EA02025

TEXAS INSTRUMENTS, INC.'S

09/10/03 LETTER TO ODI

REQUEST 10

BOX 13

PART A – G

PART G

ELCO
INDUSTRIES, INC.

Date: ______________________

To: ______________________

Jim,

This is the info I got from Dupont. Hopefully this will be OK for the PPO. Ed McKenzie knows that they have to work on what we want. Please give me a call

Brian
x3261

ELCO INDUSTRIES, INC.
1111 Samuelson Road • P.O. Box 7009
Rockford, Illinois 61125-7009
Phone 815/397-5151

F-33-1

2mil 68ft²/lb

3mil 45ft²/lb

Carr Lane

Tooling for America
... and the World

LEHIGH-ARMSTRONG, INC.
FASTENER SPECIALISTS
12 DUNHAM ROAD
BILLERICA, MA 01821
(508) 663-0010 FAX (508) 663-6125

Dupont Plastics

AUTO SENSOR & SOLENOID APPLICATION TEAM FORMED TO ...

- BETTER UNDERSTAND COMPONENT FUNCTION & REQUIREMENTS TO BETTER GUIDE MANUFACTURERS IN MATERIAL SELECTION AND PART DEVELOPMENT
- DEVELOP AND FORMULATE IMPROVED RESINS FOR APPLICATION
- DEVELOP PROCESSING AND DESIGN EXPERTISE SPECIFIC TO SENSORS AND SOLENOIDS
- DEVELOP KNOWLEDGE BASE THAT HELPS CUSTOMER TO SHORTEN DEVELOPMENT TIME AND REDUCE DEVELOPMENT COSTS
- MAKE DU PONT THE PREFERRED RESIN SUPPLIER AND DEVELOPMENT PARTNER FOR SENSOR/SOLENOID MANUFACTURERS

<u>AUTO SENSOR MARKET</u>

MARKET GROWTH	10 - 15 % PER YR
AVERAGE COST PER SENSOR	$ 3 - $ 6
AVERAGE RESIN CONTENT PER SENSOR	20 - 60 GRAMS
AVERAGE RESIN COST PER SENSOR	$ 0.20 - $ 0.40 *(5 % - 15 %)*

~10 sensors/car

KEY ACCOUNTS IN SEGMENT

System Suppliers

Delphi E&E
Visteon
Siemens
LucasVarity-Kelsey-Hayes
Bosch
Denso
ITT Automotive
Breed

Component Suppliers

Hi-Stat
Texas Instruments
Motorola
CTS Corp.
Wabash Magnetics
Phillips Technologies
SSI Technologies
Motorola
Honeywell Microswitch
Accutex

Custom Molders

Baker Electric (GP/ Hay)
Syncro (Toney)
PNC (Solenberger)
Thermotec (Treff)
Multicraft (Boyer)
Fasco (Tobar)
Huron Plastics (Fisher)
UFE (Treff)
ATS (Canada)
ITW Insert Molded (Al-Aseer)

RESIN REQUIREMENTS UNIQUE TO SENSORS

- THERMAL CYCLING DURABILITY
- PREVENTING FLUID INTRUSION - LEAKAGE
- ADHESION BETWEEN PREMOLD AND OVERMOLD
- ADHESION TO POTTING COMPOUND OR GASKET MATERIALS
- KNIT LINE STRENGTH
- LOW PRESSURE MOLDING
- DIMENSIONAL STABILITY OVER WIDE TEMPERATURE RANGE
- INSERT LOADING AND CAPTURING
- RETRACTABLE PIN TECHNIQUES

DU PONT TECHNOLOGY AND RESOURCES FOR SENSORS

RESIN DEVELOPMENT AND SELECTION - FIRST SUPPLIER TO DEVELOP AND FOCUS EXCLUSIVELY ON SENSOR APPLICATION MATERIALS

- HIGH FLOW
- WIRE FRIENDLY (COPPER WIRE CORROSION)
- LOW PRESSURE MOLDING
- IMPROVED ADHESION TO INSERTS

PROCESSING TECHNIQUES

- OVERMOLDING / INSERT MOLDING GUIDELINES
- OPTIMIZING MOLDING CONDITIONS AND EQUIPMENT TO REDUCE DOWN TIME AND SCRAP
- MOLDING CONDITIONS TO MINIMIZE INSERT MOVEMENT

DESIGN PRINCIPLES

- GUIDELINES FOR OPTIMUM DIMENSIONAL STABILITY AND PART PERFORMANCE
- INCORPORATE PART FEATURES THAT OPTIMIZE MOLDABILITY
- CONCEPTS AND RECOMMENDATIONS FOR PART INTEGRATION
- FINITE ELEMENT ANALYSIS TO PREDICT INSERT MOVEMENT

TOOL DESIGN

- IN-HOUSE PROTOTYPING TO DEMONSTRATE TECHNIQUES AND RESINS
- DESIGN GUIDELINES TO INSURE OPTIMUM RESIN FLOW IN MOLD
- GUIDELINES ON SPECIAL FEATURES SUCH AS RETRACTABLE PINS, CORE DESIGN AND INSERT PLACEMENT

Wire Friendly & High Flow Sensor Resins

Zytel® FE5382 BK276 - 33%gr 6,12 w/ organic stabilizer & carbon black ("wire friendly")

Zytel® FE5386 BK031 - 33%gr 6,12 w/ HS and dye

Zytel® FE5369 BK276 - 33%gr 6,6 w/ organic stabilizer and carbon black ("wire friendly")

Zytel® FE5406 BK276 - 33%gr 6,6 w/ HS and carbon black

Zytel® FE5414 BK275 - 13%gr high flow 6,6 nylon w/HS and carbon black

Rynite® RE5231 BK533 - 35% glass/mica, high flow PET

Crastin® HR5015 & HR5030 - 15% gr PBT modified for improved hydrolysis resistance and high flow

Zytel® HTN 51G35 HSL - 35% gr high temperature nylon

Zenite® 6130 - 30% gr liquid crystal polymer

TWO VISIONS OF RESIN SUPPLIER AND THEIR CONSEQUENCES

TREAT RESIN AS COMMODITY AND DO TROUBLESHOOTING - REACTIVE

VERSUS

WORK CLOSELY WITH OEM AND MOLDER DURING ALL PHASES - PROACTIVE

- RESIN SELECTED BASED ON COST OR PRIOR EXPERIENCE LEADING TO WRONG CHOICE
- TIME AND RESOURCES EXPENDED TO EVALUATE MANY RESINS
- PART DESIGN DOES NOT TAKE INTO ACCOUNT RESIN CHARACTERISTICS, HANDLING OR MOLDABILITY
- DITTO WITH MOLD DESIGN
- END USE TESTING RESULTS IN PART FAILURES DUE TO RESIN DEFICIENCIES
- IMPROPERLY SIZED MOLDING MACHINE, INJECTION UNIT, OR SCREW
- IMPROPER TYPE OF HOT RUNNER SYSTEM, COOLING LINE LAYOUT, RUNNER AND GATE DESIGN, VENTING, ETC
- PRODUCTION MOLDING SET UP GIVES OUT OF SPEC PARTS DUE TO DIFFERENCES WITH PROTOTYPE MOLD
- PRODUCTION PARTS INCONSISTENT BECAUSE PROCESSING WINDOW VERY NARROW OR EQUIPMENT IS INAPPROPRIATE

HUNDREDS OF THOUSANDS OF DOLLARS ARE LOST THIS WAY EVERY YEAR !!

Information Bulletin

High Performance Films

DuPont FEP

fluorocarbon film

Teflon® as Film

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

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

FEP Is Unique Among Plastics

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

DuPont FEP Film Is Offered

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

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

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

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

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

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

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

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

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

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

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

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

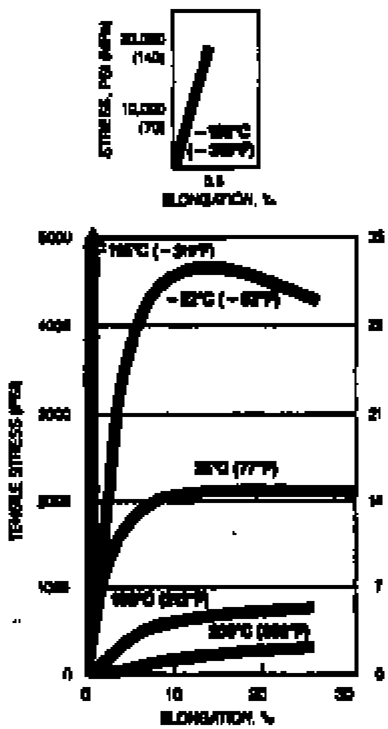


Table 2
Typical Mechanical Properties of DuPont FEP Film*

Property	ASTM Method	SI Units	English Units
Tensile strength (at break)	D-882-81	21 MPa	3000 psi
Elongation at break	D-882-81	300%	300%
Elastic modulus	D-882-81	480 MPa	70 000 psi
Yield point	D-882-81	12 MPa	1700 psi
Stress to produce 1% strain	D-882-81	12 MPa	1700 psi
Folding endurance (MIT)	D-2176-69	10,000 cycles	10,000 cycles
Initial tear strength (Graves)	D-1004-66	5.3 N	1.2 lbf
Propagating tear strength (Elmendorf)	D-1922-67	2.5 N	250 g
Bursting strength**	D-774-67 (Mullen)	76 kPa	11 psi
Density	D-1505-68	2150 kg/m³	134 lb/ft³
Coefficient of friction kinetic (film to steel)	D-1894-63	0.3	0.3

*200 gauge unless otherwise noted
**100 gauge film

Residual Shrinkage

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

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

Thermal Expansion

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

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

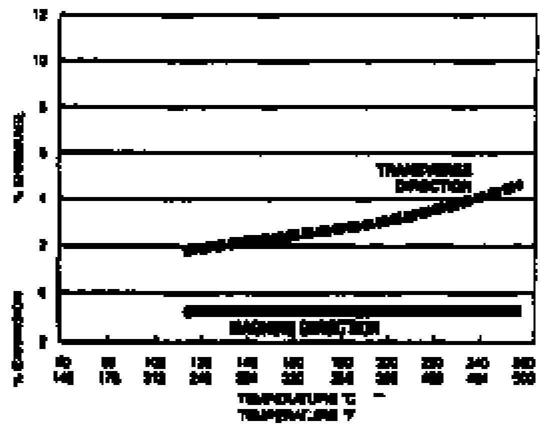


Table 3
Typical Thermal Properties of DuPont FEP Film*

Property	ASTM Method	SI Units	English Units
Melt point	D-3418 (DTA)	260–280°C	500–536°F
Maximum continuous service temperature		205°C	400°F
Zero strength** temperature	***	255°C	490°F
Specific heat		1172 J/kg·K	0.28 Btu/lb·°F
Coefficient of thermal conductivity		0.195 W/m·K	1.35 $\frac{Btu \cdot in}{h \cdot ft^2 \cdot °F}$
Coefficient of linear thermal expansion	D-696-70	$8.3 \times 10^{-5} \frac{mm}{mm \cdot °C}$	$4.6 \times 10^{-5} \frac{in}{in \cdot °F}$
Flammability classification	ANSI/UL-94	VTM-0	VTM-0
Oxygen index	D-2863-77	95%	95%
Dimensional stability MD	30 min at 150°C (302°F)	0.7% expansion	0.7% expansion
Dimensional stability TD		2.2% shrinkage	2.2% shrinkage

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

TI-NHTSA 018469

Dissipation Factor

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

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

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

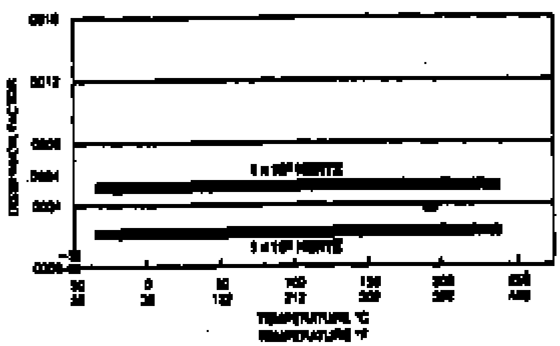
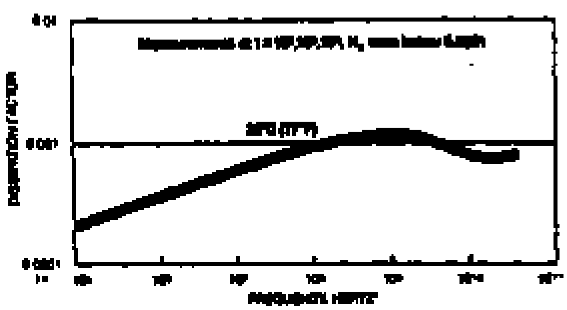


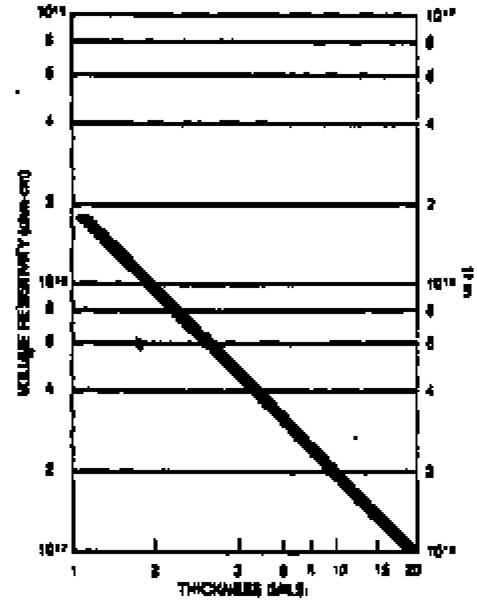
Figure 10. Dissipation Factor vs. Frequency of DuPont FEP Film



Volume Resistivity

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

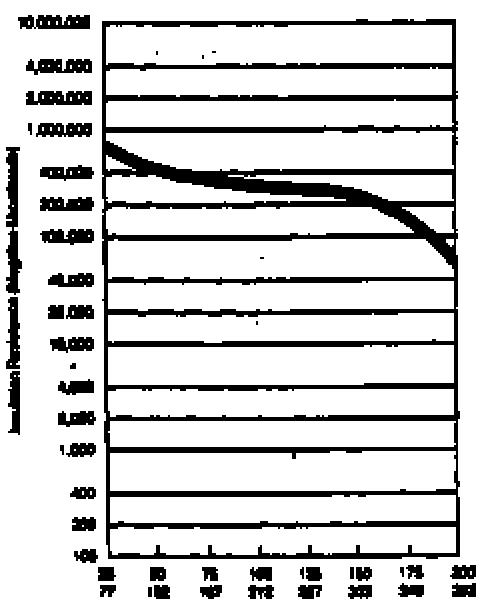
Figure 11. Volume Resistivity vs. Thickness (at 175°C (347°F))



Insulation Resistance

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

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



TI-NHTSA 018470

Chemical Properties

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

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

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

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

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

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

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

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

**Some halogenated solvents may cause moderate swelling.

TI-NHTSA 018471

Physical Properties

Absorption

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

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

Permeability

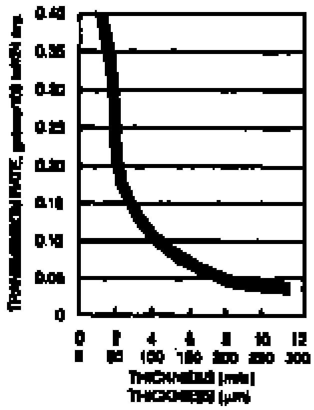
Many gases and vapors permeate FEP films at a much lower rate than for other thermoplastics (see Figure 13). In general, permeation increases with temperature, pressure, and surface contact area and decreases with increased film thickness. Table 6 lists rates at which various gases are transmitted through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

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

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

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

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



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

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

Vapor	Temperature °C	Temperature °F	Vapor Transmission Rate SI Units (g/m²·d)	Vapor Transmission Rate English Units (g/100 in²·d)
Acetic Acid	35	95	6.3	0.41
Acetone	35	95	14.7	0.95
Benzene	35	95	9.9	0.64
Carbon Tetrachloride	35	95	4.8	0.31
Ethyl Acetate	35	95	11.7	0.76
Ethyl Alcohol	35	95	10.7	0.69
Freon® F-12	23	73	372.0	24.0
Hexane	35	95	8.7	0.56
Hydrochloric Acid	25	77	<0.2	<0.01
Nitric Acid (Red Fuming)	25	77	160.0	10.5
Sodium Hydroxide, 50%	25	77	<0.2	<0.01
Sulfuric Acid, 98%	25	77	2×10^{-4}	1×10^{-5}
Water	39.5	103	7.0	0.45

TI-NHTSA 018472

07. 07. 92 11:00 AM P01

ROUTE TO

TEXAS INSTRUMENTS — REPORT OF DISCREPANT IN-PROCESS MATERIAL

No. 007745

27225-1 CARTON STRIP	☐	Y	[illegible]	[illegible]	Mfg. Supervision Review
DUPONT		[illegible]	045	1	

ITEM	[illegible]	ACTUAL				
01	Workmanship	Contamination trapped between layers of Kapton				
	6-15-92					

MATL/PROD. CONTROL

COMMENTS:

3 pages

TO: [redacted]

FROM: KEN BELEY FAX# 508-699-3788

508-699-[illegible]

TI-NHTSA 018473

07. 07. 92 11:00 AM P02

TEXAS INSTRUMENTS - M & C

CORRECTIVE ACTION REQUEST

THIS RESPONSE IS DUE 10 WORKDAYS AFTER RECEIPT AT YOUR FACILITY

RETURN TO:
Ken Beley MS 11-11
Texas Instruments Incorporated
34 Forest Street
Attleboro, MA 02703

DATE PREPARED:

SUPPLIER: E.I. DUPONT

PART NUMBER: 27225-1

ATTENTION: MIKE YEAGER

CAR/RDIMP: 007745

1. Do you understand the specification requirement(s) for the characteristic(s) rejected ? YES ☐ NO ☐

If no - describe concern:

If the requirement is not understood, what specific area of information needs clarification?

