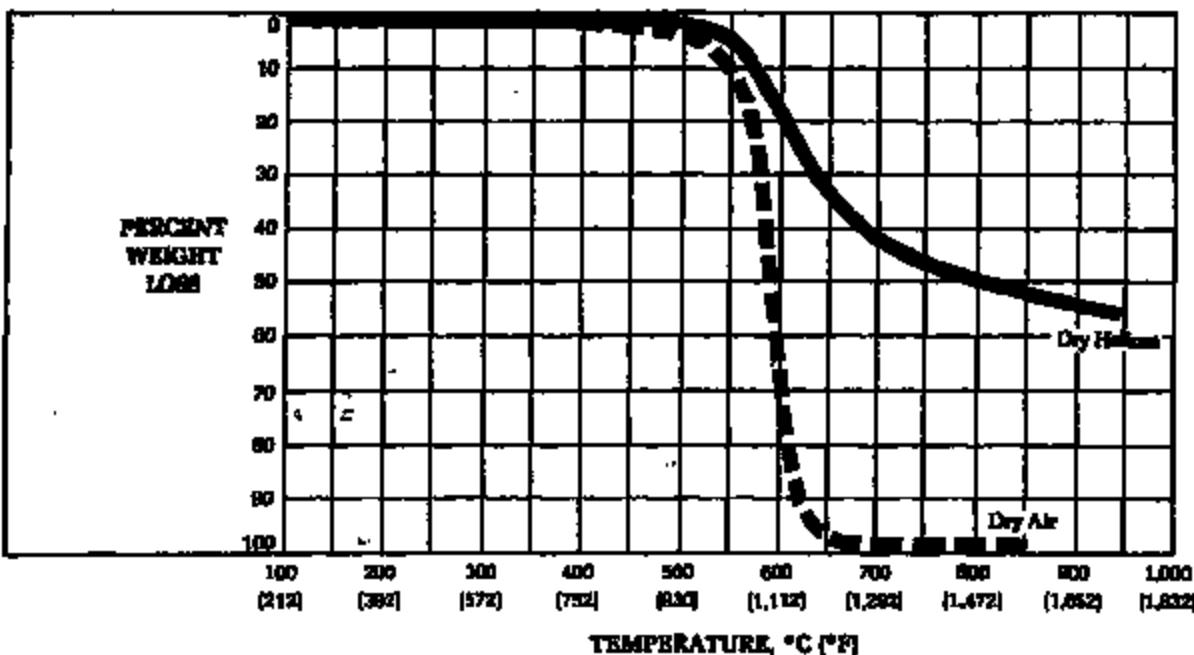
Temperature	Air Environment*
450°C (840°F)	2 hours
425°C (800°F)	5 hours
400°C (750°F)	12 hours
375°C (710°F)	2 days
350°C (660°F)	8 days
325°C (620°F)	1 month
300°C (570°F)	3 months
275°C (520°F)	1 year
250°C (480°F)	8 years

*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 μ m (1 mil))

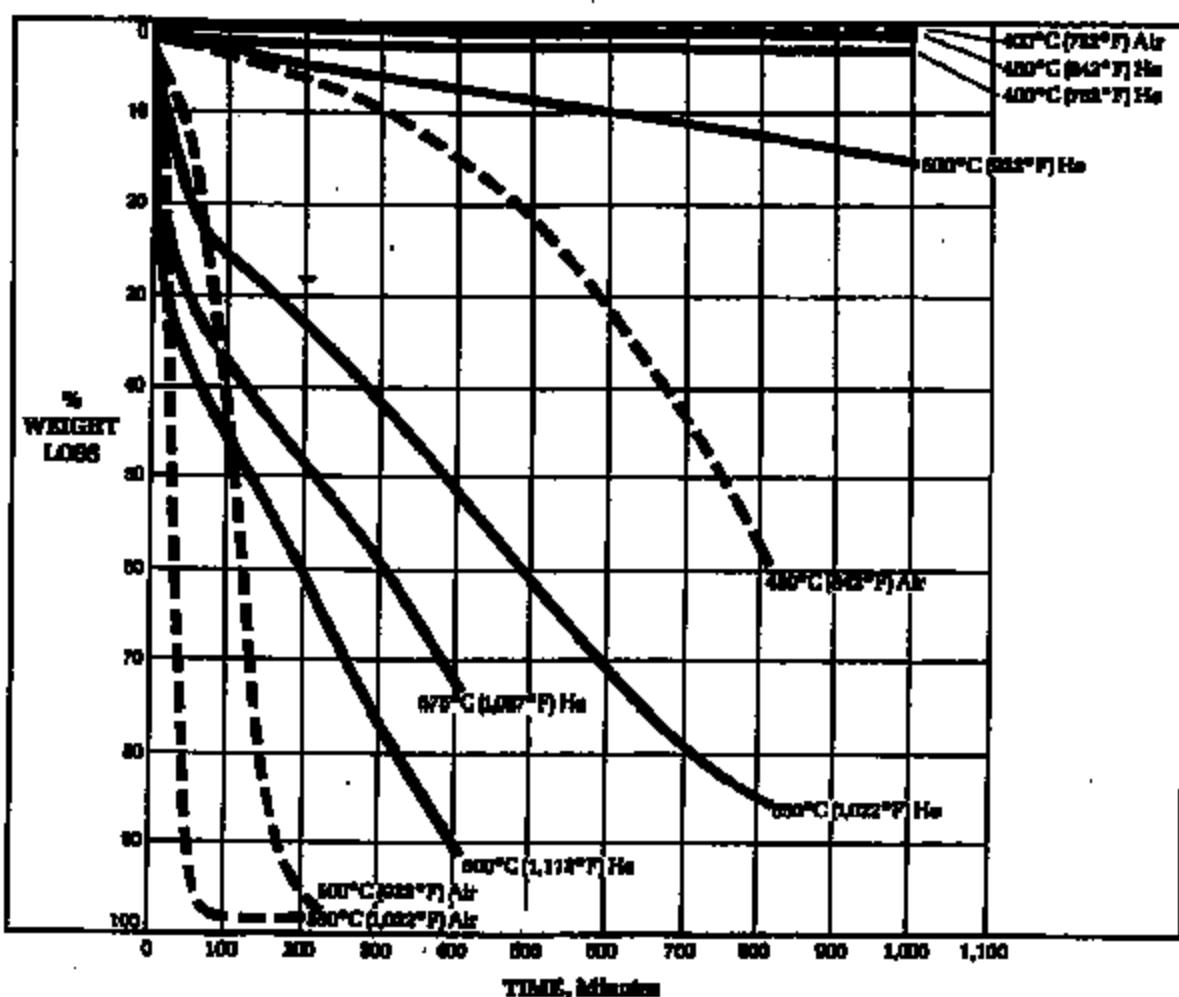
KAPTON[®] polyimide film has significantly extended life in reduced oxygen environments at high temperatures. Using a Du Pont 1080 Thermal Analyzer System, the weight loss characteristics of KAPTON in air and helium at elevated temperatures are shown below.



TI-NHTSA 018223

ISOTHERMAL WEIGHT LOSS

(Type HN Film, 25 μ m (1 mil))



TI-NHTSA 018224

ELECTRICAL PROPERTIES

The electrical and physical properties of TAPTON® polyimide film for various thicknesses are shown on the following pages. These include temperature, 121°C (250°F) and 500°C (932°F) dielectric strength, the dielectric coefficient, flexibility, temperature coefficient of resistance, thermal stability, and breakdown voltage.