- TI print notation ☐
- TI purchase order ☐
- Standards of acceptance ☐
- Other - ☐

2. Please identify the actions you have taken to contain or limit the non-conformance at your facility until a corrective action is in place. Include comments on your inventory, in-transit material, and TI inventory.

What was the Effectivity Date of this containment action ? ______

3. Has your process, machinery or operation been significantly changed since this part number was qualified by M & C ?

07. 07. 92 11:00 AM P03

4. Have your measurement methods or inspection equipment significantly changed since this part number was qualified by M & C ? Please state your present measurement method.

5. What allowed this non-conformance to escape your testing ?

6. Other than "increased inspection," what specific action(s) will be taken to prevent the defect from recurring ?

What was the Effectivity Date of this corrective action ? ____________

Have you audited or verified that the above corrective action(s) will be effective in correcting the problem ?

If your current process or quality system is no longer capable of meeting M & C's specifications, contact the TI Purchasing agent or Procurement Assurance Engineer.

SUPPLIER'S AGENT : ____________ (please print) TITLE: ____________

DATE COMPLETED : ____________

TI-NHTSA 018474

DU PONT

CIRCLEVILLE PLANT
P.O. Box 89
Circleville OH 43113

cc: E.C.McKenzie,Conn.
S.T.Lewandowski,EMP192207,Wilm.

BCC: R.V.Gunn
File: 2-5-A

July 7, 1992

Mr. Ken Barry
Texas Instruments
Attleboro, Mass. 02703

Dear Mr. Barry:

The tested inspection system used for Kapton® uses a laser to detect either opaque objects or holes.

The equipment includes lane identifiers and lights to assist the operator in locating the object that activated the laser.

If an opaque object is larger than 50 mils in its largest dimension it is considered a defect.

As such it is marked and flagged so that it can be removed in a subsequent operation as the film is slit to customer's orders.

The black spot returned by Texas Instruments was only 13 mils in the largest dimension, so it is not considered a defect by existing standards.

If you have any further questions about the inspection method or the definition of a defect in Kapton® film, please do not hesitate to call Ed McKenzie at 302-871-7426 or me at 614-474-0127.

Sincerely,

J. M. Tesker

sjlm

Charting a Course for Excellence

Kapton & Oasis Products

DuPont

DuPont Films

customer | satisfaction | survey

'89–'96

TI-NHTSA 018475

ear Customer and Partner:

Thank you for responding to the 1996 Customer Satisfaction Survey for DuPont Kapton polyimide and Oasis composite films. This year's survey was mailed to 158 customers at 75 different companies in North America. We received responses from almost 60 percent of those customers, 90 percent of whom provided us with specific comments. We greatly appreciate so many of you taking the time to share your thoughts with us because we use this feedback to help drive our strategic business plans.

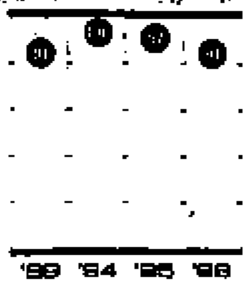
Compared to other suppliers of polyimide or composite films, 60 percent of you thought DuPont came out ahead in terms of industry leadership, sales representative support, customer service support, technical support and breadth of product line.

Also this year, we were pleased to receive yet another perfect score for our technical service representatives' understanding of your technical and manufacturing needs. Additionally, you gave us high marks for our range of film types, gauges, widths and put-ups; our responsiveness in modifying our products to meet your special needs; the way our products perform in your manufacturing operations and finished products; our responsiveness and effectiveness in solving technical problems; our contribution to improving your operational efficiency; our sales representatives' knowledge of high performance films and polymers; and our overall technical support.

We appreciate your continued confidence in us as a dependable supplier of polyimide film. At the same time, we realize there are other areas where we need to focus our improvement efforts. For example, you noted there is progress to be made in improving the consistency of our product quality, and in our communication to you of new and improved products. In addition, although many of you noted satisfaction with our delivery dates, your overall feedback indicates that our performance has deteriorated in this area.

TI-NHTSA 018476

[illegible]



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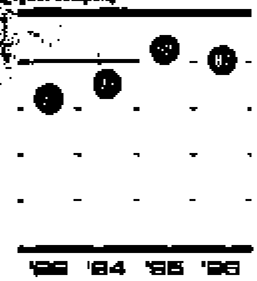
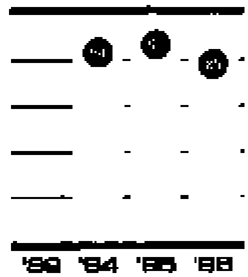
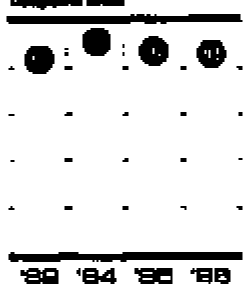


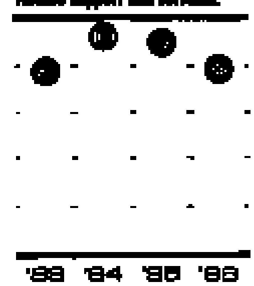
Our overall performance in helping make your business more successful.



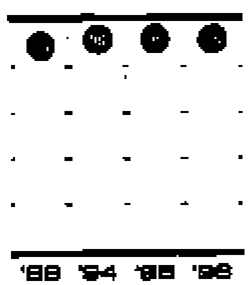
Your confidence in us as a dependable, long-term source of supply for polyimide and composite films.



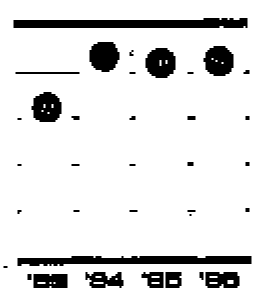
Your overall satisfaction with the value you receive from Kapton®/[illegible]® films and our related support and services.



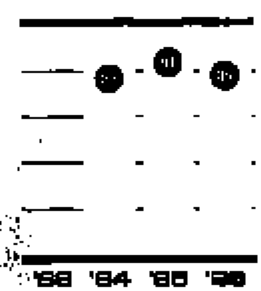
The range of Kapton®/[illegible]® film types, gauges, widths and/or [illegible] to meet your needs.



Our responsiveness in modifying Kapton®/[illegible]® to meet your special needs.



Our leadership in new product development in support of your business.



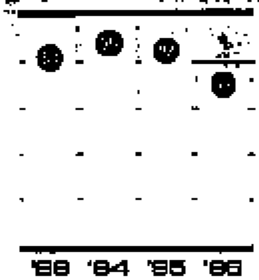
TI-NHTSA 018477

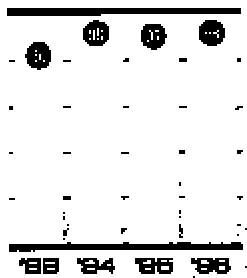
Last year, despite productivity increases of 15 percent at our Circleville, Ohio, facility and 100 percent at our Bayport site in Texas, the significant demand for polyimide and composite films extended order lead times. To address this issue, we are better integrating our manufacturing and business teams to improve our ability to forecast demand levels. In addition, we are expanding the schedule of our finishing area (where film is coated, laminated, treated, slit and converted for use in specific industry applications) from five days per week to seven. This will enable us to fill orders from semi-finished stock faster and to reduce delays. Our commitment to you is that if a shipment date cannot be met, one of our customer service representatives will call you five days in advance. If you are not completely satisfied, please call Leah Arledge, our Integrated Operations Superintendent, at (614) 474-0430.

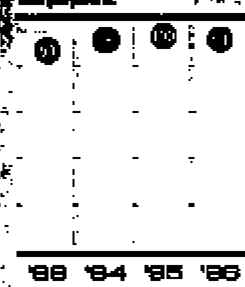
We are taking a number of additional steps to further improve our service to you. For example:

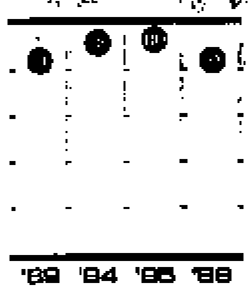
- *We have installed a new telecommunications system.* This system will enable us to more efficiently handle the increased volume of inquiries. We also have increased our Customer Service staff by 20 percent to provide faster, more personal response to your needs.
- *We are continuing our ongoing commitment to growth.* Output from our Bayport site has doubled, and we are on track to quadruple capacity for base film at this facility by 1998. In addition, we are increasing our finishing/slitting capacity in Luxembourg — consistent with our growth plans — and believe our production capability will benefit from raw material supplier expansions.
- *We are expanding our global operations.* At Tokai, Japan (a site operated as a 50/50 joint venture with Toray Industries, Inc.), we are adding a line for Kapton® polyimide film that will be operational by 1998. This new line will strengthen our ability to meet the needs of our customers and their end users in Asia, as well as provide additional global

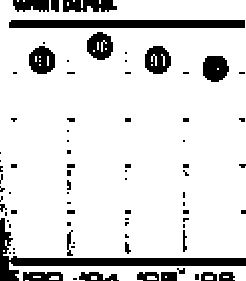
TI-NHTSA 018478











TI-NHTSA 018479

DuPont Films

High Performance Films

Kapton®

polyimide film

General Specifications

Introduction

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

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

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

Types of Kapton® Polyimide Film

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

Types H, F, and V are alternative, special versions of these standard types. The specifications in this bulletin apply to them as well. In addition to these three types of Kapton®, films are available with the following attributes:

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

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

Type HN Film

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

Type FN Film

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

TI-NHTSA 018483

Table 1
Kapton® FN Polyimide Film Types

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

Type VN Film

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

Certification

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

Thermal Durability

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

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

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

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

Properties of Type FN Film

Heat Seal Strength

Film-to-Film Seals

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

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

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

Film-to-Copper Seals

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

The peel strength is measured with the FEP side sealed to the untreated side of 1 mil (25.4 µm), ½ oz GT copper foil; it will be a minimum of 300 g/in (1.2 N/cm).

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

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

TI-NHTSA 018484

Table 2
Mechanical Properties of Kapton* Type HN Polyimide Film

Property	Property Value—Film Thickness, mil (µm) 0.30 (7.6)	0.50 (12.7)*	1.00 (25.4)*	2.00 (50.8)*	3.00 (76.2)*	5.00 (127)*	Method
Tensile Strength, psi (MPa) at 23°C (73°F), Machine Direction (MD) and Transverse Direction (TD), min.	16,000 (110)	20,000 (138)	24,000 (165)	24,000 (165)	24,000 (165)	24,000 (165)	ASTM D-882-91, Method A, using an Instron Tensile Tester (specimen size: ½" × 6" [12.7 mm × 152 mm]; jaw separation: 4" [102 mm]; jaw speed: 2"/min [51 mm/min]). Calculate the average of five specimens based on original measured thickness.
Elongation, %, MD and TD, min.	25	35	40	45	50	50	Same as above.
Shrinkage, %, MD and TD at 400°C (752°F), max.	4.0	4.0	2.5	2.5	2.5	2.5	MIL-P-46112B. The percent shrinkage is obtained for either the MD or TD using the average of three measurements in either direction before and after conditioning. Prior to measurement, the 8½" × 11" (216 mm × 279 mm) specimen is conditioned by freely suspending it for 2 hr** in an oven controlled to 400°C (752°F).
Moisture Absorption, %, max.	4.0	4.0	4.0	4.0	4.0	4.0	ASTM D-570-92, using 24-hr immersion at 23°C (73°F). Average of three specimens.

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

Table 3
Electrical Properties of HN Film

Property	Property Value—Film Thickness, mil (µm) 0.30 (7.6)	0.50 (12.7)*	1.00 (25.4)*	2.00 (50.8)*	3.00 (76.2)*	5.00 (127)*	Method
Dielectric Strength, AC V/mil (kV/mm), min.	3,000 (118)	3,000 (118)	6,000 (236)	5,000 (197)	4,500 (177)	3,000 (118)	ASTM D-149-94. (Average of ten specimens.) Flat sheets in air placed between ¼" (6 mm) diameter brass electrodes with $\frac{1}{32}$" (0.8 mm) edge radius subjected to 60 cycles AC voltage at 500 V/sec rate of rise to the breakdown voltage.
Volume Resistivity, ohm-cm at 200°C (392°F), min.	10^{12}	10^{12}	10^{12}	10^{13}	10^{13}	10^{13}	ASTM D-257-93
Dielectric Constant at 1 kHz, max.	4.0	4.0	3.9	3.9	3.9	3.9	ASTM D-150-94. Use conducting silver paint electrodes, two-terminal system of measurement at standard conditions. Results are based on an average of five tests using measured thickness of specimens.
Dissipation Factor at 1 kHz, max.	0.0070	0.0050	0.0036	0.0036	0.0036	0.0036	Same as above.

*Also applies to Type VN

TI-NHTSA 018486

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

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

Luxembourg Supply

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

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

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

Standard universal: core length

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

Wide universal: core length

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

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

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

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

Outside diameter tolerance: ±0.4" (10 mm)

Table 6
Kapton* Polyimide Film Specifications and Tolerances

Film Type	Thickness Nominal mil (µm)*	Thickness Tolerance Min. mil (µm)	Thickness Tolerance Max. mil (µm)	Width Range Min. in (mm)	Width Range Max. in (mm)	Unit Weight Min. g/m²	Unit Weight Max. g/m²	Area Factor ft²/lb	Area Factor (m²/kg)
30HN	0.30 (7.6)	0.24 (6.1)	0.36 (9.1)	3/16 (4.8)	52 (1320)	7.0	14.0	453	92.8
50HN	0.50 (12.7)	0.35 (8.9)	0.65 (16.5)	3/16 (4.8)	52 (1320)	14.0	26.0	272	55.7
100HN	1.00 (25.4)	0.85 (21.6)	1.15 (29.2)	3/16 (4.8)	52 (1320)	32.7	38.7	136	27.9
200HN	2.00 (50.8)	1.75 (44.5)	2.25 (57.2)	3/16 (4.8)	52 (1320)	66.9	77.9	68	13.9
300HN	3.00 (76.2)	2.72 (69.1)	3.28 (83.3)	3/16 (4.8)	52 (1320)	101.9	115.4	45	9.2
500HN	5.00 (127)	4.65 (118)	5.35 (136)	3/16 (4.8)	52 (1320)	169.5	192.5	27	5.5
50VN	0.50 (12.7)	0.35 (8.9)	0.65 (16.5)	3/16 (4.8)	52 (1320)	14.0	26.0	272	55.7
100VN	1.00 (25.4)	0.85 (21.6)	1.15 (29.2)	3/16 (4.8)	52 (1320)	32.7	38.7	136	27.9
200VN	2.00 (50.8)	1.75 (44.5)	2.25 (57.2)	3/16 (4.8)	52 (1320)	66.9	77.9	68	13.9
300VN	3.00 (76.2)	2.72 (69.1)	3.28 (83.3)	3/16 (4.8)	50 (1270)	101.9	115.4	45	9.2
500VN	5.00 (127)	4.65 (118)	5.35 (136)	3/16 (4.8)	50 (1270)	169.5	192.5	27	5.5
120FN616	1.20 (30.5)	1.10 (27.9)	1.40 (35.6)	3/16 (4.8)	44 (1118)	41.0	58.0	104	21.3
120FN616B	1.30 (33.0)	1.20 (30.5)	1.50 (38.1)	3/16 (4.8)	44 (1118)	47.0	54.0	92	18.8
150FN019	1.50 (38.1)	1.25 (31.8)	1.75 (44.5)	3/16 (4.8)	44 (1118)	53.0	74.0	77	15.8
200FN011	2.00 (50.8)	1.70 (43.2)	2.30 (58.4)	3/16 (4.8)	44 (1118)	77.0	104.0	54	11.1
200FN919	2.00 (50.8)	1.70 (43.2)	2.30 (58.4)	3/16 (4.8)	44 (1118)	77.0	104.0	54	11.1
250FN029	2.50 (63.5)	2.25 (57.2)	2.75 (69.9)	3/16 (4.8)	44 (1118)	87.0	113.0	49	10.0
300FN021	3.00 (76.2)	2.60 (66.0)	3.40 (86.4)	3/16 (4.8)	44 (1118)	111.0	142.0	39	8.0
300FN929	3.00 (76.2)	2.60 (66.0)	3.40 (86.4)	3/16 (4.8)	44 (1118)	111.0	142.0	39	8.0
400FN022	4.00 (102)	3.50 (88.9)	4.50 (114)	3/16 (4.8)	44 (1118)	163.0	200.0	27	5.5
500FN131	5.00 (127)	4.50 (114)	5.50 (140)	3/16 (4.8)	44 (1118)	199.0	230.0	23	4.7

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

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

DuPont High Performance Films

Kapton® polyimide film

TI-NHTSA 018487

General Information

Kapton® polyimide film possesses a unique combination of properties that make it ideal for a variety of applications in many different industries. The ability of Kapton® to maintain its excellent physical, electrical, and mechanical properties over a wide temperature range has opened new design and application areas to plastic films.

Kapton® is synthesized by polymerizing an aromatic dianhydride and an aromatic diamine. It has excellent chemical resistance; there are no known organic solvents for the film. Kapton® does not melt or burn as it has the highest UL-94 flammability rating: V-0. The outstanding properties of Kapton® permit it to be used at both high and low temperature extremes where other organic polymeric materials would not be functional.

Adhesives are available for bonding Kapton® to itself and to metals, various paper types, and other films.

Kapton® polyimide film can be used in a variety of electrical and electronic insulation applications: wire and cable tapes, formed coil insulation, substrates for flexible printed circuits, motor slot liners, magnet wire insulation, transformer and capacitor insulation, magnetic and pressure-sensitive tapes, and tubing. Many of these applications are based on the excellent balance of electrical, thermal, mechanical, physical, and chemical properties of Kapton® over a wide range of temperatures. It is this combination of useful properties at temperature extremes that makes Kapton® a unique industrial material.

Three types of Kapton® are described in this bulletin:

- Kapton® Type HN, all-polyimide film, has been used successfully in applications at temperatures as low as −269°C (−452°F) and as high as 400°C (752°F).

  Type HN film can be laminated, metallized, punched, formed, or adhesive coated. It is available as 7.5 µm (0.3 mil), 12.5 µm (0.5 mil), 19 µm (0.75 mil), 25 µm (1 mil), 50 µm (2 mil), 75 µm (3 mil), and 125 µm (5 mil) films.

- Kapton® Type VN, all-polyimide film with all of the properties of Type HN, plus superior dimensional stability. Type VN is available as 12.5 µm (0.5 mil), 19 µm (0.75 mil), 25 µm (1 mil), 50 µm (2 mil), 75 µm (3 mil), and 125 µm (5 mil) films.

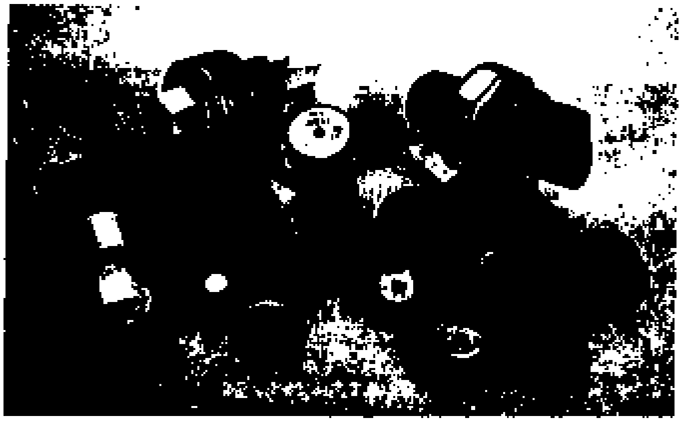
- Kapton® Type FN, a Type HN film coated on one or both sides with Teflon® FEP fluoropolymer resin, imparts heat sealability, provides a moisture barrier, and enhances chemical resistance. Type FN is available in a number of combinations of polyimide and Teflon® FEP thicknesses (see Table 16).

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

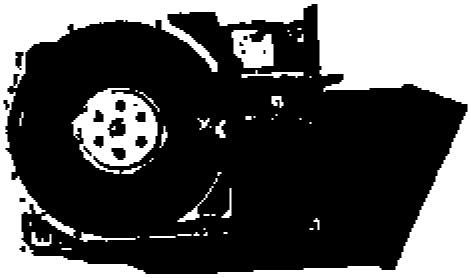
- antistat
- thermally conductive
- polyimides for fine line circuitry
- cryogenic insulation
- corona resistant
- pigmented for color
- conformable
- other films tailored to meet customers' needs

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

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



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



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

TI-NHTSA 018489

Physical and Thermal Properties

Kapton® polyimide films retain their physical properties over a wide temperature range. They have been used in field applications where the environmental temperatures were as low as −269°C (−452°F) and as high as 400°C (752°F). Complete data are not available at these extreme conditions, and the majority of technical data presented in this section falls in the 23 to 200°C (73 to 392°F) range.

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

Physical Property	Typical Value at 23°C (73°F)	Typical Value at 200°C (392°F)	Test Method
Ultimate Tensile Strength, MPa (psi)	231 (33,500)	139 (20,000)	ASTM D-882-91, Method A*
Yield Point at 3%, MPa (psi)	69 (10,000)	41 (6000)	ASTM D-882-91
Stress to Produce 5% Elongation, MPa (psi)	90 (13,000)	61 (9000)	ASTM D-882-91
Ultimate Elongation, %	72	83	ASTM D-882-91
Tensile Modulus, GPa (psi)	2.5 (370,000)	2.0 (290,000)	ASTM D-882-91
Impact Strength, N·cm (ft·lb)	78 (0.58)		DuPont Pneumatic Impact Test
Folding Endurance (MIT), cycles	285,000		ASTM D-2176-89
Tear Strength—Propagating (Elmendorf), N (lbf)	0.07 (0.02)		ASTM D-1922-89
Tear Strength—Initial (Graves), N (lbf)	7.2 (1.6)		ASTM D-1004-90
Density, g/cc or g/mL	1.42		ASTM D-1505-90
Coefficient of Friction—Kinetic (Film-to-Film)	0.48		ASTM D-1894-90
Coefficient of Friction—Static (Film-to-Film)	0.63		ASTM D-1894-90
Refractive Index (Sodium D Line)	1.70		ASTM D-542-90
Poisson's Ratio	0.34		Avg. Three Samples Elongated at 5%, 7%, 10%
Low Temperature Flex Life	Pass		IPC TM 650, Method 2.6.18

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

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

Thermal Property	Typical Value	Test Condition	Test Method
Melting Point	None	None	ASTM E-794-85 (1989)
Thermal Coefficient of Linear Expansion	20 ppm/°C (11 ppm/°F)	−14 to 38°C (7 to 100°F)	ASTM D-696-91
Coefficient of Thermal Conductivity, W/m·K	0.12	296 K	ASTM F-433-77 (1987)ε1
$\frac{cal}{cm \cdot sec \cdot °C}$	2.87×10^{-4}	23°C	
Specific Heat, J/g·K (cal/g·°C)	1.09 (0.261)		Differential Calorimetry
Flammability	94V-0		UL-94 (2-8-85)
Shrinkage, %	0.17 1.25	30 min at 150°C 120 min at 400°C	IPC TM 650, Method 2.2.4A ASTM D-5214-91
Heat Sealability	Not Heat Sealable		
Limiting Oxygen Index, %	37		ASTM D-2863-87
Solder Float	Pass		IPC TM 650, Method 2.4.13A
Smoke Generation	DM = <1	NBS Smoke Chamber	NFPA-258
Glass Transition Temperature (T_g)	A second order transition occurs in Kapton® between 360°C (680°F) and 410°C (770°F) and is assumed to be the glass transition temperature. Different measurement techniques produce different results within the above temperature range.		

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

Property	Typical Value for Film Thickness				Test Method
	25 µm (1 mil)	50 µm (2 mil)	75 µm (3 mil)	125 µm (5 mil)	
Ultimate Tensile Strength, MPa (psi)	231 (33,500)	234 (34,000)	231 (33,500)	231 (33,500)	ASTM D-882-91
Ultimate Elongation, %	72	82	82	82	ASTM D-882-91
Tear Strength—Propagating (Elmendorf), N	0.07	0.21	0.38	0.58	ASTM D-1922-89
Tear Strength—Initial (Graves), N	7.2	18.3	26.3	46.9	ASTM D-1004-90
Folding Endurance (MIT), × 10³ cycles	285	55	6	5	ASTM D-2176-89
Density, g/cc or g/mL	1.42	1.42	1.42	1.42	ASTM D-1505-90
Flammability	94V-0	94V-0	94V-0	94V-0	UL-94 (2-8-85)
Shrinkage, %, 30 min at 150°C (302°F)	0.03	0.03	0.03	0.03	IPC TM 650 Method 2.2.4A
Limiting Oxygen Index, %	37	43	46	45	ASTM D-2863-87

Table 4
Physical Properties of Kapton® Type FN Film*

Property	Typical Value for Film Type**		
	120FN616	150FN019	250FN029
Ultimate Tensile Strength, MPa (psi)			
23°C (73°F)	207 (30,000)	162 (23,500)	200 (29,000)
200°C (392°F)	121 (17,500)	89 (13,000)	115 (17,000)
Yield Point at 3%, MPa (psi)			
23°C (73°F)	61 (9000)	49 (7000)	58 (8500)
200°C (392°F)	42 (6000)	43 (6000)	39 (6000)
Stress at 5% Elongation, MPa (psi)			
23°C (73°F)	79 (11,500)	65 (9,500)	76 (11,000)
200°C (392°F)	53 (8000)	41 (6000)	48 (7000)
Ultimate Elongation, %			
23°C (73°F)	75	70	85
200°C (392°F)	80	75	110
Tensile Modulus, GPa (psi)			
23°C (73°F)	2.48 (360,000)	2.28 (330,000)	2.62 (380,000)
200°C (392°F)	1.62 (235,000)	1.14 (165,000)	1.38 (200,000)
Impact Strength at 23°C (73°F), N·cm (ft·lb)	78 (0.58)	68.6 (0.51)	156.9 (1.16)
Tear Strength—Propagating (Elmendorf), N (lbf)	0.08 (0.02)	0.47 (0.11)	0.57 (0.13)
Tear Strength—Initial (Graves), N (lbf)	11.8 (2.6)	11.5 (2.6)	17.8 (4.0)
Polyimide, wt%	80	57	73
FEP, wt%	20	43	27
Density, g/cc or g/mL	1.53	1.67	1.57

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

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

TI-NHTSA 018491

Mechanical Properties

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

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

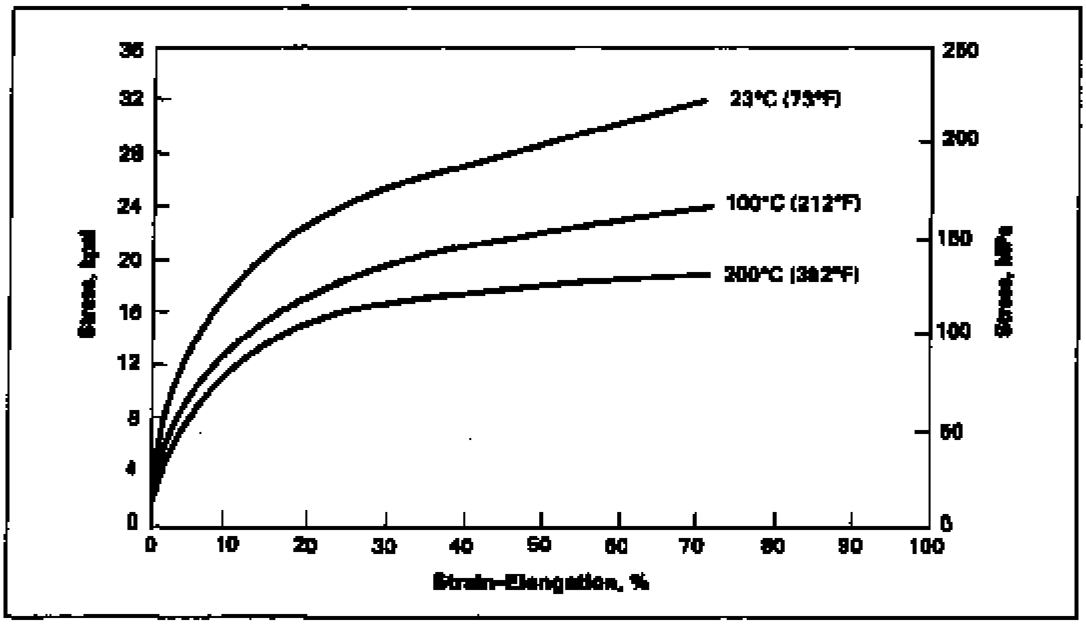
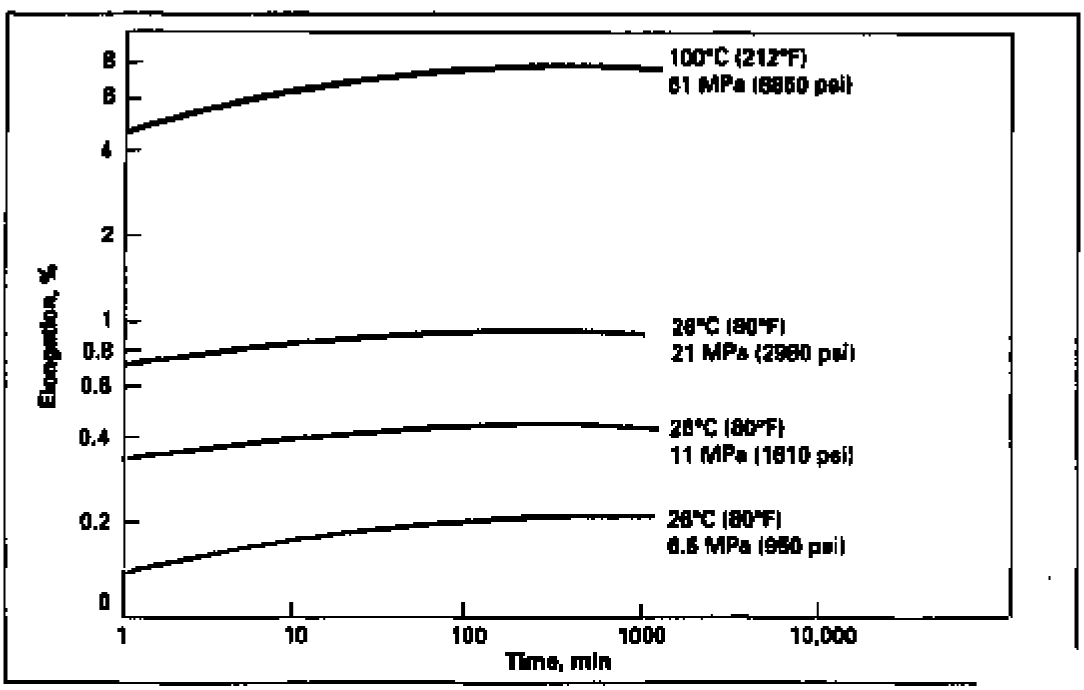