TI-NHTSA 018225

DIVNHTSA 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/mm	7,700 v/mil	
50 µm (2 mil)	240 v/mm	6,100 v/mil	50 hertz
75 µm (3 mil)	218 v/mm	5,200 v/mil	14" electrodes
125 µm (5 mil)	154 v/mm	3,800 v/mil	ACD voltmeter disc
Dielectric Constant			
25 µm (1 mil)	3.4	1 kilohertz	ASTM D-150-61
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-150-61
50 µm (2 mil)	.0020		
75 µm (3 mil)	.0020		
125 µm (5 mil)	.0023		
Volume Resistivity			
25 µm (1 mil)	1.5×10^{17} ohm-cm		ASTM D-257-73 (1988)
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	1200FN610	1200FN610	2000FN620
Dielectric Strength			
Volt/mil	6,800	5,000	6,000
Volt/µm	272	197	197
Dielectric Constant	3.1	3.7	3.0
Dissipation Factor	.0015	.0013	.0018
Volume Resistivity			
ohm-cm @ 23°C (73°F)	1.4×10^{17}	2.3×10^{17}	1.8×10^{17}
ohm-cm @ 200°C (392°F)	4.4×10^{14}	3.8×10^{14}	3.7×10^{14}

TI-NHTSA 018226

EFFECT OF HUMIDITY

(Type HN Film, 25 μ m (1 mil))

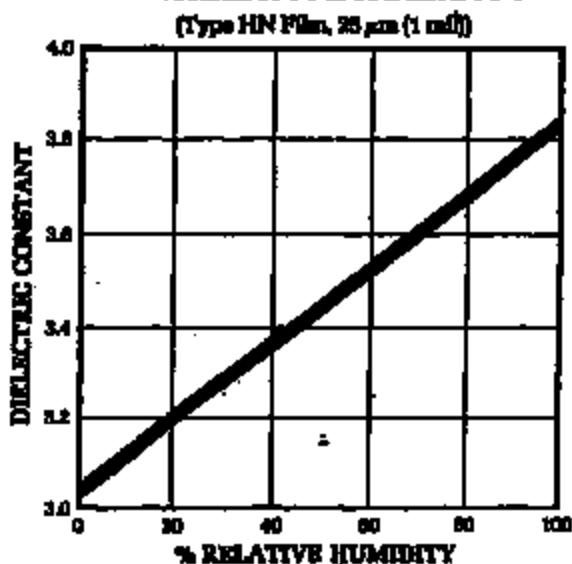
Because the water content of KAPTON[®] polyimide film can affect its electrical properties, electrical measurements were made on 1 mil film after exposure to environments of varying relative humidities at 23°C (73°F). The results of these measurements are graphed below.

RELATIVE HUMIDITY VS. ELECTRICAL PROPERTIES OF KAPTON

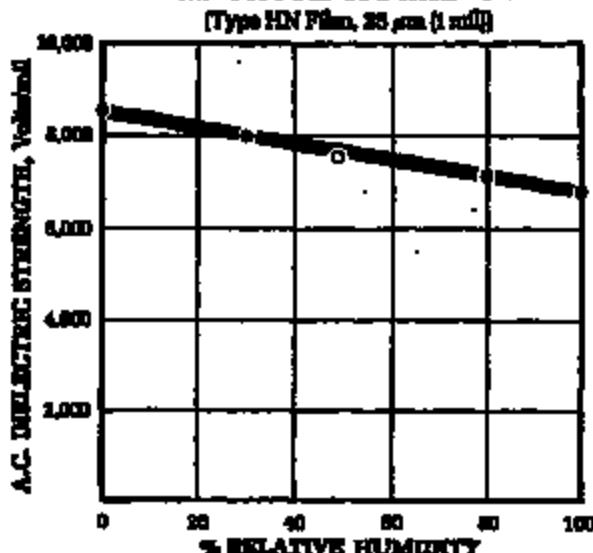
% RELATIVE HUMIDITY	AC DIELECTRIC STRENGTH, V/mil (V/ μ m)	DIELECTRIC CONSTANT	DISSIPATION FACTOR
0	230 (9000)	3.0	.0005
20	215 (8500)	3.1	.0017
40	203 (7700)	3.3	.0030
60	190 (7100)	3.7	.0057
80	185 (6800)	3.8	.0085

For calculations involving absolute water content, 100% RH in our study is equal to 1.0% water in the film and 100% RHT is equal to 2.0% water, the maximum adsorption possible regardless of the driving force.

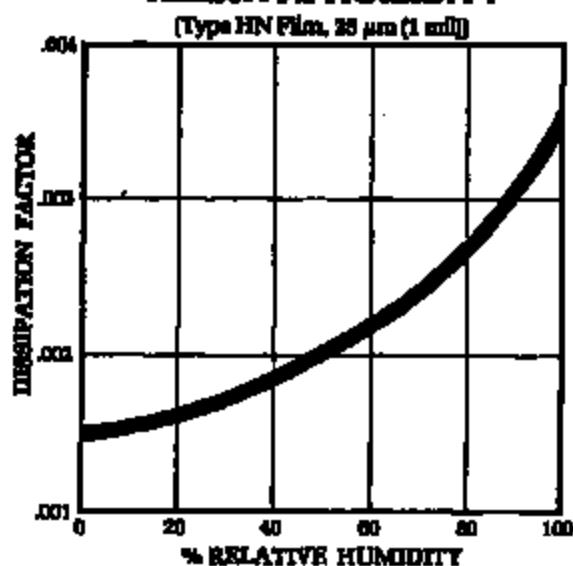
DIELECTRIC CONSTANT VS. RELATIVE HUMIDITY



A.C. DIELECTRIC STRENGTH VS. RELATIVE HUMIDITY



DISSIPATION FACTOR VS. RELATIVE HUMIDITY



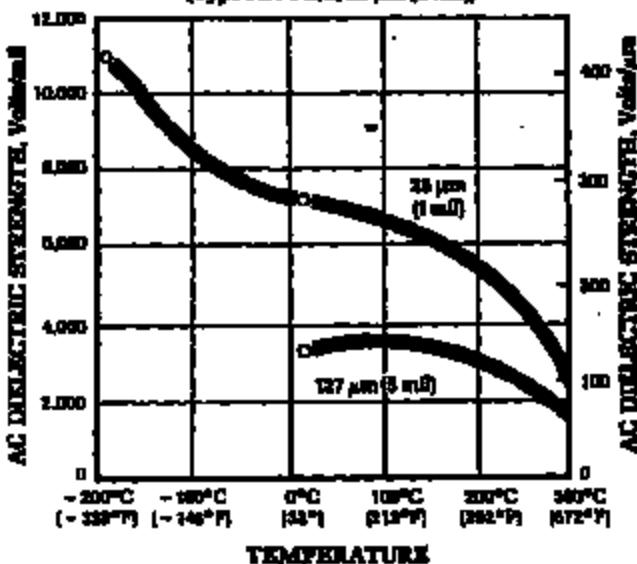
TI-NHTSA 018227

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.

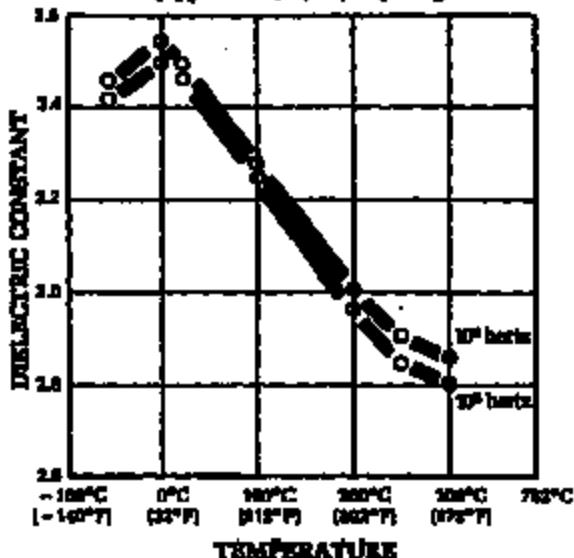
AC DIELECTRIC STRENGTH VS. TEMPERATURE

(Type HN Film, 25 μ m (1 mil)



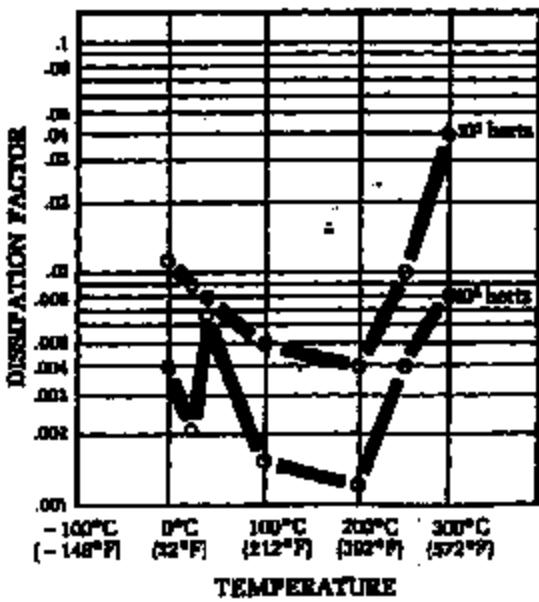
DIELECTRIC CONSTANT VS. TEMPERATURE

(Type HN Film, 25 μ m (1 mil)