Figure 2. Tensile Creep Properties, Type HN Film, 25 µm (1 mil)



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Hydrolytic Stability

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

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

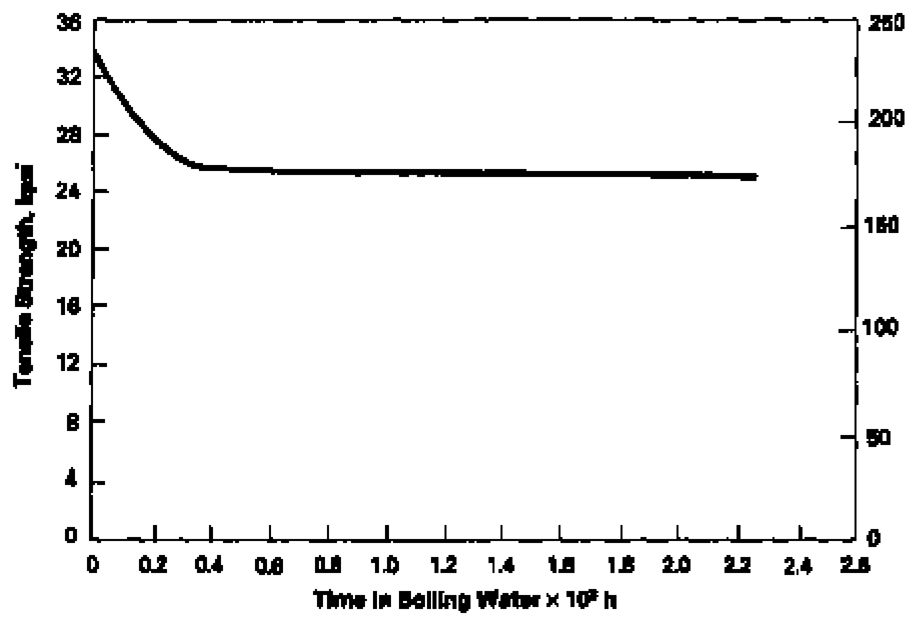
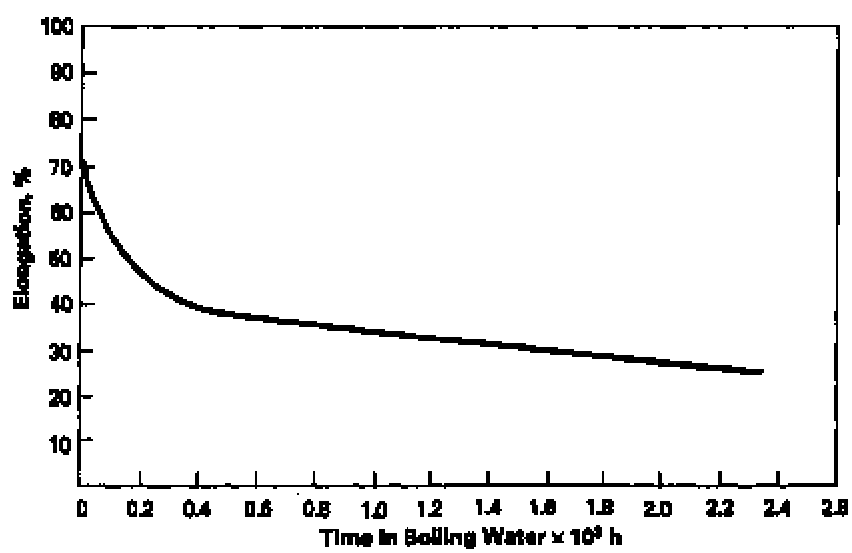


Figure 4. Ultimate Elongation After Exposure to 100°C (212°F) Water, Type HN Film, 25 µm (1 mil)

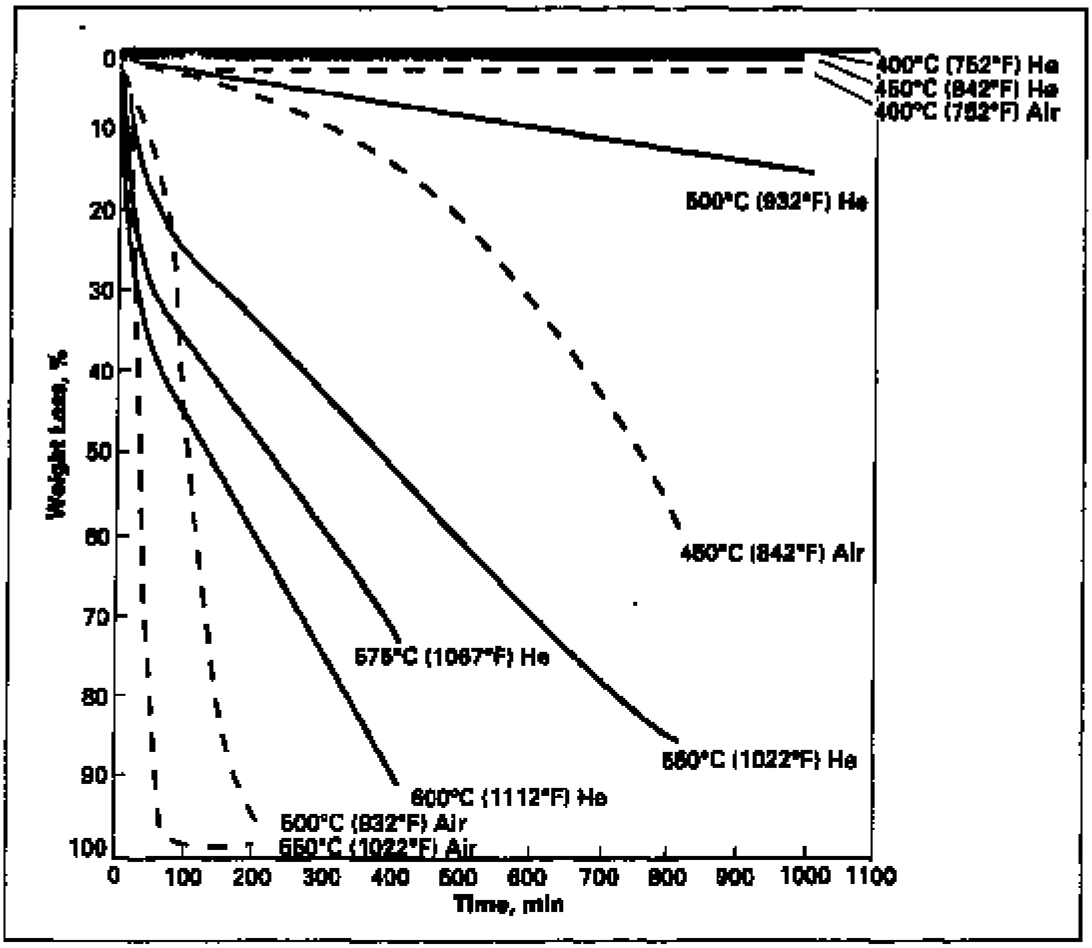


TI-NHTSA 018493

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

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

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



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Chemical Properties

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

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

Property	Typical Value: Tensile Retained, %	Typical Value: Elongation Retained, %	Test Condition	Test Method
Chemical Resistance				
Isopropyl Alcohol	96	94	10 min at 23°C	IPC TM-650 Method 2.3.3B
Toluene	99	91		
Methyl Ethyl Ketone	99	90		
Methylene Chloride/ Trichloroethylene (1:1)	98	85		
2 N Hydrochloric Acid	86	89		
2 N Sodium Hydroxide	82	54		
Fungus Resistance	Nonnutrient			IPC TM-650 Method 2.6.1
Moisture Absorption	1.8% Types HN and VN		50% RH at 23°C	ASTM D-570-81 (1988)*1
	2.8% Types HN and VN		Immersion for 24 h at 23°C (73°F)	
Hygroscopic Coefficient of Expansion	22 ppm/% RH		23°C (73°F), 20–80% RH	
Permeability				
Gas	*mL/m²·24 h·MPa*	*cc/(100 in²·24 h·atm)*	23°C (73°F), 50% RH	ASTM D-1434-82 (1988)*1
Carbon Dioxide	6840	45		
Oxygen	3800	25		
Hydrogen	38,000	250		
Nitrogen	910	6		
Helium	63,080	415		
Vapor	*g/(m²·24 h)*	*g/(100 in²·24 h)*		ASTM E-96-92
Water	54	3.5		

Table 11
Chemical Properties of Kapton® Type FN Film

Property	120FN616	150FN019	400FN022
Moisture Absorption, %			
at 23°C (73°F), 50% RH	1.3	0.8	0.4
95% RH	2.5	1.7	1.2
Water Vapor Permeability,			
g/(m²·24 h)	17.5	9.6	2.4
g/(100 in²·24 h)	1.13	0.62	0.16

CONTENTS

Kapton® POLYIMIDE FILM

GENERAL INFORMATION

KAPTON* polyimide film possesses a unique combination of properties previously unavailable among polymeric film materials. The ability of KAPTON to maintain its excellent physical, electrical and mechanical properties over a wide temperature range has opened new design and application areas to plastic films. KAPTON has proved to be especially useful in applications involving high operating temperatures.

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

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

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

Du Pont makes three types of KAPTON:

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

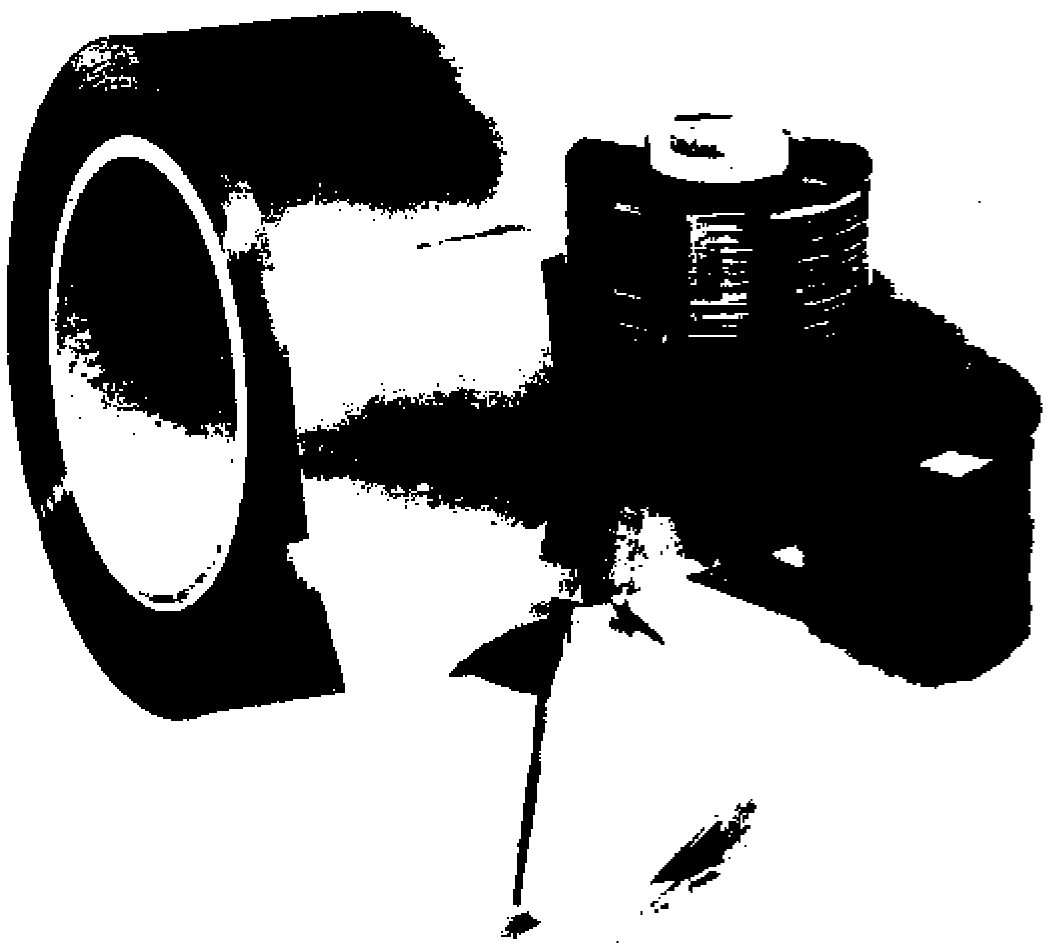
Note: This bulletin provides a summary of typical properties for all three KAPTON polyimide films Type H, Type V and Type F. Additional data should be obtained from your Du Pont Industrial Films Division representative for specification purposes.

*Reg. U.S. Pat. Off.

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

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

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



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DU PONT

TI-NHTSA 018499

DuPont High Performance Films

Kapton® polyimide film

TI-NHTSA 018500

Table of Contents

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

General Information

Kapton® polyimide film possesses a unique combination of properties that make it ideal for a variety of applications in many different industries. The ability of Kapton® to maintain its excellent physical, electrical, and mechanical properties over a wide temperature range has opened new design and application areas to plastic films.

Kapton® is synthesized by polymerizing an aromatic dianhydride and an aromatic diamine. It has excellent chemical resistance; there are no known organic solvents for the film. Kapton® does not melt or burn as it has the highest UL-94 flammability rating: V-0. The outstanding properties of Kapton® permit it to be used at both high and low temperature extremes where other organic polymeric materials would not be functional.

Adhesives are available for bonding Kapton® to itself and to metals, various paper types, and other films.

Kapton® polyimide film can be used in a variety of electrical and electronic insulation applications: wire and cable tapes, formed coil insulation, substrates for flexible printed circuits, motor slot liners, magnet wire insulation, transformer and capacitor insulation, magnetic and pressure-sensitive tapes, and tubing. Many of these applications are based on the excellent balance of electrical, thermal, mechanical, physical, and chemical properties of Kapton® over a wide range of temperatures. It is this combination of useful properties at temperature extremes that makes Kapton® a unique industrial material.

Three types of Kapton® are described in this bulletin:

- Kapton® Type HN, all-polyimide film, has been used successfully in applications at temperatures as low as −269°C (−452°F) and as high as 400°C (752°F).

  Type HN film can be laminated, metallized, punched, formed, or adhesive coated. It is available as 7.5 µm (0.3 mil), 12.5 µm (0.5 mil), 19 µm (0.75 mil), 25 µm (1 mil), 50 µm (2 mil), 75 µm (3 mil), and 125 µm (5 mil) films.
- Kapton® Type VN, all-polyimide film with all of the properties of Type HN, plus superior dimensional stability. Type VN is available as 12.5 µm (0.5 mil), 19 µm (0.75 mil), 25 µm (1 mil), 50 µm (2 mil), 75 µm (3 mil), and 125 µm (5 mil) films.
- Kapton® Type FN, a Type HN film coated on one or both sides with Teflon® FEP fluoropolymer resin, imparts heat sealability, provides a moisture barrier, and enhances chemical resistance. Type FN is available in a number of combinations of polyimide and Teflon® FEP thicknesses (see **Table 16**).

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

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

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

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

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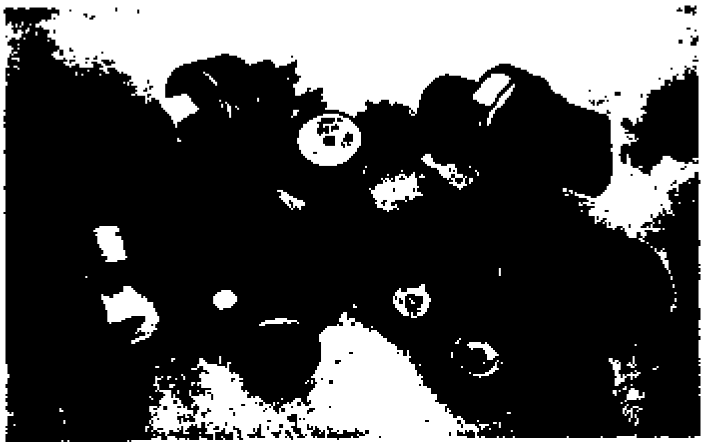
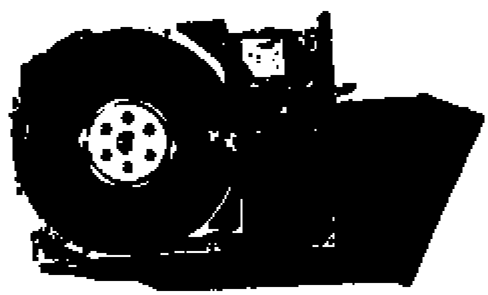


Kapton® withstands the harsh chemical and physical demands on diaphragms used in automotive switches.