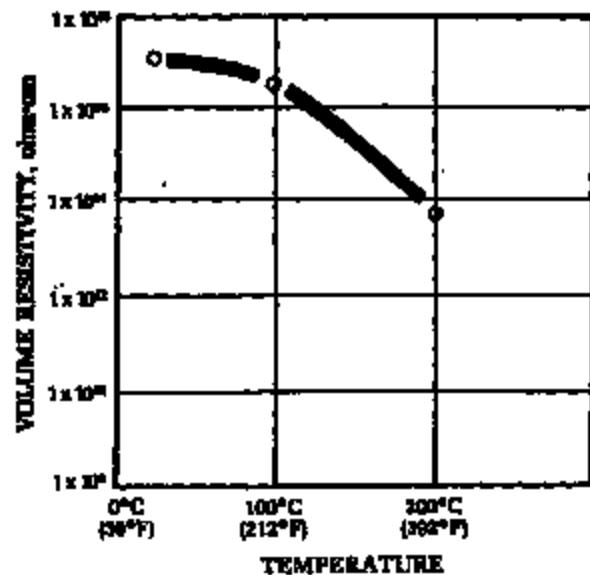
DISSIPATION FACTOR VS. TEMPERATURE

(Type HN Film, 25 μ m (1 mil)



VOLUME RESISTIVITY VS. TEMPERATURE

(Type HN Film, 25 μ m (1 mil))

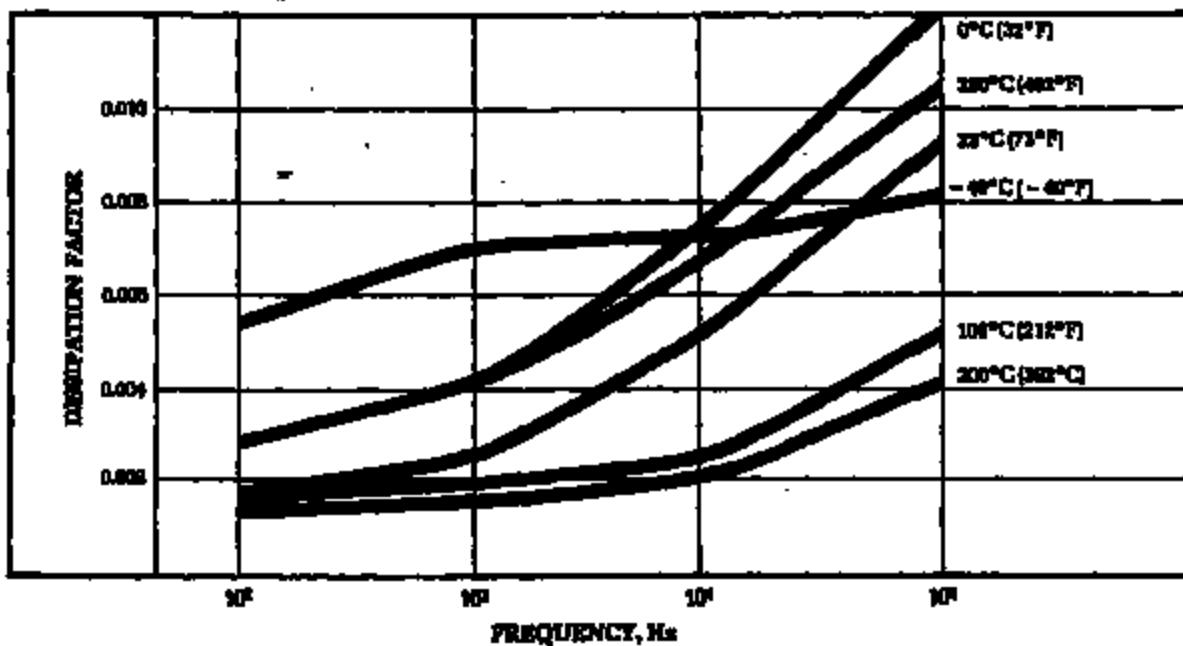


EFFECT OF FREQUENCY

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

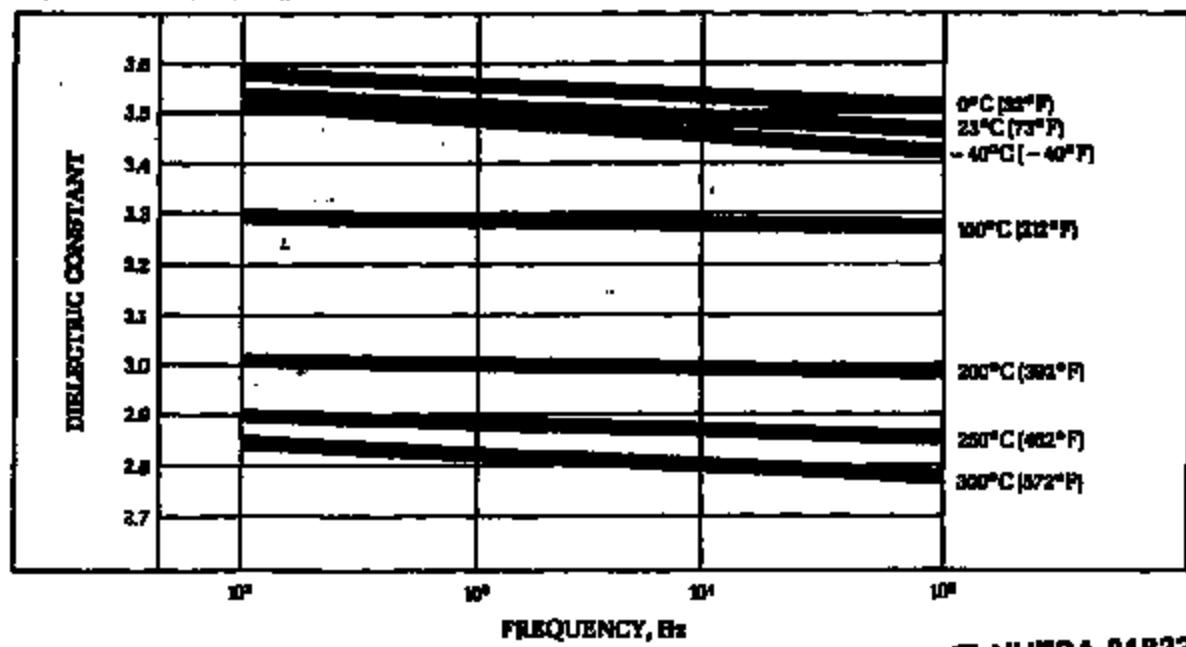
DISSIPATION FACTOR VS. FREQUENCY

(Type HN Film, 25 μ m (1 mil))



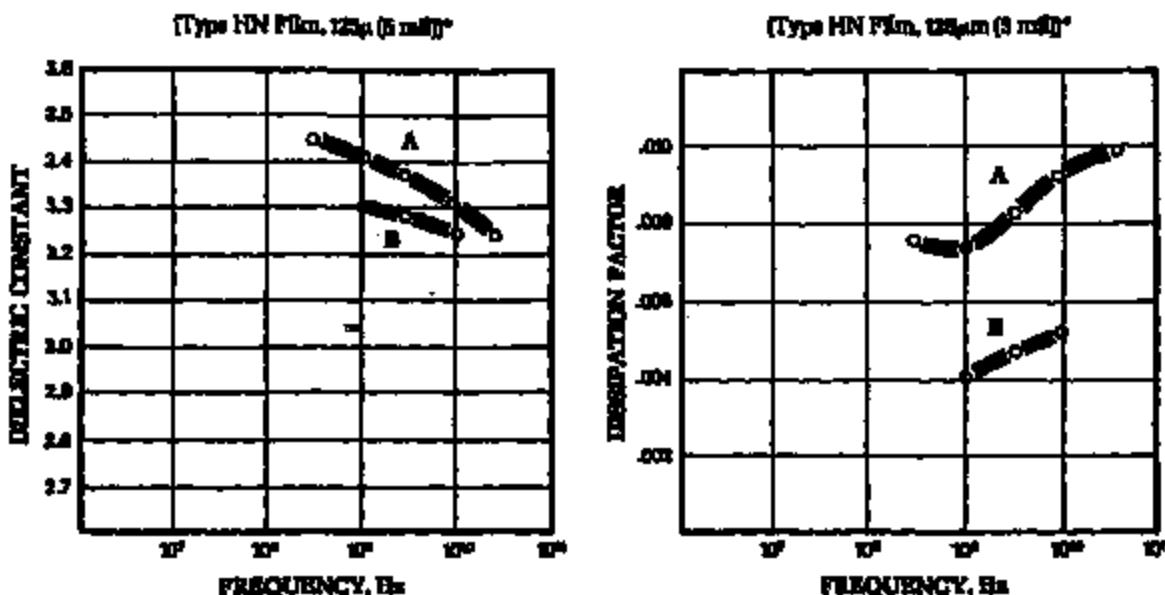
DIELCTRIC CONSTANT VS. FREQUENCY

(Type HN Film, 25 μ m (1 mil))



TI-NHTSA 018229

DIELECTRIC PROPERTIES IN GIGAHERTZ FREQUENCY RANGE



*Technical Report AFML-TR-72-28—Curve A is 125 μ m KAPTON as received and measured at 20°C and 40% 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. Performance of 125 μ m is believed equivalent to 100 μ m.

TRACKING RESISTANCE

A 125 μ m (5 mil) KAPTON® polyimide film, Type HN, has a tracking resistance of 181 seconds as measured by ASTM D-488-64. 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 DuPont technical representative on the suitability of KAPTON for specific applications where corona may be present.

CHEMICAL PROPERTIES

TI-NHT8A 018231

**DD/NHT8A No. 3
M298**

KAPTON® Type HN Film 25 µm (1 mil)

CHEMICAL PROPERTIES

PROPERTY	TYPICAL VALUES (25 µm (1 mil))		TEST CONDITION	TEST METHOD
	% Tensile Retained	% Elongation Retained		
CHEMICAL RESISTANCE				
Isopropanol	96	94	10 min @ 23°C	IPC TM-650 Method 2.2.3B
Toluene	96	91		
MEK	96	90		
Methylene Chloride				
Trichloroethylene (50/50)	96	91		
2N HCl	96	93		
2N NaOH	92	94		
FUNGUS RESISTANCE				
	Nonreactive			IPC TM-650 Method 2.6.1
MOISTURE ABSORPTION				
	1.8% Type HN & VN		50% Relative Humidity at 23°C	ASTM D-470-81
		2.0% Type HN & VN	Immergence for 24 hrs at 23°C (73°F)	
HYGROSCOPIC COEFFICIENT OF EXPANSION				
		22 ppm/% RH	23°C (73°F), 20-60% Relative Humidity	
PERMEABILITY				
GAS	cc/(100 in²·24 hr·cm)			
Carbon Dioxide	45		23°C (73°F), 50% Relative Humidity	ASTM D-1434-82
Oxygen	25			
Hydrogen	280			
Nitrogen	8			
Helium	415			
VAPOR				
Water	g(m²)d	g(100 in²·24 hr)		
	54	3.5		ASTM E-63-80

RADIATION RESISTANCE*

PROPERTY	TYPICAL VALUES (25 µm (1 mil))		TEST CONDITION	TEST METHOD
	% Tensile Retained	% Elongation Retained		
Gamma (Savannah River)	Still Flexible (100° Bend)		Exposure: 4.18 x 10³ Gy	
Electron (Van de Graaf)	Retains 50% of Original Elongation		Exposure: 6 x 10³ Gy	
Neutron Plus Gamma (Brookhaven)	Darkened but Tough		Exposure: 10³ 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 of insulation 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, Case of Cooker Accelerator (LOCA) tests for qualification of containment tanks in power plants expose the system to nitric acid and sodium hydroxide both of which tend to degrade KAPTON. Accordingly, when KAPTON is used in nuclear power systems that requires certification to IEEE-325 and -365, engineering designs which protect KAPTON from direct exposure to LOCA sprays are required.

TI-NHTSA 018232

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	120°F/40°C 50% R.H. 90% R.H.	130°F/50°C 50% R.H. 90% R.H.	400°F/200°C 50% R.H. 90% R.H.
Moisture Absorption			
@ 23°C (73°F), 50% R.H. 90% R.H.	1.3% 2.8%	0.9% 1.7%	0.4% 1.7%
Water Vapor Permeability g/m ² d g/100 in ² -24 hrs	17.5 1.13	8.6 .98	2.4 .16

TI-NHTSA 018233

KAPTON® FILM TYPE INFORMATION

TI-NHTSA 018234

DD/NHTSA No. J
09283

TYPE AND THICKNESS

TYPE	NOMINAL THICKNESS		AREA FACTOR	
	μm	mil	μm ² /sq	ft ² /lb
50 HN	8	0.3	54	110
50 HN	13	0.5	55	272
75 HN	13	0.5	52	204
100 HN	13	0.5	50	136
200 HN	50	2.0	14	68
300 HN	75	3.0	9.5	43
500 HN	125	5.0	5.5	27
50 VN	13	0.5	55	272
75 VN	13	0.5	42	204
100 VN	13	0.5	38	136
200 VN	50	2.0	14	68
300 VN	75	3.0	9.5	43
500 VN	125	5.0	5.5	27
100FN000	25	1.0	28	110
100FN010	30	1.2	21	104
100FN020	30	1.2	14	56
150FN010	35	1.5	18	77
200FN011	50	2.0	11	54
200FN010	50	2.0	11	54
250FN020	65	2.5	10	46
300FN021	75	3.0	8.0	39
300FN020	75	3.0	8.0	39
400FN022	100	4.0	5.5	27
400FN031	100	4.0	5.5	27
500FN131	125	5.0	4.5	23
600FN051	150	6.0	4.5	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 TEFILON® PTFE fluorocarbon resin in mils. The symbol 0 is used to represent 25 μm (1 mil) and 5 to represent 50 μm (2 mil). Example: 100FN010 is a 100-gauge structure consisting of a 25 μm (1 mil) base film with a 2.5 μm (1 mil) coating of TEFILON on each side. Illustrated are several examples of the many types available.

TYPE	CONSTRUCTION				PTFE	SIN
	PTFE	μm	mil	μm	mil	μm
100FN000				13	0.50	13
100FN010		2.5	0.10	25	1.00	2.5
100FN020		13	0.50	13	0.50	13
150FN010				25	1.00	13
200FN011				25	1.00	25
200FN010		13	0.50	25	1.00	13
250FN020				50	2.00	13
300FN021				50	2.00	25
300FN020		13	0.50	50	2.00	13
400FN022				50	2.00	25
400FN031				75	3.00	25
500FN131		25	1.00	75	3.00	25
600FN051				125	5.00	25

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 VM.

KAPTON film can be used safely at elevated temperatures with proper ventilation. At elevated temperatures, KAPTON can release small amounts of dichloroacetyl acetone-like 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-NHTSA 018236

INQUIRIES

All inquiries should be directed to:

The Bend Company
Electronics Department
Component Manufacturing Division
Wilmington, Delaware 19883
Phone: (302) 227-2600

71-NHTSA 018237

NHTSA No. 3
08236

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TINHTSA 018238

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E-5316

130,000

Kapton® Polyimide Film

FPC-E for Fine Line and Metallized FPC

DuPont
Electronics

High Performance Films

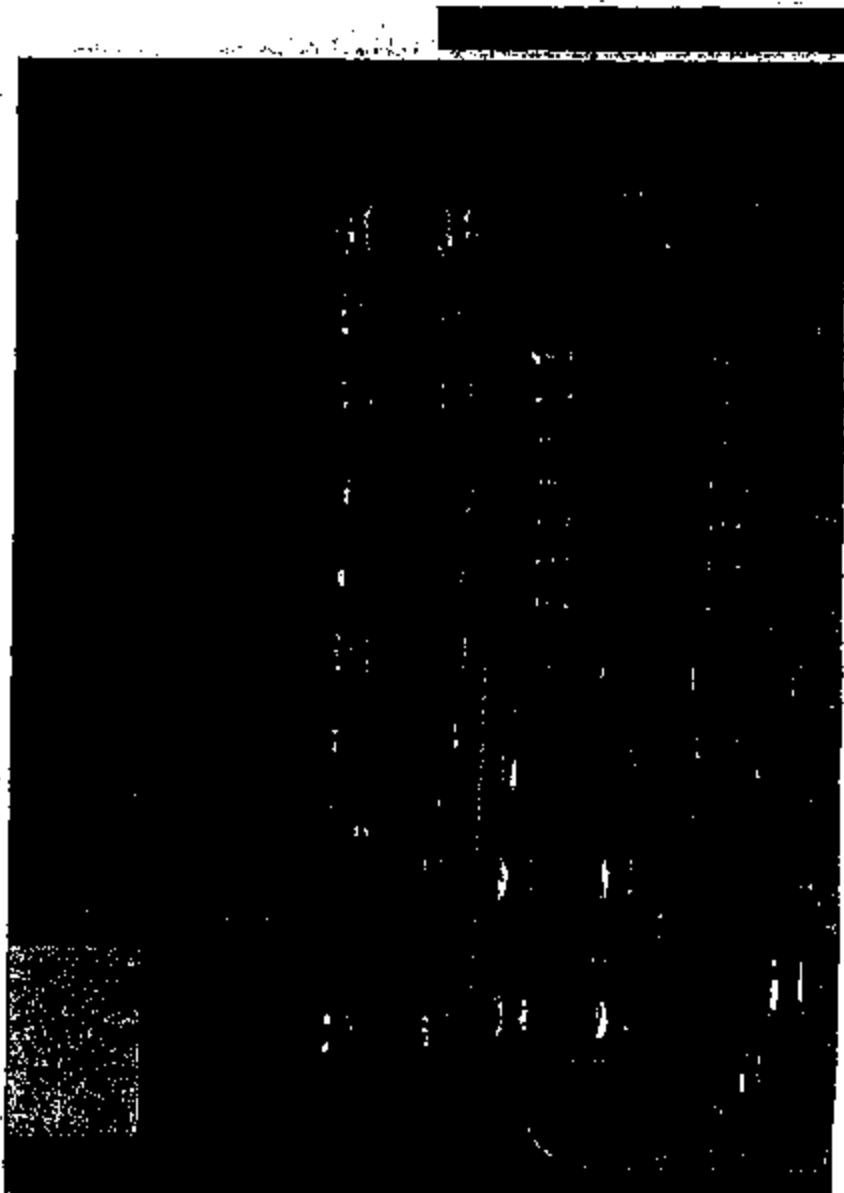
- New E-Polymer Formulation
- Designed for Metallization
- Tailored Dimensional Properties
(Thermal Expansion Matched to
Copper)
- Low Absorption and Less
Expansion in Water
- High/Durable Adhesion
(85°C/85% RH)
- Low Level of Surface
Contamination
- High Modulus