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

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Physical and Thermal Properties

Kapton® polyimide films retain their physical properties over a wide temperature range. They have been used in field applications where the environmental temperatures were as low as −269°C (−452°F) and as high as 400°C (752°F). Complete data are not available at these extreme conditions, and the majority of technical data presented in this section falls in the 23 to 200°C (73 to 392°F) range.

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

Physical Property	Typical Value at 23°C (73°F)	Typical Value at 200°C (392°F)	Test Method
Ultimate Tensile Strength, MPa (psi)	231 (33,500)	139 (20,000)	ASTM D-882-91, Method A*
Yield Point at 3%, MPa (psi)	69 (10,000)	41 (6000)	ASTM D-882-91
Stress to Produce 5% Elongation, MPa (psi)	90 (13,000)	61 (9000)	ASTM D-882-91
Ultimate Elongation, %	72	83	ASTM D-882-91
Tensile Modulus, GPa (psi)	2.5 (370,000)	2.0 (290,000)	ASTM D-882-91
Impact Strength, N·cm (ft·lb)	78 (0.58)		DuPont Pneumatic Impact Test
Folding Endurance (MIT), cycles	285,000		ASTM D-2176-89
Tear Strength—Propagating (Elmendorf), N (lbf)	0.07 (0.02)		ASTM D-1922-89
Tear Strength—Initial (Graves), N (lbf)	7.2 (1.6)		ASTM D-1004-90
Density, g/cc or g/mL	1.42		ASTM D-1505-90
Coefficient of Friction—Kinetic (Film-to-Film)	0.48		ASTM D-1894-90
Coefficient of Friction—Static (Film-to-Film)	0.63		ASTM D-1894-90
Refractive Index (Sodium D Line)	1.70		ASTM D-542-90
Poisson's Ratio	0.34		Avg. Three Samples Elongated at 5%, 7%, 10%
Low Temperature Flex Life	Pass		IPC TM 650, Method 2.6.18

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

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

Thermal Property	Typical Value	Test Condition	Test Method
Melting Point	None	None	ASTM E-794-85 (1989)
Thermal Coefficient of Linear Expansion	20 ppm/°C (11 ppm/°F)	−14 to 38°C (7 to 100°F)	ASTM D-696-91
Coefficient of Thermal Conductivity, W/m·K	0.12	296 K	ASTM F-433-77 (1987)ε1
$\frac{cal}{cm \cdot sec \cdot °C}$	2.87×10^{-4}	23°C	
Specific Heat, J/g·K (cal/g·°C)	1.09 (0.261)		Differential Calorimetry
Flammability	94V-0		UL-94 (2-8-85)
Shrinkage, %	0.17 1.25	30 min at 150°C 120 min at 400°C	IPC TM 650, Method 2.2.4A ASTM D-5214-91
Heat Sealability	Not Heat Sealable		
Limiting Oxygen Index, %	37		ASTM D-2863-87
Solder Float	Pass		IPC TM 650, Method 2.4.13A
Smoke Generation	DM = <1	NBS Smoke Chamber	NFPA-258
Glass Transition Temperature (T_g)	A second order transition occurs in Kapton® between 360°C (680°F) and 410°C (770°F) and is assumed to be the glass transition temperature. Different measurement techniques produce different results within the above temperature range.		

TI-NHTSA 018604

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

Property	Typical Value for Film Thickness: 25 µm (1 mil)	50 µm (2 mil)	75 µm (3 mil)	125 µm (5 mil)	Test Method
Ultimate Tensile Strength, MPa (psi)	231 (33,500)	234 (34,000)	231 (33,500)	231 (33,500)	ASTM D-882-91
Ultimate Elongation, %	72	82	82	82	ASTM D-882-91
Tear Strength—Propagating (Elmendorf), N	0.07	0.21	0.38	0.58	ASTM D-1922-89
Tear Strength—Initial (Graves), N	7.2	16.3	26.3	46.9	ASTM D-1004-90
Folding Endurance (MIT), × 10³ cycles	285	55	6	5	ASTM D-2176-89
Density, g/cc or g/mL	1.42	1.42	1.42	1.42	ASTM D-1505-90
Flammability	94V-0	94V-0	94V-0	94V-0	UL-94 (2-8-85)
Shrinkage, %, 30 min at 150°C (302°F)	0.03	0.03	0.03	0.03	IPC TM 650 Method 2.2.4A
Limiting Oxygen Index, %	37	43	46	45	ASTM D-2863-87

Table 4
Physical Properties of Kapton® Type FN Film*

Property	Typical Value for Film Type**: 120FN616	150FN019	250FN029
Ultimate Tensile Strength, MPa (psi)			
23°C (73°F)	207 (30,000)	162 (23,500)	200 (29,000)
200°C (392°F)	121 (17,500)	89 (13,000)	115 (17,000)
Yield Point at 3%, MPa (psi)			
23°C (73°F)	61 (9000)	49 (7000)	58 (8500)
200°C (392°F)	42 (6000)	43 (6000)	36 (5000)
Stress at 5% Elongation, MPa (psi)			
23°C (73°F)	79 (11,500)	65 (9,500)	76 (11,000)
200°C (392°F)	53 (8000)	41 (6000)	48 (7000)
Ultimate Elongation, %			
23°C (73°F)	75	70	85
200°C (392°F)	80	75	110
Tensile Modulus, GPa (psi)			
23°C (73°F)	2.48 (360,000)	2.28 (330,000)	2.62 (380,000)
200°C (392°F)	1.62 (235,000)	1.14 (165,000)	1.38 (200,000)
Impact Strength at 23°C (73°F), N·cm (ft·lb)	78 (0.58)	68.6 (0.51)	156.9 (1.16)
Tear Strength—Propagating (Elmendorf), N (lbf)	0.08 (0.02)	0.47 (0.11)	0.57 (0.13)
Tear Strength—Initial (Graves), N (lbf)	11.8 (2.6)	11.5 (2.6)	17.8 (4.0)
Polyimide, wt%	80	57	73
FEP, wt%	20	43	27
Density, g/cc or g/mL	1.53	1.67	1.57

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

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

TI-NHTSA 018505

Mechanical Properties

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

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

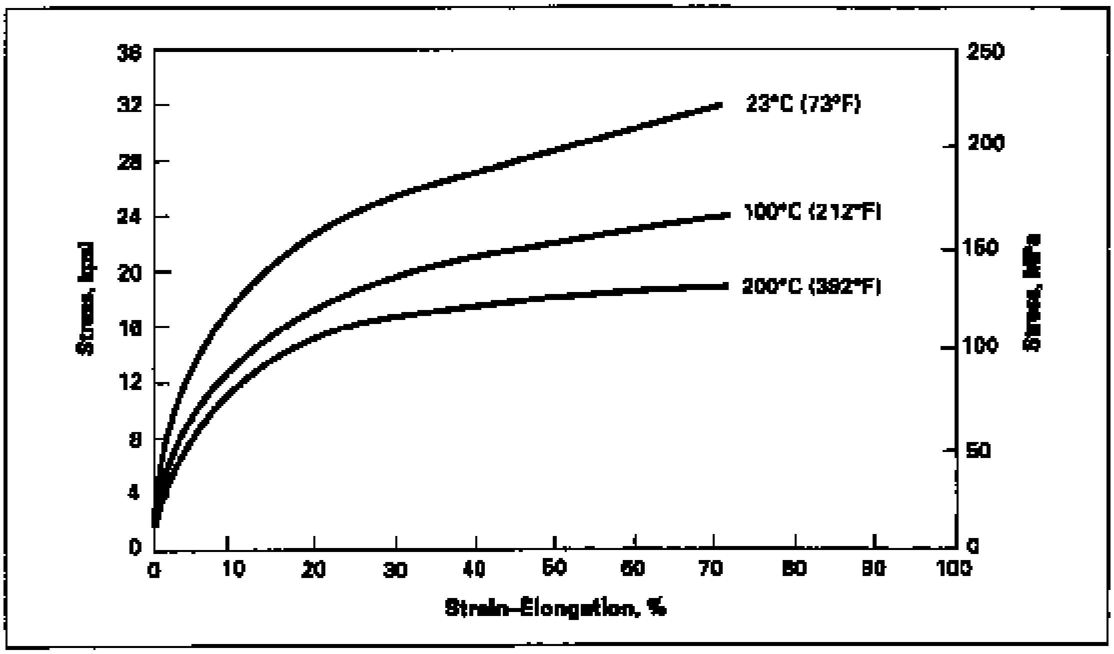
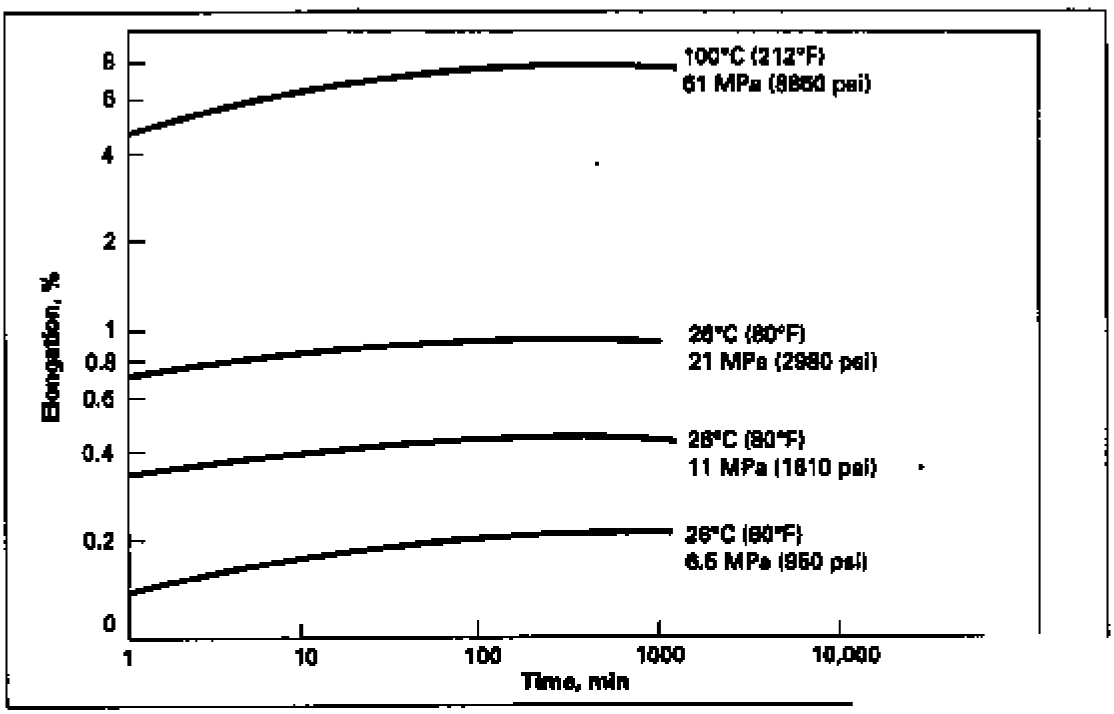


Figure 2. Tensile Creep Properties, Type HN Film, 25 µm (1 mil)



TI-NHTSA 016505

Hydrolytic Stability

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

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

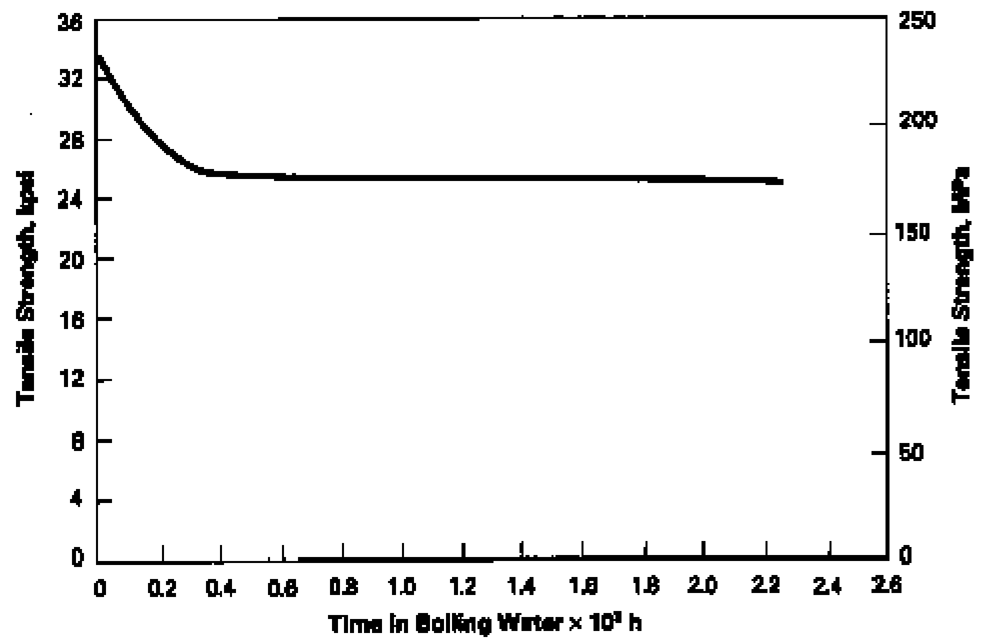
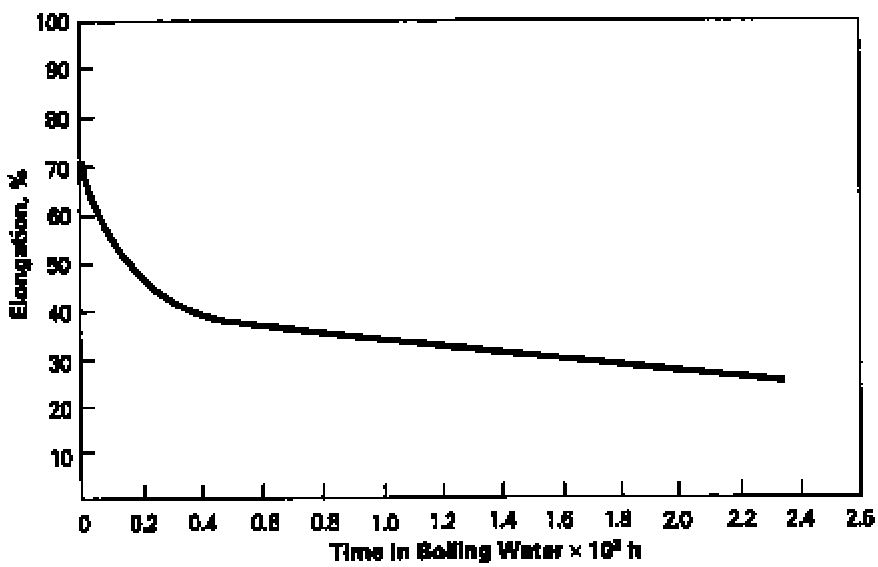


Figure 4. Ultimate Elongation After Exposure to 100°C (212°F) Water, Type HN Film, 25 μm (1 mil)

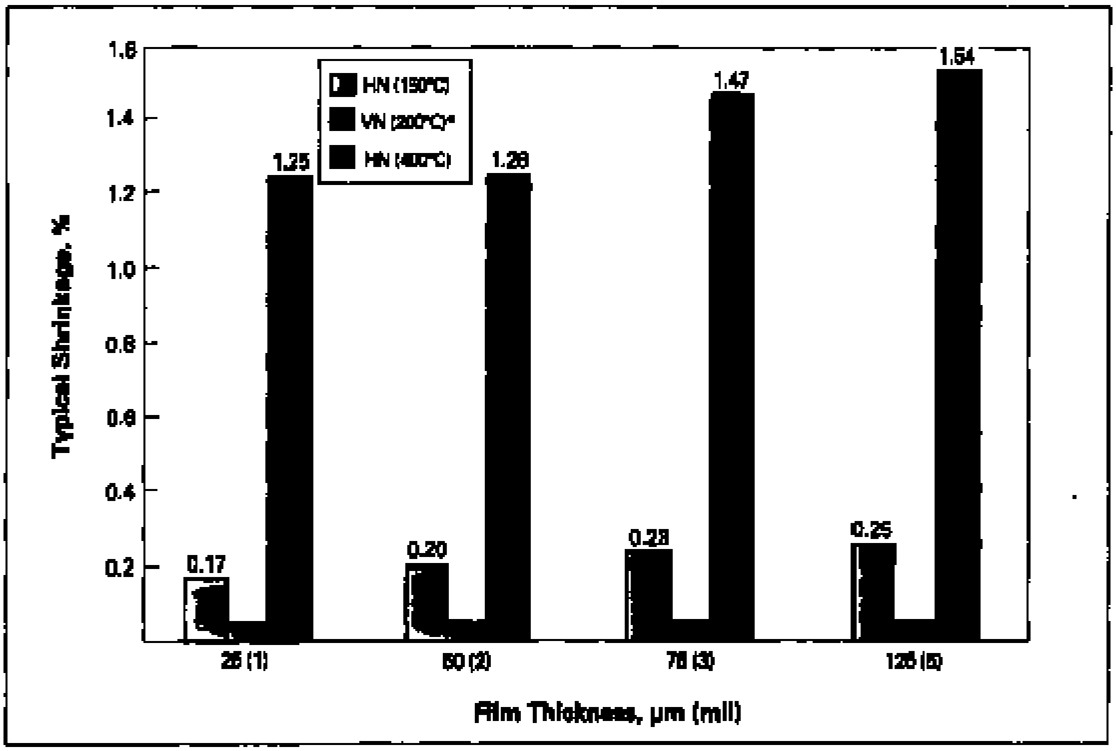


TI-NHTSA 018507

Dimensional Stability

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

Figure 5. Residual Shrinkage vs. Exposure Temperature and Thickness, Type HN and VN Films



*Type VN shrinkage is 0.03% for all thicknesses.