Available:

100FPC-E

200FPC-E

300FPC-E



Kapton® FPC-E for High Resolution and Metallized PPC

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) CRH = 9 PPM/% RH Shrinkage = 0.03% (200°C)
■ Low water absorption	■ 2.2%
■ High/durable adhesion	■ >8 pli 90+% retention, 250 hrs at - 65°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

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Electronics

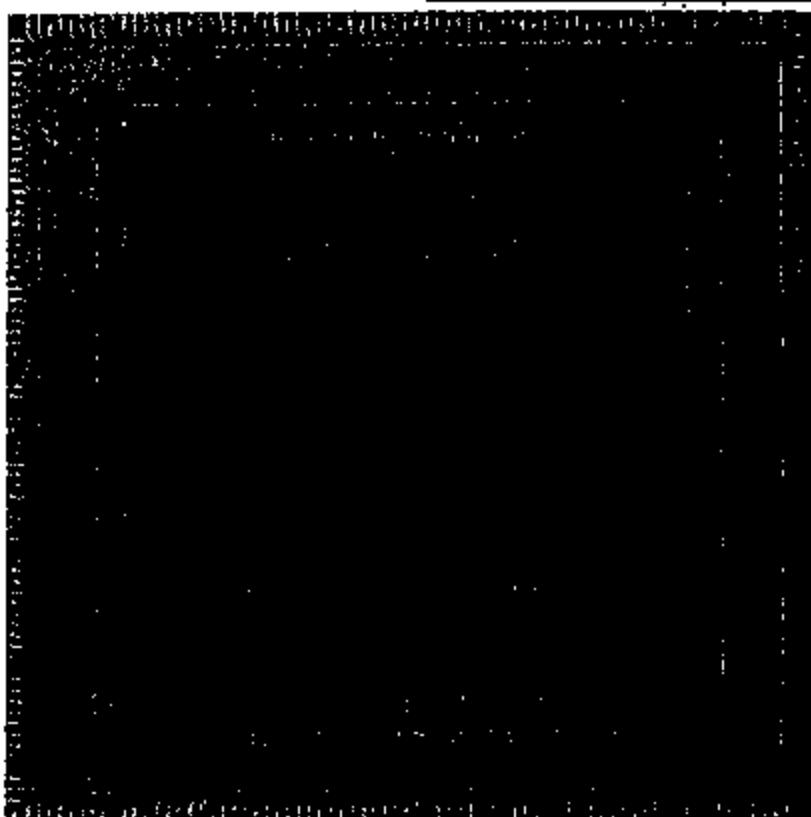
High Performance Films

- 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-NHTSA 018241



IDNHTSA No. 3
00210

Kapton® TAB-X for High Resolution TAB

Market Coordinator-Harland Tote Technical Service-Steve Simpson

Industry Need	Typical Kapton® TAB-X Feature (Average)
■ High modulus	■ 300 Kpsi
■ Tailored dimensional properties	■ CTE = 17 PPM/°C (35-260°C) CHC = 9 PPM/% RH Shrinkage = 0.03% (200°C)
■ Low water absorption	■ 2.2%
■ High/durable adhesion	■ >8 pH 90+% retention, 260 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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TI-NHTSA 018242

KAPTON® Polyimide Film

Advanced Flexible Dielectric Substrates For FPC/TAB Applications

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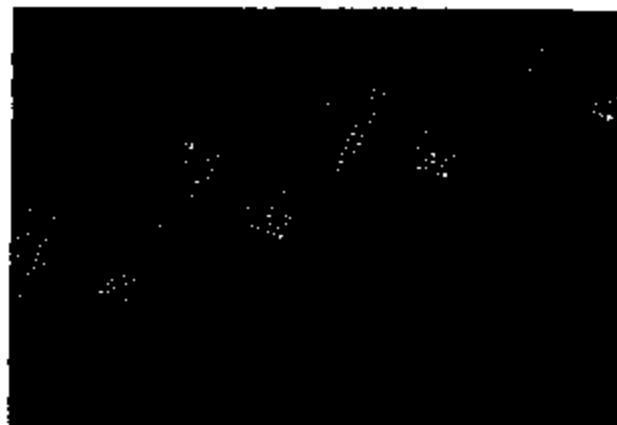
High Performance Films

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

Flexible Printed Circuits

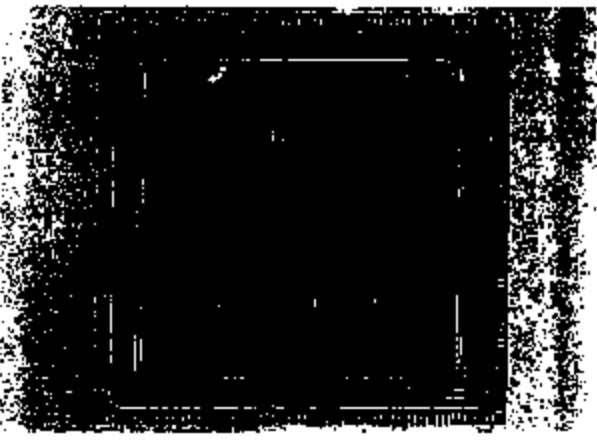


Fine Line

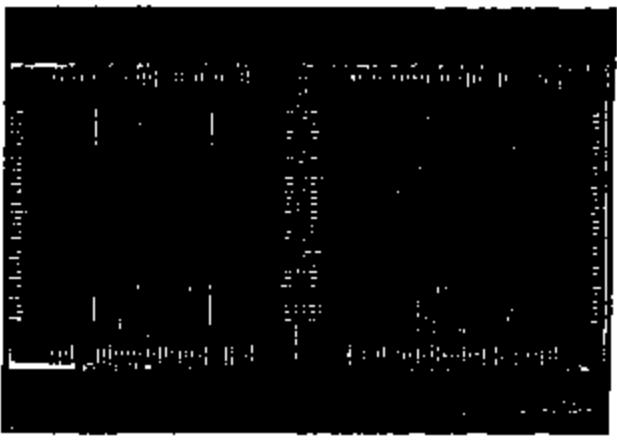


Roll Cuts

Tape Automated Bonding



High Resolution TAB



TAB



TI-NHTSA 018243

IDNHTSA No. 3
00232

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 distortion resistance to harsh environments such as high temperature bonding stations and corrosive aqueous etchants.

Historically, functionality advantages have included several areas. Circuitry is electrically 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, robotics, 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 Microbond 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-minimization 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 these properties of dielectric substrates which need improvements have been the subject of several recent papers, and of market studies by Du Pont. Holzinger (Ref. 4 & 5) has considered TAB substrate materials from the aspects of their functionality. Morlingger (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 quantification 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, 25°-250°C, ppm/°C	17
Modulus, 23°C, Kpsi	750
H ₂ O 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 0.1 mils/in., because it affords excellent ability 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 17 ppm 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 distortion. A modulus of 750 Kpsi is believed to be an economic incentive, because it allows the design engineer to obtain adequate stiffness with 2.3 mil film as an alternative to EMI film with a modulus of 400 Kpsi. 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.

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Approaches to Attract 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-use. The Type-K is targeted at one and two sided circuitry via roll chipping. 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 adhesively. 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'-oxydiamine 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 test 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, adhesivity is a constant issue with my 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 adhesively products.

Specific effects of stiff codiamine segments were demonstrated by investigation of peripheralediamine (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

Modulus of Experimental Copolyimide Films

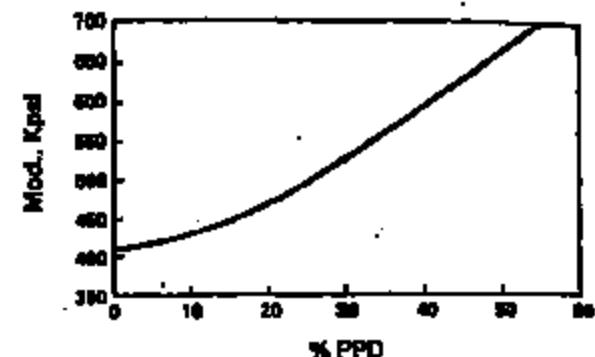
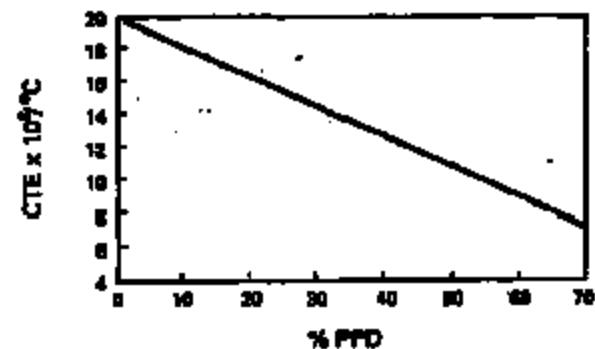


Fig. 2

Coefficient of Thermal Expansion Experimental Copolyimide Films



TI-NHTSA 018245

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 than 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 (CHG), 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 gauges, 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 CHG 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. in./in.	0.1	0.3	0.3	0.3
CTE, ppm/°C	17	38	17	17
Modulus, 23°C. Kpsi	750	400	650	800
H2O Absorb., % Etchable, OH ⁻	1.5 Yes	3.0 Yes	3.7 Yes	2.4 Yes

* All are 75μ (3.0 mil) films.

Table 3

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

	Type-V	Type-K	Type-E
CHG, ppm/RH	17	14	9
H ₂ O, Permeability, gm/m ² /day	22	23	4
OXYGEN, Permeability, cc/m ² /day	114	105	4

* All are 75μ (3.0 mil) 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 film, as measured by change in elongation after 1000 hours exposure to 80% 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.

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Table 4

Property	Additional Properties of New Polyimide Films 3 MIL Types-K & E for FPC/TAB/Multilayer Flex Applications*		
	Type-V	Type-K	Type-E
Tensile, Kpsi	34	40	40
Elongation, %	80	50	40
Initial Tear (Graves), lb./in.	2.4	2.6	2.4
Propagating Tear (Kgm.), gm./cm.	12	17	6.6
Adhesion, pH	12	17	14
L-Color	33	34	49
Density, gm./cc	1.43	1.45	1.46
Diel. Str., v./adl	4500	5000	6000
Diel. Const.			
100 KHz, 10% RH	3.1	3.1	3.2
100 KHz, 50% RH	3.5	2.6	3.4
Diss. Factor,			
100 KHz, 10% RH	0.0012	0.0022	0.0023
100 KHz, 50% RH	0.0065	0.0032	0.0034
Volume Resistivity, ohm-cm			
10% RH	3.5x10 ¹⁷	2.4x10 ¹⁷	3.1x10 ¹⁷
50% RH	1.8x10 ¹⁷	1.0x10 ¹⁷	1.3x10 ¹⁷
Surface Resistivity, ohm			
10% RH	9.3x10 ¹⁷	8.8x10 ¹⁷	13.0x10 ¹⁷
50% RH	0.1x10 ¹⁷	3.1x10 ¹⁷	1.3x10 ¹⁷

* All are 75squ (0.001) Glass.

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 circuitry via roll coating 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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- (1) Marketing Bulletin, "Flexible Circuitry", E.I. du Pont de Nemours & Co., Inc., Electronics Department, H-05302
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- (3) T.J. Matovick, "Microcircuit Interconnection Techniques and Applications", Am. Ceram. Soc. Bull. (USA), Vol.51, #4, 358 (1973).
- (4) S.T. Hohberger, "TAB Types and Material Choices", EXPO SMT '86 Technical Proceedings, 247, (1986).
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- (7) L.R. Williams, J.D. Young, and E.H. Schmidt, "Design and Development Engineering Handbook of Thermal Expansion Properties Aerospace Materials at Cryogenic and Elevated Temperatures", Rockwell International Contract No. NAS-6-10, March 30, 1967.

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EXHIBIT A No. 3
M213

TI-NHT&A 018249

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

De 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.

Designation	Construction (mils)		
	FEP	HN	FEP
120FN616	0.10	1.00	0.10
100FN030		0.50	0.50
150FN600	0.50	0.50	0.50
150FN019		1.00	0.50
200FN919	0.50	1.00	0.50
200FN011		1.00	1.00
250FN028		2.00	0.50
300FN928	0.50	2.00	0.50
300FN021		2.00	1.00
400FN022		2.00	2.00
400FN031		3.00	2.00
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.



PROPERTIES OF TYPE BN FILM

Mechanical

Property	Property Value						Method
	Film Thickness (inches)						
Tensile Strength psi, at 23°C. Machine Direction (MD) and Transverse Direction (TD). (Minimum)	16,000	20,000	24,000	24,000	24,000	24,000	ASTM D-632-61, Method A using an Instron Tensile Tester (specimen size 1/8" 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	60	Same as above method.
Shrinkage, % MD and TD at 450°C (Maximum)	4.5	4.5	3.5	2.5	2.5	2.5	ME-P-481125 (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 0.125" x 1" specimen is conditioned by finely suspending for 2 ^{1/2} hours in an oven controlled to 450° ± 10°C.
Moisture absorption, % (Maximum)	4.0	4.0	4.0	4.0	4.0	4.0	ASTM D-670-61, using 24 hour immersion at 23°C. Average of 3 specimens.

*1 hour for 30 & 60 gauge film.

Electrical

Property	Property Value						Method
	Film Thickness (inches)						
Dielectric Strength, AC voltage/kV, (Minimum)	2,000	3,000	5,000	5,000	4,500	3,000	ASTM D-148-61. (Average of 10 specimens.) Flat sheets in air placed between 1/4" diameter brass electrodes with 1/32" edge radial subjected to 60 cycle AC voltage at 600 volt/sec. rate of rise to the breakdown voltage.
Volume Resistivity, ohm-cm at 20°C (Minimum)	10 ¹¹	10 ¹¹	10 ¹¹	10 ¹¹	10 ¹¹	10 ¹¹	ASTM D-257-78
Dielectric constant at 1 kHz (Maximum)	4.0	4.0	3.4	3.6	3.8	3.8	ASTM D-180-61. 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.
Dielectric factor at 1 kHz (Maximum)	.0070	.0060	.0038	.0034	.0038	.0035	Same as above method.

TI-NHTSA 018251

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 3-1/2" x 1-1/2" 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 $\pm 2^\circ\text{C}$. Sheets are removed after 2 hours¹ 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-45112 B (MIL).

Underwriter's 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. E39605 for "Kapton" polyimide film.

PROPERTIES OF TYPE FN FILM

Heat Seal Strength

Film to Film Seal

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 few seconds 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 grams./inch except for 120FN616 which will be 450 grams./in. The minimum peel strength between the coated and uncoated side of one side coated "Kapton" will be 450 grams./inch.

Film to Copper Seal for 120FN616

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 grams./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 grams./in. as measured using an Instron type tensile tester and a 180° peel.

Dielectric Strength

Gauge Construction	Mil. Breakdown (Volts/mil)	Test Method
120FN616	4800	
100FN099	3800	
150FN099	3000	
150FN4019	3800	
200FN410	3000	
200FN011	3000	
250FN029	2800	
300FN829	2500	
300FN021	2500	
400FN022	2000	
400FN031	2700	
500FN131	2200	
600FN061	2100	

Average of 10 samples tested per ASTM D-149-81. Flat sheets in air plated between 1/4" diameter brass electrodes with 1/32" edge radius subjected to 60 cycles AC voltage. Rise in 500 volts/sec. to the breakdown voltage.

¹1 hour for 30 & 50 gauge film.