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

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

TI-NHTSA 018508

Thermal Aging

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

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

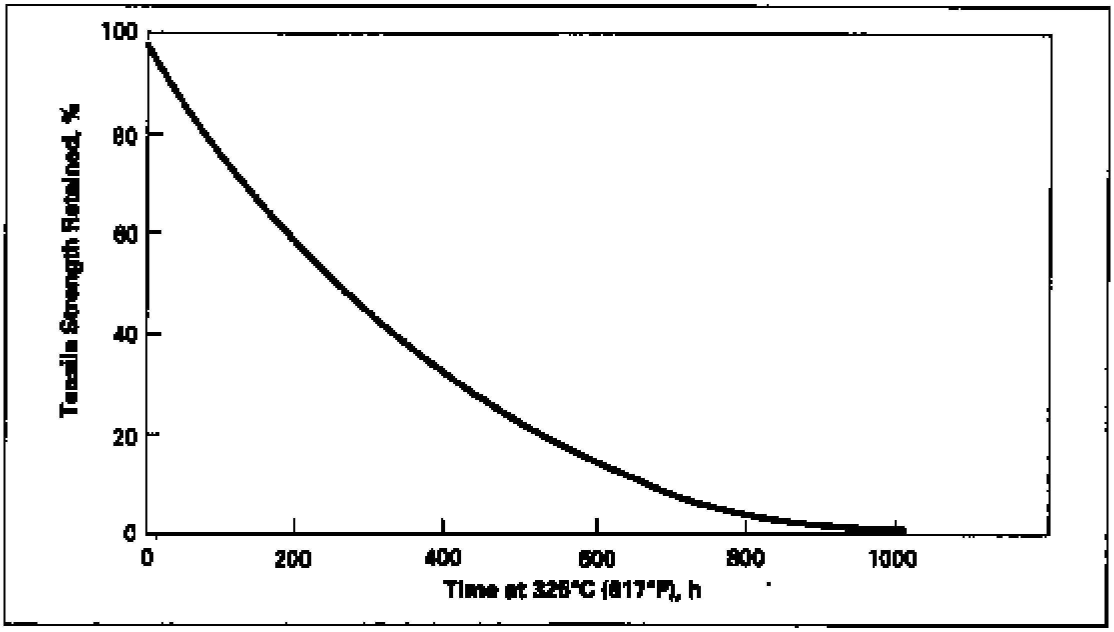
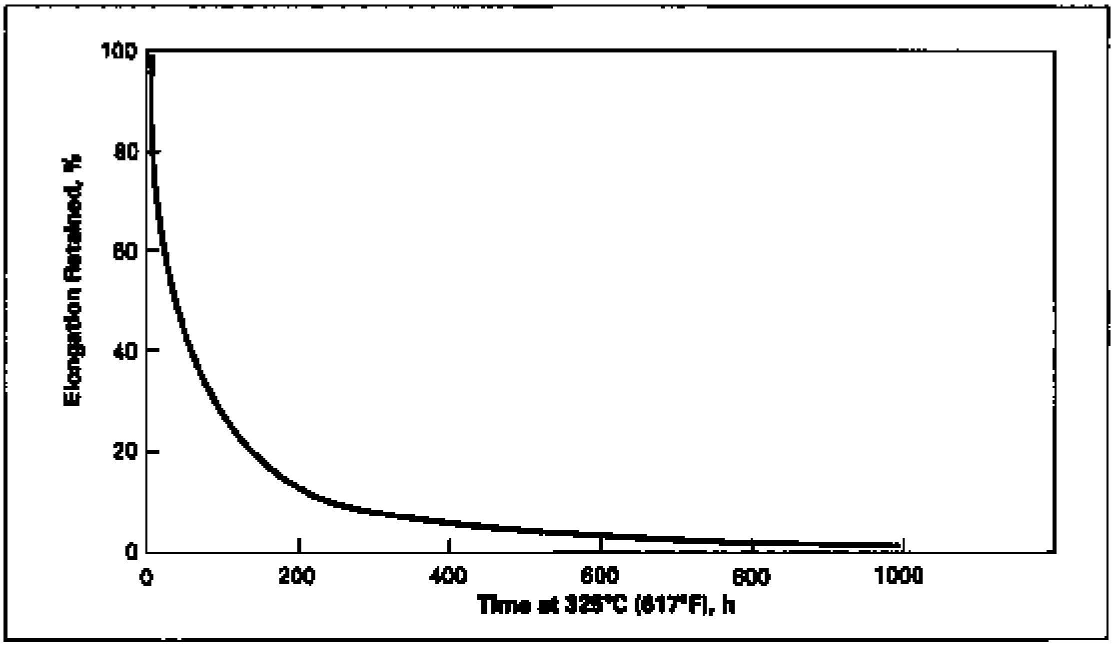
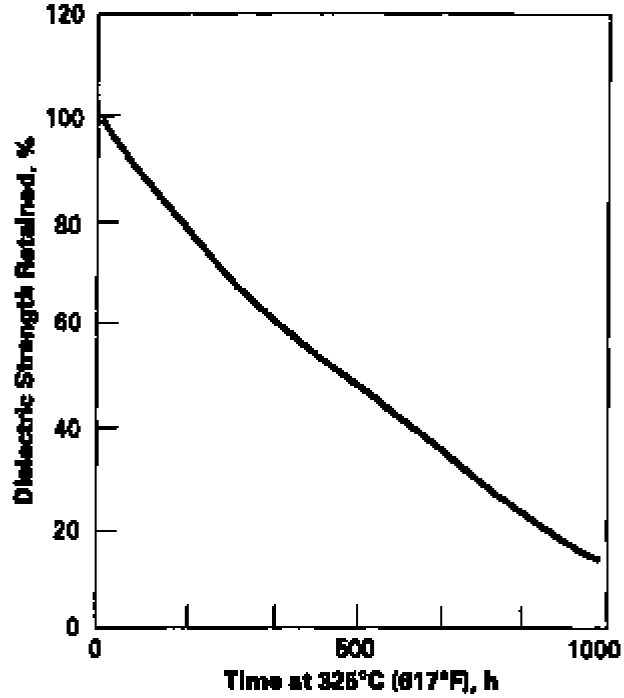


Figure 7. Ultimate Elongation vs. Aging in Air at 325°C (617°F), Type HN Film, 25 μm (1 mil)



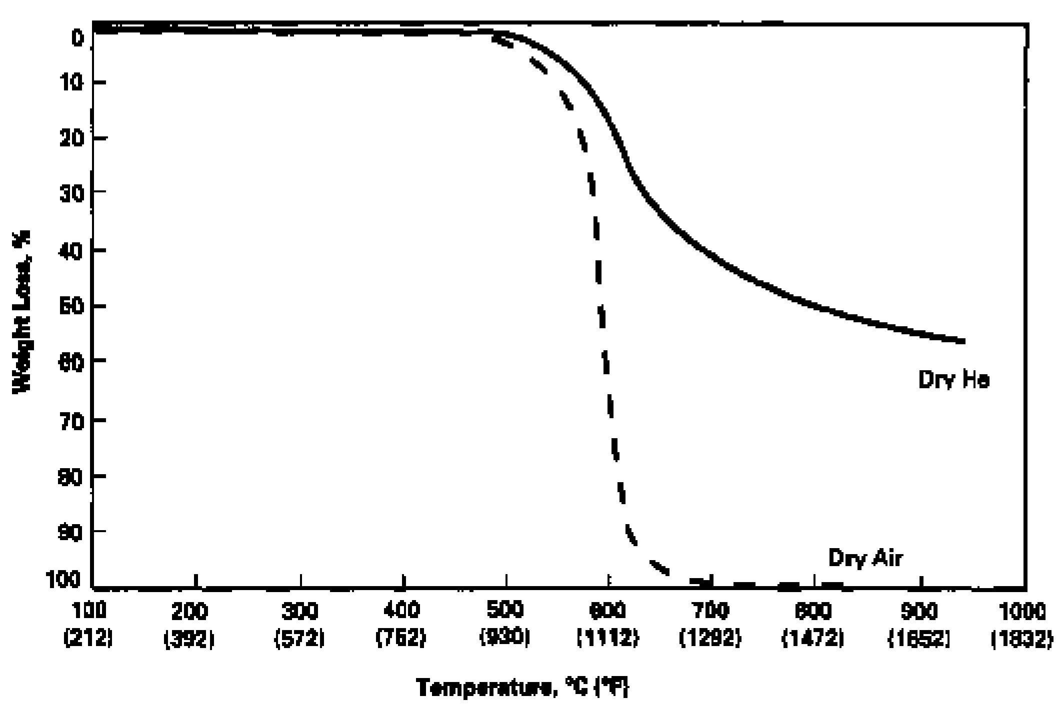
TI-NHTSA 018509

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



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

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



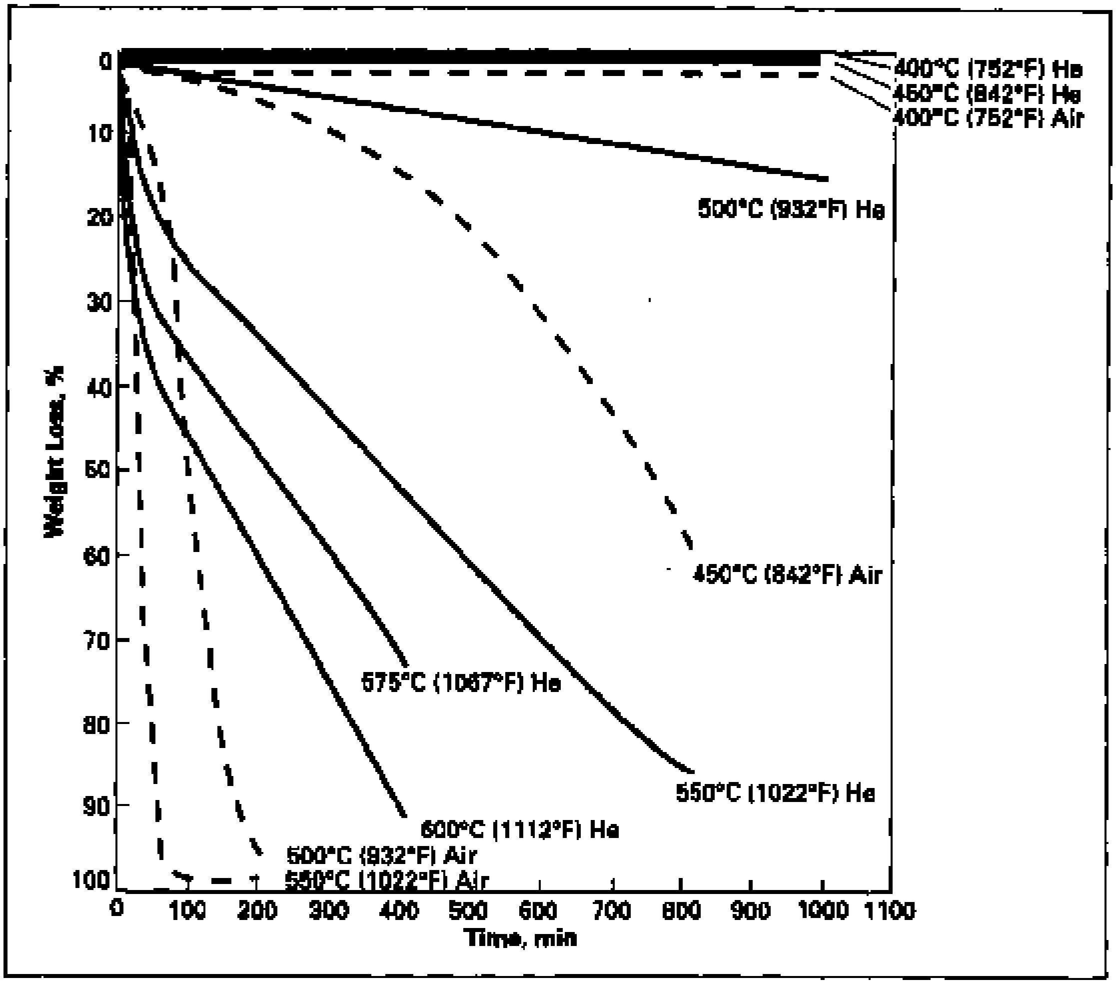
*Rate of temperature rise in °C (°F) was 3°C/min (5.4°F/min).

TI-NHTSA 018510

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

Temperature	Air Environment
450°C (840°F)	2 hours
425°C (800°F)	6 hours
400°C (760°F)	12 hours
375°C (710°F)	2 days
350°C (660°F)	6 days
325°C (620°F)	1 month
300°C (570°F)	3 months
275°C (530°F)	1 year
250°C (480°F)	8 years

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



TI-NHTSA 018511

Electrical Properties

The most common electrical properties of Kapton® polyimide film of various gauges are shown in Tables 6 and 7. These values were measured at 23°C (73°F) and 50% relative humidity. The effect of such factors as humidity, temperature, and frequency on these basic values can be found in Table 9 and Figures 11–13.