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PROPERTIES OF TYPE VN FILM

Mechanical

Property	Property Value						Method	
	Film Thickness (mils)							
	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-882-61, Method A using an Instron Tensile Tester (specimen size: 1/2" x 5", jaw separation: 4", jaw speed: 2" / min.). Calculate the average of 5 specimens based on original measured thickness.	
Elongation, % MD and TD (Maximum)	25	35	45	80	80	80	Same method as above.	
Shrinkage, % MD and TD after 60 min. at 200°C. (Maximum)	0.10	0.15*	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 stepwise 200°F ± 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-570-61, using 24 hour immersion at 23°C. Average of 3 specimens.	

Electrical

Property	Property Value						Method	
	Film Thickness (mils)							
	0.50	0.75	1.00	2.00	3.00	5.00		
Dielectric Strength, volt/mil, AC (Minimum)	3,000	3,000	3,000	5,000	4,000	3,000	ASTM D-148-61. (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^{12}	10^{14}	10^{16}	10^{14}	10^{15}	10^{13}	ASTM D-287-72	
Dielectric constant at 1 kHz (Maximum)	3.0	3.0	3.0	3.0	3.0	3.0	ASTM D-150-61. Use conducting silver paint electrodes, thin terminal system of measurement at standard conditions. Results are based on an average of 5 tests using measured thickness of specimens.	
Dissipation factor at 3 MHz (Maximum)	0.0050	0.0050	.0038	.0036	.0036	.0038	Same method as above.	

Thermal Durability

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

Sheets of film 9-1/2" 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 $\pm 2^\circ\text{C}$. 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 4.4.6) 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. E29305 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 LD.'s are 3" and 6" with

the following specifications: 3" LD. is $3.025^\circ \pm 0.005^\circ$, 6" LD. is $6.025^\circ \pm 0.010^\circ$. Core material will be plastic for 3" LD. cores less than 5/8" wide. Core material will be fiber for 3" LD. cores wider than 5/8" and 6" LD. cores. A split 3" LD. fibre core is standard for all universal rolls. Core width for universal wind is 23/32".

If these cores are not suitable, further information on other options may be obtained from your Electronics Department marketing representative.

Width Tolerances

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

Stock 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 mils	Thickness μm	Width Range Min. in. Max. in.	Pad Ratio S.D. x O.D.I. (in.)			Universal Ratio S.D. x O.D.I. (in.)			Area Factor (ft²/m²)
				3x6	3x8-1/2	6x11	6x14	3x6	3x8	
30HN	0.3	8	3/16	30						410
50HN	0.5	12	3/16	50						272
100HN	1.0	25	3/16	50	+					138
200HN	2.0	50	3/16	50	+	+				66
300HN	3.0	75	3/16	50	+	+				45
500HN	5.0	125	3/16	50	+	+				27
60VN	0.5	13	7/32	52						272
75VN	0.75	18	7/32	50						181
100VN	1.0	25	7/32	50						138
200VN	2.0	50	7/32	50						66
300VN	3.0	75	7/32	50						45
500VN	5.0	125	7/32	50						27
100FN026	1.0	25	1/8	36						110
120FN014	1.2	20	1/8	36						104
160FN009	1.5	30	1/8	36						66
180FN016	1.5	36	2/5	36						77
200FN011	2.0	50	3/16	36						54
200FN010	2.0	50	3/16	36						54
250FN029	2.0	60	1/8	36	+	+				45
300FN021	2.0	75	3/16	36	+	+				39
300FN020	2.0	75	3/16	36	+	+				39
400FN027	4.0	100	3/16	36	+					27
400FN021	4.0	100	3/16	36	+					20
500FN131	5.0	125	3/16	36	+	+				23
600FN051	8.0	150	1/2	36	+	+				21

1" x 10' part roll is available in widths up to 7/8" only in 100HN, 200HN, 300HN, 500HN, 100FN026, 200FN011, 300FN021, 400FN021, 500FN131.

* S.D. Tolerance is $\pm 1/4^\circ$ for parts and $\pm 1/2^\circ$ for universal.

* Type HN, FN and VN films in pads are supplied in width increments of 1/16".

Note: Films are supplied in width increments of 1/16" in widths 3/16" to 1".

* All universal rolls are supplied in 1000' which increments with 100' minimum roll length. The minimum width is 10" for 2" x 10' (S.D. x D.O.I.); the minimum width is 10" for 3" x 10', and 3" x 12' x D.O.I. x 0.80.

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TDINHTSA No. 3
00223

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 "capping" 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 2/16".
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 $\pm 1/4"$.

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 0.003" thick a 1" wide pressure sensitive tape is used. For films 0.003" 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 SH 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

Minimum Average Splice Free Length (Feet)																	
200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600
2	1	1-10	Pad	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
3	5	8-12	Pad	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	8	11	Pad	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	9	Universal	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Minimum Length Between Splices or Beginning and End of a Roll (Feet)																	
3	5	8-12	Pad	—	100	100	100	100	100	100	100	100	100	100	100	100	100
3	8	11	Pad	—	—	100	100	100	100	100	100	100	100	100	100	100	100
3	9	12	Universal	—	—	—	100	100	100	100	100	100	100	100	100	100	100

NOTES: * To 80" wide for 300M, 82" wide for 350M

** To 60" wide

*** To 4" wide

* To 80" wide. For widths greater than 80" to the maximum, the minimum average footage will be one half that shown in the table.

** 50" to 70" 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 HV Film Thickness (mils)	Unit Weight (oz/ft ²)	
	Minimum	Maximum
0.50	7.0	14.0
0.60 ^a	14.0	26.0
0.75 ^a	21.0	32.0
1.00 ^a	32.7	38.7
2.00 ^a	68.5	77.5
3.00 ^a	101.0	115.4
5.00 ^a	188.5	192.5

^a Applies to Type VN films also.

Type FN Film Gauge & Construction	Minimum	Maximum
120FN4010	41	55
100FN4000	57	65
100FN4000	61	65
100FN4010	62	74
200FN4010	77	104
200FN4011	77	104
200FN4020	87	113
300FN4021	111	142
300FN4020	111	142
400FN4022	160	200
400FN4021	140	170
500FN4011	196	230
500FN4011	211	250

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 HM Gauge	Nominal Thickness (mils)	Thickness Tolerance (mils) Minimum	Thickness Tolerance (mils) Maximum
30	0.30	0.24	0.36
50 ^a	0.50	0.38	0.62
75 ^a	0.75	0.60	0.90
100 ^a	1.00	0.85	1.15
200 ^a	2.00	1.75	2.25
300 ^a	3.00	2.72	3.28
500 ^a	5.00	4.50	5.50

^a Applies to Type VN films also.

Type FN Film Gauge	Nominal Thickness (mils)	Thickness Tolerance (mils) Minimum	Thickness Tolerance (mils) Maximum
120FN4010	1.00	1.10	1.40
100FN4000	1.00	0.75	1.25
100FN4000	1.00	1.20	1.40
100FN4010	1.00	1.25	1.75
200FN4010	2.00	1.70	2.30
200FN4011	2.00	1.70	2.30
200FN4020	2.00	2.30	2.60
300FN4021	3.00	2.60	3.40
300FN4020	3.00	2.60	3.40
400FN4022	4.00	3.60	4.40
400FN4021	4.00	3.60	4.40
500FN4011	5.00	4.50	5.50
500FN4011	5.00	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 width since that roll is limited to a maximum of 7/8" wide.

Table 2. Kapton® Polyimide Film Gauge Depression Standards—Pad Rolls

Pad-Off	Gauge	Maximum allowable depression in 1/32" increments														Width
		1/8"	1-5/16"	1-7/16"	1-9/16"	1-11/16"	1-13/16"	1-15/16"	1-17/16"	1-19/16"	2-1/16"	2-3/16"	2-5/16"	2-7/16"		
1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22"
2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Width
3	2-1/2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Width
4	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Width
5	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Width
6	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Width
7	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Width
8	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Width
9	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Width
10	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Width
11	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Width
12	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Width
13	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Width
14	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Width
15	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Width

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*
1. Scheduled Date	X	X	X
2. Customer Order Number	X	X	X*
3. DuPont 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	

* 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.

^a Inside diameter of core and nominal outside diameter of roll.

^b Available for up to 12 characters.