Table 7
Typical Electrical Properties of Kapton® Type HN and VN Films

Property Film Gauge	Typical Value		Test Condition	Test Method
Dielectric Strength	V/µm (kV/mm)	(V/mil)	60 Hz	ASTM D-149-91[ε1]
25 µm (1 mil)	303	(7700)	1/4 in electrodes	
50 µm (2 mil)	240	(6100)	500 V/sec rise	
75 µm (3 mil)	205	(5200)		
125 µm (5 mil)	154	(3900)		
Dielectric Constant			1 kHz	ASTM D-150-92
25 µm (1 mil)	3.4			
50 µm (2 mil)	3.4			
75 µm (3 mil)	3.5			
125 µm (5 mil)	3.5			
Dissipation Factor			1 kHz	ASTM D-150-92
25 µm (1 mil)	0.0018			
50 µm (2 mil)	0.0020			
75 µm (3 mil)	0.0020			
125 µm (5 mil)	0.0026			
Volume Resistivity	Ω-cm			ASTM D-257-91
25 µm (1 mil)	1.5×10^{17}			
50 µm (2 mil)	1.5×10^{17}			
75 µm (3 mil)	1.4×10^{17}			
125 µm (5 mil)	1.0×10^{17}			

Table 8
Typical Electrical Properties of Kapton® Type FN Film

Property	120FN616	150FN019	250FN029
Dielectric Strength, V/µm (V/mil)	272 (6900)	197 (5000)	197 (5000)
Dielectric Constant	3.1	2.7	3.0
Dissipation Factor	0.0015	0.0013	0.0013
Volume Resistivity, Ω-cm			
at 23°C (73°F)	1.4×10^{17}	2.3×10^{17}	1.9×10^{17}
at 200°C (392°F)	4.4×10^{14}	3.5×10^{14}	3.7×10^{14}

TI-NHTSA 018512

Effect of Humidity

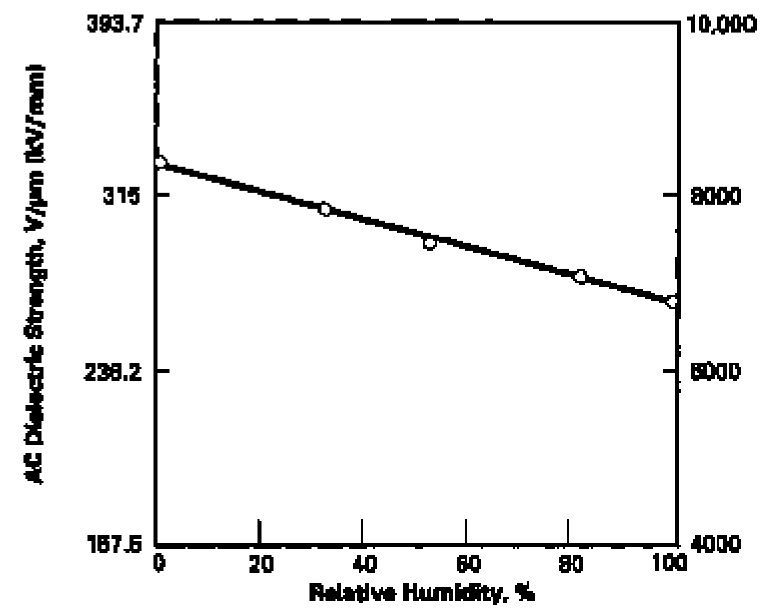
Because the water content of Kapton® polyimide film can affect its electrical properties, electrical measurements were made on 25 µm (1 mil) film after exposure to environments of varying relative humidities at 23°C (73°F). The results of these measurements are shown in **Table 9** and **Figures 11–13**.

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

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

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

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



TI-NHTSA 018513

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

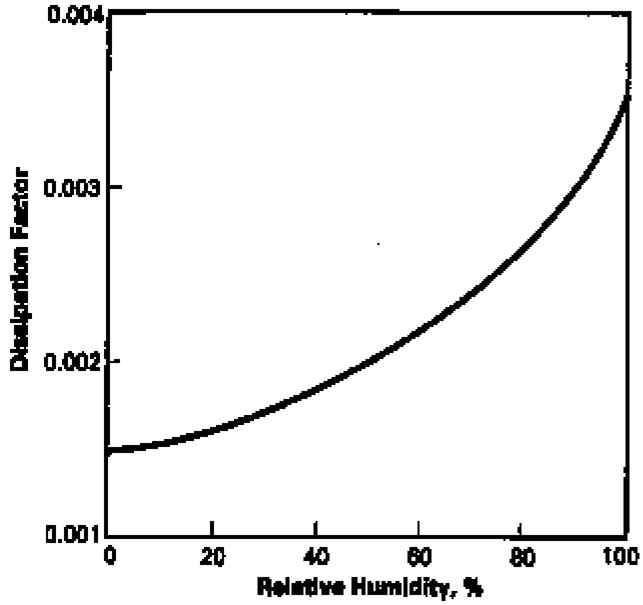
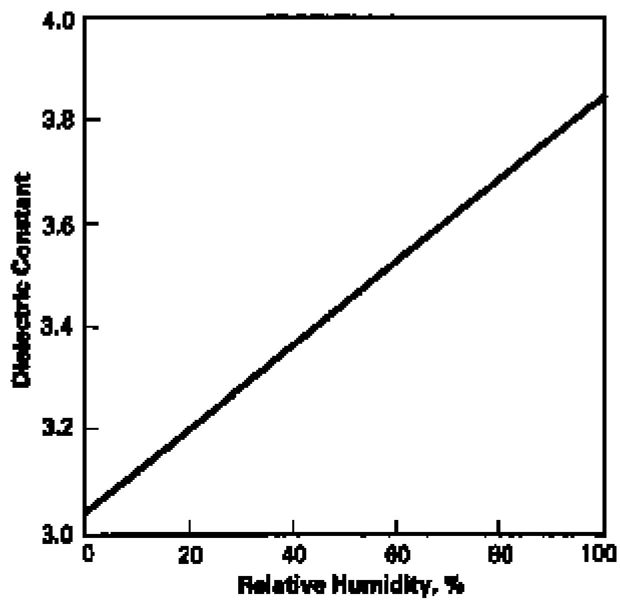


Figure 13. Dielectric Constant vs. Relative Humidity, Type HN Film, 25 µm (1 mil)



TI-NHTSA 018514

Effect of Temperature

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

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

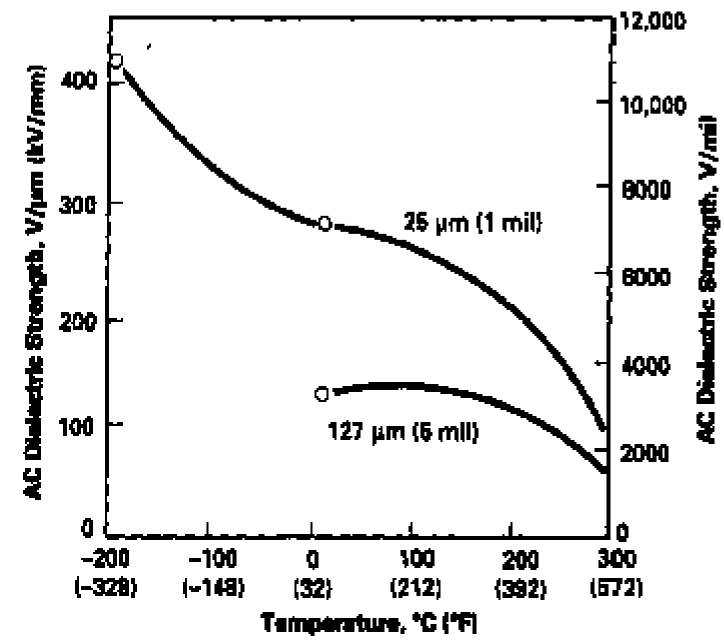
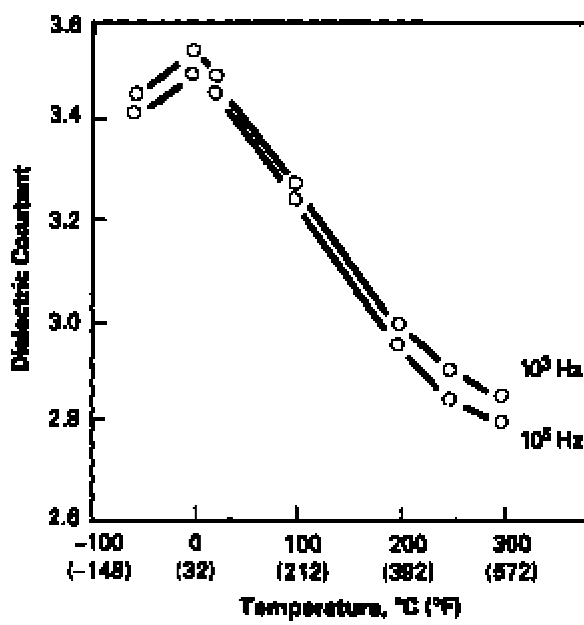


Figure 15. Dielectric Constant vs. Temperature, Type HN Film, 25 μm (1 mil)



TI-NHTSA 018515

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

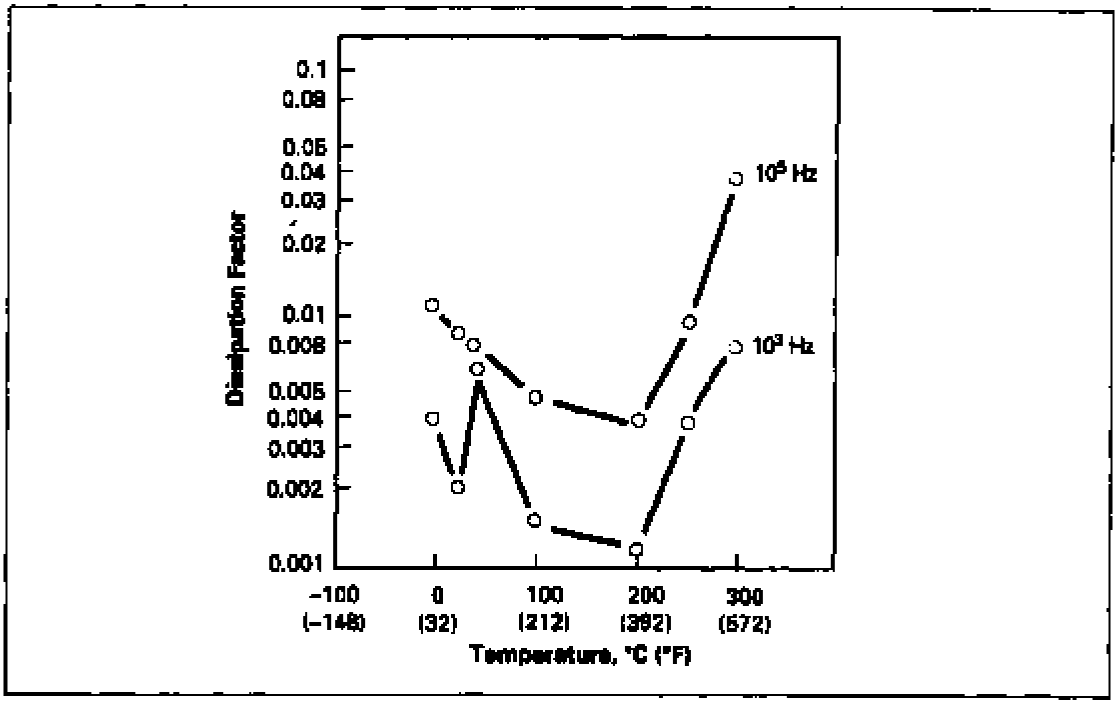
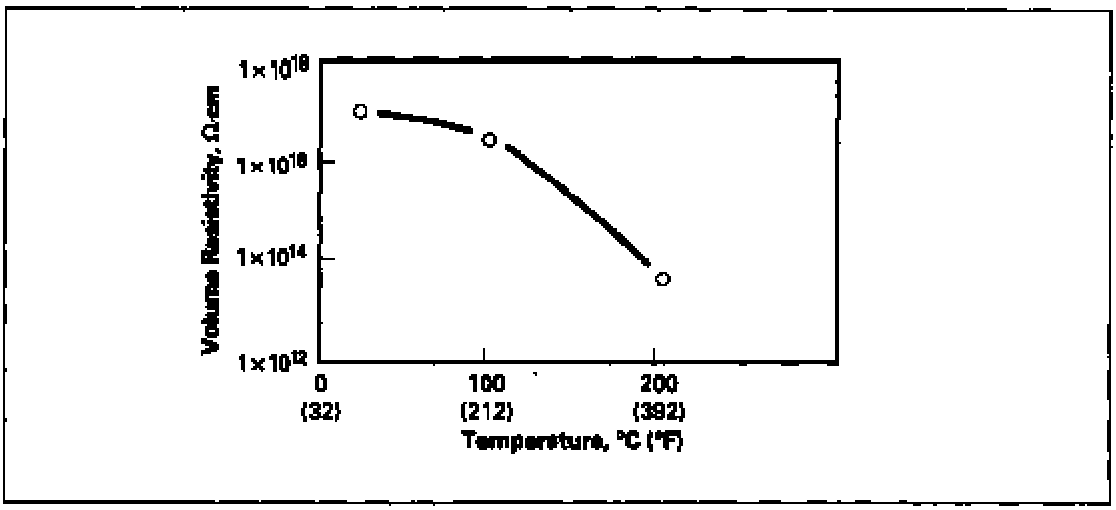


Figure 17. Volume Resistivity vs. Temperature, Type HN Film, 25 μm (1 mil)



TI-NHTSA 018516

Effect of Frequency

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

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

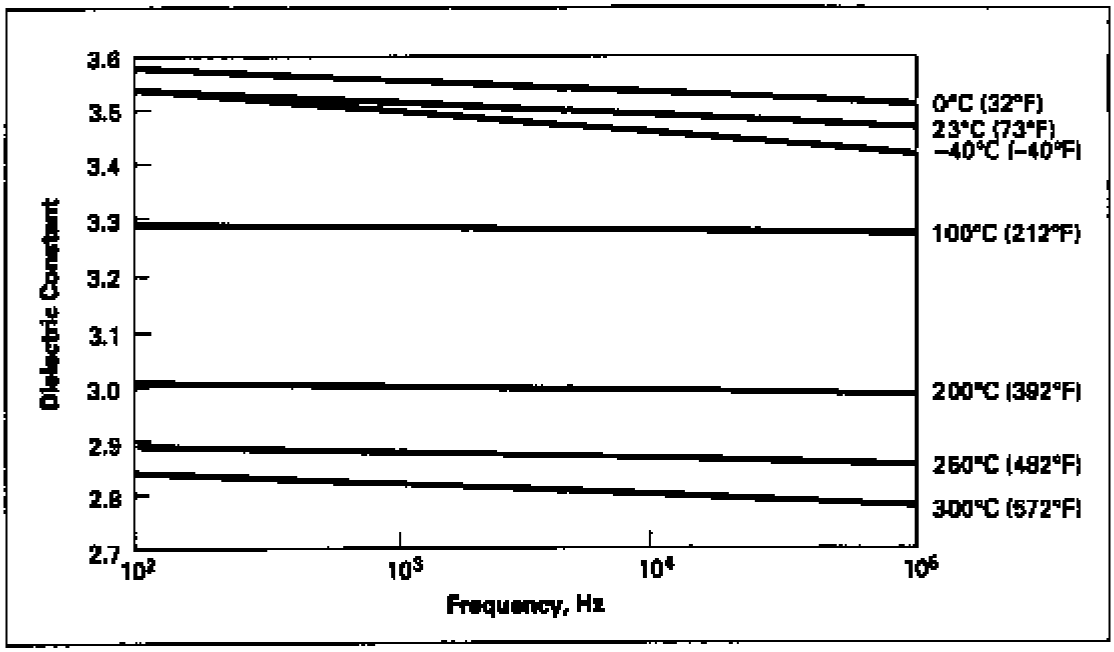
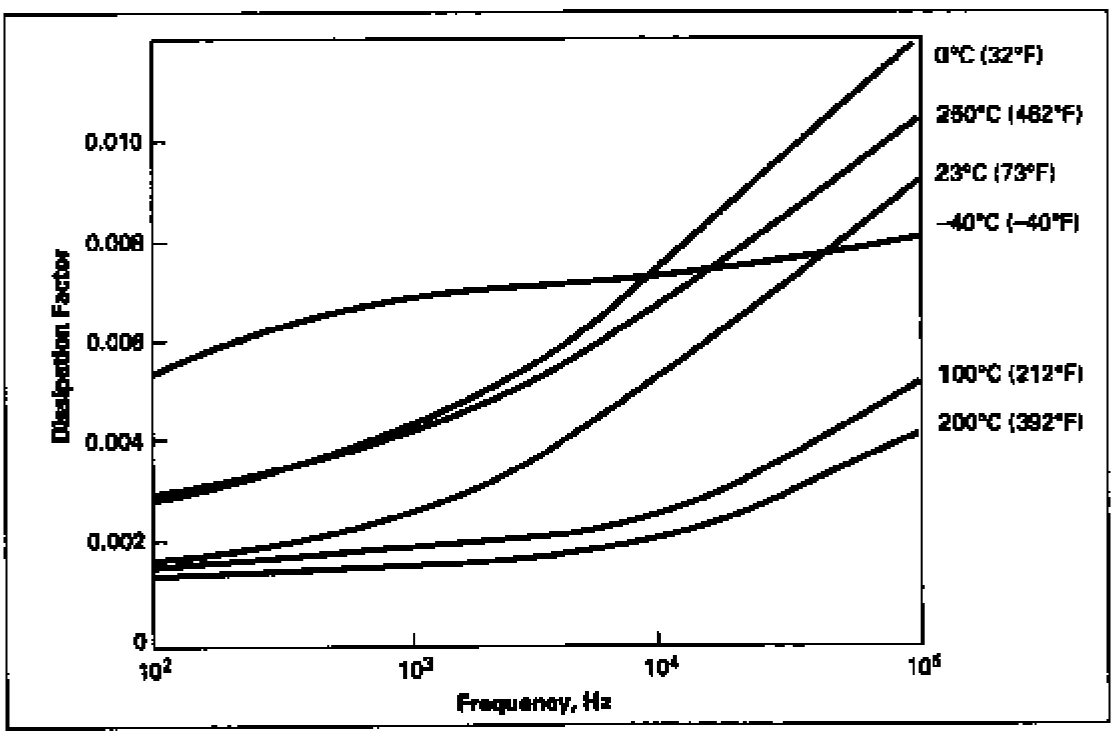