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Kapton

POLYIMIDE FILM

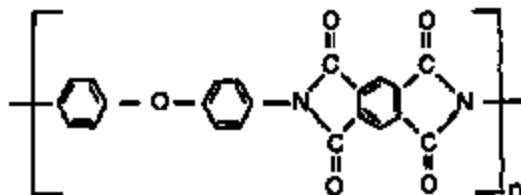
safe handling

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

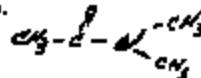
KAPTON Type H and Type V, exhibits no melting point or softening point. A one-mil thick film has a zero-strength temperature of 815°C (1500°F). Zero-strength is measured as the

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 188 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 CFR 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 85% 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)

Kapton

POLYIMIDE FILM

DRY FILM LAMINATING ADHESIVES

ADHESION TO KAPTON®

KAPTON® polyimide film, made only by DuPont, 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 TEFLOW® 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-87624, "Industry Specifications Bulletin FC-86-2." 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, butyl-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 I

Adhesive Type	Lamination Temperatures °F (°C)	Maximum Operating Temperature °F (°C)
Fluorocarbons	650-800 (290-315)	to 500 (260)
Polyimides	500-700 (260-370)	to 650 (345)
Epoxies	73-450 (-23-230)	to 800 (315)
Pressure Sensitive Silicones	73-300 (-23-150)	to 600 (260)
Rubber-Phenolics	300-400 (150-205)	to 600 (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. 8) 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 volatile 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 polyimide 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

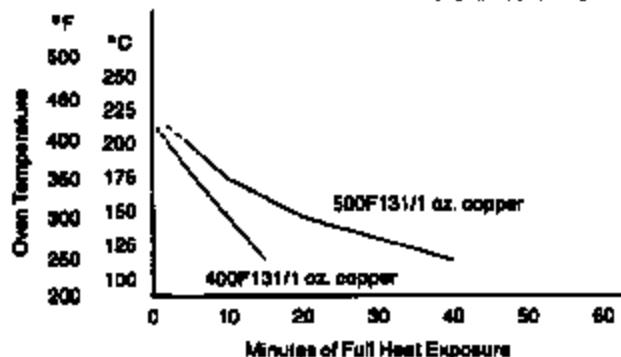
The processing of KAPTON polyimide film can cause the generation of a strong static charge. Unless this charge is bled off as it forms through the use of ionizing radiation or metal tinsel, it can build to many thousands of volts and discharge to people or to metal equipment. In dust or solvent-laden 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

1. J. T. Milek, "Polyimide Plastics: A State-of-the-Art Report," Electronic Properties Information Center, S-8, October 1, 1965, Air Force Systems Command, Contract AF33 (618)-2480, Project 7381: Task 738103.
2. C. E. Sroog, A. L. Endrey, S. V. Abrams, G. E. Blodgett, W. M. Edwards, and K. L. Oliver, *J. Poly. Sci. Polym. Phys. Ed.*, 3(4), 1373-80 (1965).

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 8 lbs. per linear inch (10.5 N/cm). Those adhesives which do not have hydroscopic 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 (9.6)	10.0 (17.6)
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 linear 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 8 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.

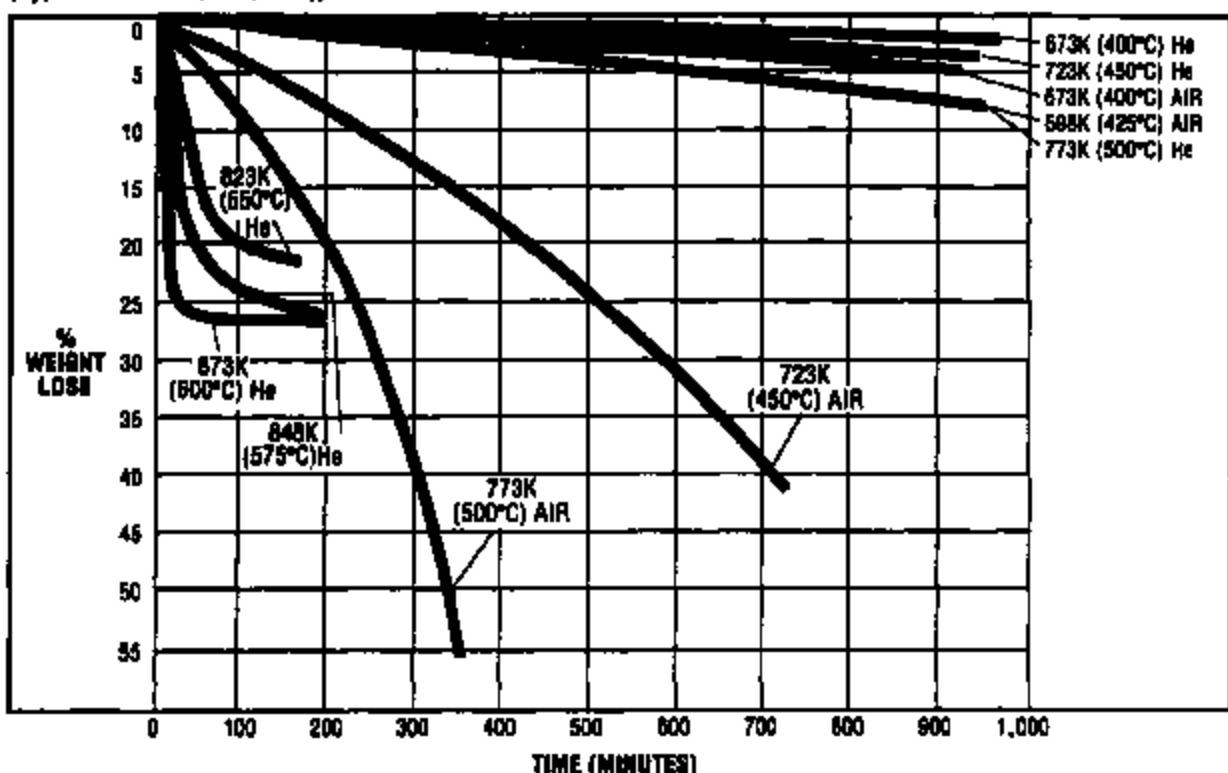
When higher adhesion levels are required for a given adhesive system, the range of the peel strength values for the laminate may usually be reduced if the surface of the film is mechanically or chemically abraded, light pumice scrubbing or caustic etching. Caution must be exercised with any such treatment 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 adhesion 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 butyral and phenolic nitriles. Improvement over standard film averaged from 40% to 97% for these adhesive types.

ISOTHERMAL WEIGHT LOSS

(Type H Film 25 μm (1 mil))



3. N. A. Androva, M. I. Bassonov, L. A. Laius, and A. P. Rudakov, "Polyimides — A New Class of Thermally Stable Polymers," *Progress in Matl. Sci. Series*, Vol. VII, Technomic Publ. Co., Stamford, Conn., 1970, p. 79-85.
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6. R. F. Stabler and L. L. Lewis, "KAPTON Polyimide Film — A New Insulation for Aerospace Wire and Cable," Paper presented at Soc. of Aerospace Materials and Process Engineers Meeting, San Francisco, May 26, 1965.

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Kapton® Polyimide Film

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KAPTON® Polyimide Film

Technical Bulletin

Suppliers of Adhesives to
the Electronics Industry

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September 1989

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○ GE/ Silicon Products Div., Waterford, NY	(518) 237-3330
● B. F. Goodrich Adhesives Div., Akron, OH	(216) 574-2000
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Technit, Cranford, NJ	(201) 272-6500
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○ Tra-Con Inc., Medford, MA	(617) 391-5550
Vigor Co., New York, NY	(212) 807-3845
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KAPTON® Polyimide Film

Technical Bulletin

● Suppliers of Adhesives to
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DU PONT

MATERIAL SAFETY DATA SHEET

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NAME	CHEMICAL FAMILY
HFC-134a	Halogenated Hydrocarbon
FORMULA	TSCA INVENTORY STATUS
CH ₂ FCF ₃	Reported/Included
MANUFACTURER/DISTRIBUTOR	PRODUCT INFORMATION PHONE
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PHYSICAL DATA

BOILING POINT	PERCENT VOLATILE BY VOLUME
-26.5°C (-14.5°F) @ 736 mmHg	100
LIQUID DENSITY	VAPOR PRESSURE
1.21 g/cc @ 25°C (77°F)	96 psig @ 25°C (77°F)
VAPOR DENSITY (AIR = 1)	SOLUBILITY IN WATER
3.18	0.15% by wt at 25°C (77°F) & 14.7 psia
FORM	APPEARANCE
Liquefied Gas	Clear
COLOR	ODOR
Colorless	Slight Ethereal

E-94938 Date: 4/88

TI-NHTSA 018273

The data in this Material Safety Data Sheet relate only to the specific material designated herein and does not relate to use in combination with any other material or in any process.

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 51,000 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^a (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.

^aTLV is a registered trademark of the American Conference of Governmental Industrial Hygienists.

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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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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

NFPA - 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: 4/84

PERSON RESPONSIBLE FOR MSDS:

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