Figure 19. Dissipation Factor vs. Frequency, Type HN Film, 25 μm (1 mil)



TI-NHTSA 018517

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

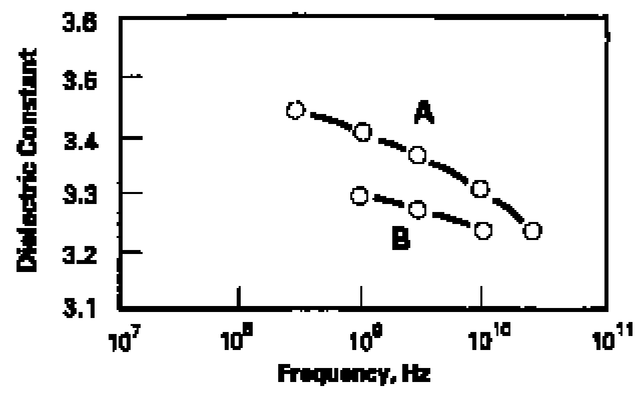
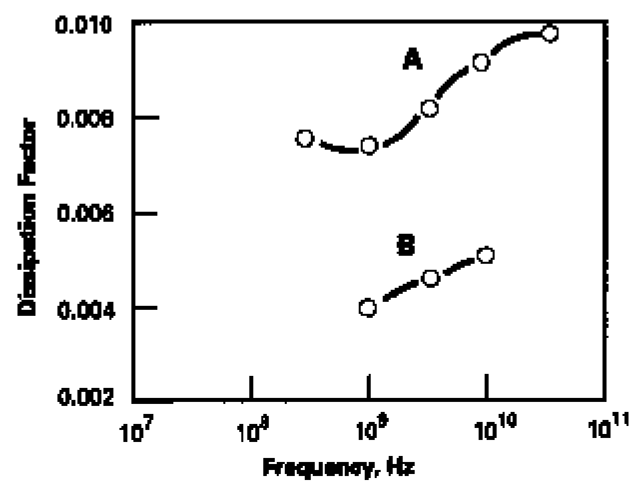


Figure 21. Dissipation Factor vs. Frequency, Type HN Film, 125 µm (5 mil)*



* Technical Report AFML-TR-72-38—Curve A is 500H Kapton® as received and measured at 25°C (77°F) and 45% RH with the electric field in the plane of the sheet. Curve B is the same measurement after conditioning the film at 100°C (212°F) for 48 h. Performance of 500HN is believed to be equivalent to 500H.

TI-NHTSA 018516

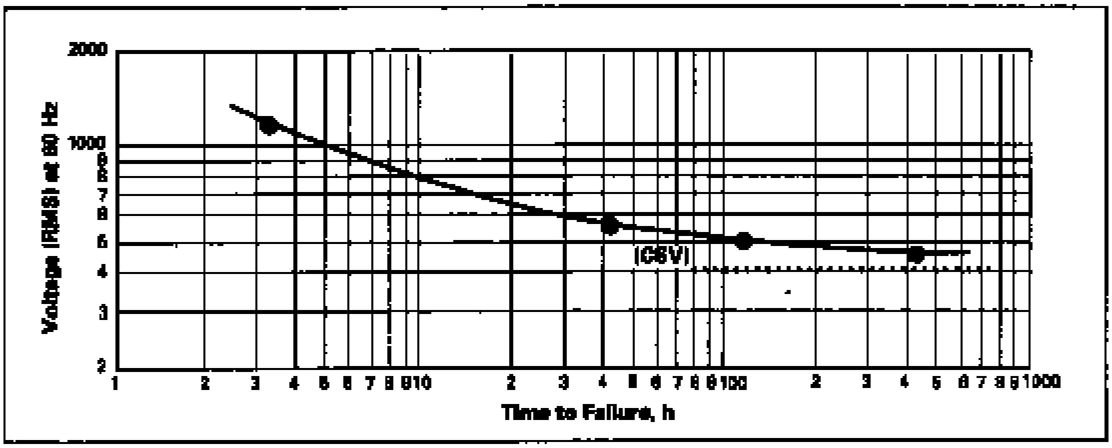
Corona Life

Like all organic materials, Kapton® is attacked by a corona discharge and when exposed continuously to it will ultimately fail dielectrically. At moderate levels of corona exposure, devices insulated with Kapton® have survived up to 3000 h, giving reasonable assurance that brief exposure to a corona will not significantly affect the life of a properly designed insulation system based on Kapton®.

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

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

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



*Corona Starting Voltage (CSV) = 425 V

TI-NHTSA 018519

Chemical Properties

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

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

Property	Typical Value: Tensile Retained, %	Typical Value: Elongation Retained, %	Test Condition	Test Method
Chemical Resistance				
Isopropyl Alcohol	96	94	10 min at 23°C	IPC TM-650 Method 2.2.3B
Toluene	98	91		
Methyl Ethyl Ketone	99	90		
Methylene Chloride/ Trichloroethylene (1:1)	98	85		
2 N Hydrochloric Acid	98	88		
2 N Sodium Hydroxide	62	54		
Fungus Resistance	Nonnutrient			IPC TM-650 Method 2.6.1
Moisture Absorption	1.8% Types HN and VN		50% RH at 23°C	ASTM D-570-81 (1988)ε1
	2.8% Types HN and VN		Immersion for 24 h at 23°C (73°F)	
Hygroscopic Coefficient of Expansion	22 ppm/% RH		23°C (73°F), 20–80% RH	
Permeability				
Gas	*mL/m²·24 h·MPa*	*cc/(100 in²·24 h·atm)*	23°C (73°F), 50% RH	ASTM D-1434-82 (1988)ε1
Carbon Dioxide	6840	45		
Oxygen	3800	25		
Hydrogen	36,000	250		
Nitrogen	910	6		
Helium	63,080	415		
Vapor	*g/(m²·24 h)*	*g/(100 in²·24 h)*		ASTM E-96-92
Water	54	3.5		

Table 11
Chemical Properties of Kapton® Type FN Film

Property	120FN616	150FN019	400FN022
Moisture Absorption, %			
at 23°C (73°F), 50% RH	1.3	0.8	0.4
98% RH	2.5	1.7	1.2
Water Vapor Permeability,			
g/(m²·24 h)	17.5	9.5	2.4
g/(100 in²·24 h)	1.13	0.62	0.16

TI-NHTSA 018520

Radiation Resistance

Because of its excellent radiation resistance, Kapton® is frequently used in high radiation environments where a flexible insulating material is required. In outer space, Kapton® is used both alone and in combination with other materials for applications that require radiation resistance at minimum weight. U.S. Government laboratory test data on gamma and neutron radiation exposure of Kapton® are summarized in **Tables 12** and **13**.

Testing the suitability of Kapton® for nuclear reactors and linear accelerators involves exposure to an adverse chemical environment in addition to radiation. For example, loss of coolant accident (LOCA) tests for qualification in containment areas in nuclear power plants expose the system to steam and sodium hydroxide, both of which tend to degrade Kapton®.

Accordingly, when Kapton® is used in nuclear power systems that require certification to IEEE-323 and -383, engineered designs that protect Kapton® from direct exposure to LOCA sprays are required.

The excellent ultraviolet resistance of Kapton® in the high vacuum of outer space is demonstrated by the data in **Table 14**. In the earth's atmosphere, however, there is a synergistic effect upon Kapton® if it is directly exposed to some combinations of ultraviolet radiation, oxygen, and water. **Figure 23** shows this effect as a loss of elongation when Kapton® was exposed in Florida test panels. **Figure 24** shows the loss of elongation as a function of exposure time in an Atlas Weatherometer. Design considerations should recognize this phenomenon.

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

Property	Control 1 mil Film	10^4 Gy 1 h	10^5 Gy 10 h	10^6 Gy 4 d	10^7 Gy 42 d
Tensile Strength, MPa (psi × 10^3)	207 (30)	207 (30)	214 (31)	214 (31)	152 (22)
Elongation, %	80	78	78	79	42
Tensile Modulus, MPa (psi × 10^3)	3172 (460)	3275 (475)	3378 (490)	3278 (476)	2903 (421)
Volume Resistivity Ω·cm × 10^{13} at 200°C (392°F)	4.8	6.6	5.2	1.7	1.6
Dielectric Constant 1 kHz at 23°C (73°F)	3.46	3.54	3.63	3.71	3.50
Dissipation Factor 1 kHz at 23°C (73°F)	0.0020	0.0023	0.0024	0.0037	0.0029
Dielectric Strength V/μm (kV/mm)	256	223	218	221	254

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

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

TI-NHTSA 018621

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

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

*Vacuum environment, 2×10^{-4} mmHg at 50°C (122°F). UV intensity equal to space sunlight to 2500A.

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

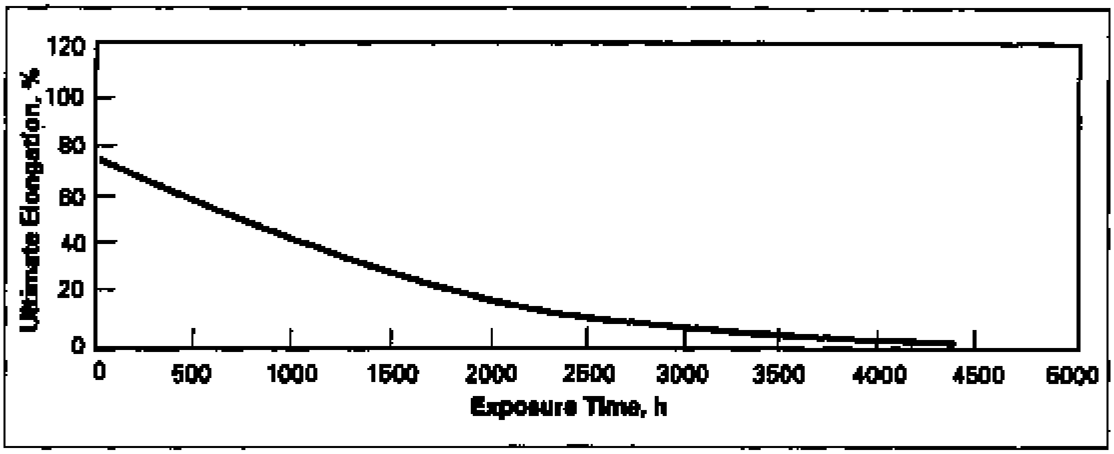
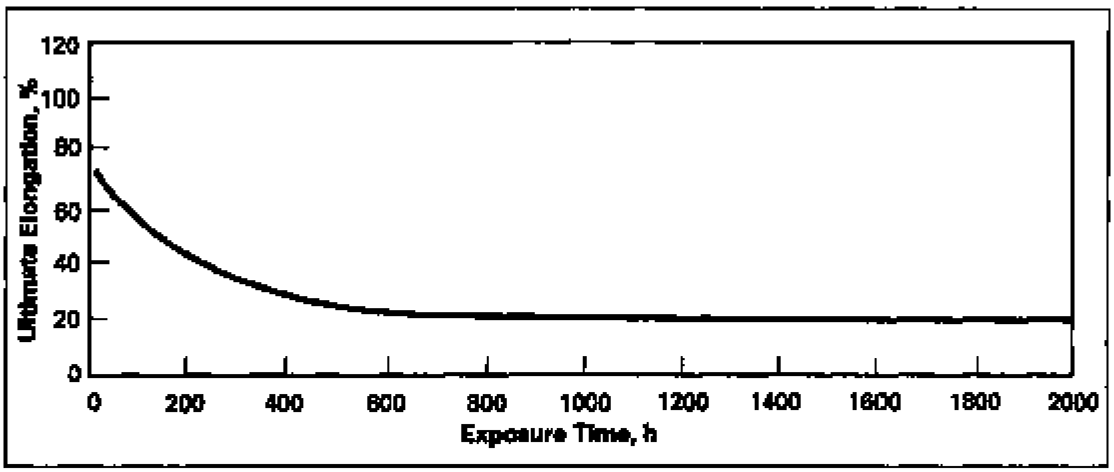


Figure 24. Effect of Weathering on Kapton® Polyimide Film (Atlas Weatherometer)



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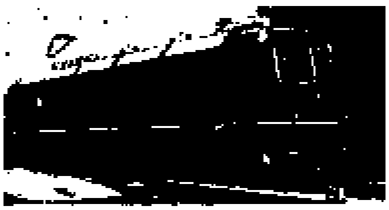
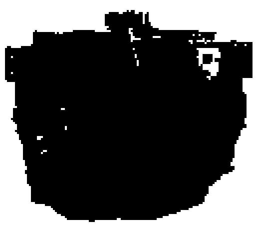


Kapton® is used as primary insulation for traction motors because of its outstanding combination of thermal, mechanical, and electrical properties.



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

TI-NHTSA 018523

Kapton® Film Type Information

Table 15
Type and Thickness

Type	Nominal Thickness		Area Factor	
	µm	mil	m²/kg	ft²/lb
30HN	7.6	0.3	93	455
50HN	12.7	0.5	56	272
75HN	19.1	0.75	37	181
100HN	25.4	1.0	28	136
200HN	50.8	2.0	14	68
300HN	76.2	3.0	9.2	45
500HN	127	5.0	5.5	27
50VN	12.7	0.5	56	272
75VN	19.1	0.75	37	181
100VN	25.4	1.0	28	136
200VN	50.8	2.0	14	68
300VN	76.2	3.0	9.2	45
500VN	127	5.0	5.5	27
100FN099	25.4	1.0	23	110
120FN616	30.5	1.2	21	104
150FN999	38.1	1.5	14	68
150FN019	38.1	1.5	16	77
200FN011	50.8	2.0	11	54
200FN919	50.8	2.0	11	54
250FN029	63.5	2.5	10	49
300FN021	76.2	3.0	8.0	39
300FN929	76.2	3.0	8.0	39
400FN022	101.6	4.0	5.5	27
400FN031	101.6	4.0	6.1	30
500FN131	127	5.0	4.7	23
600FN051	152.4	6.0	4.3	21

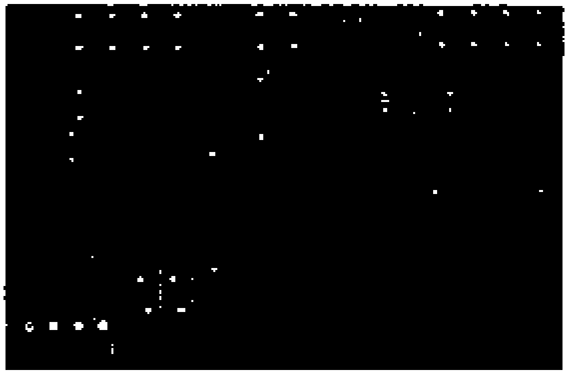
Nominal Construction, Type FN

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

Table 16
Type FN Film Constructions

	Construction					
	FEP		*HN*		*FEP*	
Type	*µm*	*mil*	*µm*	*mil*	*µm*	*mil*
100FN099			12.7	0.50	12.7	0.50
120FN616	2.54	0.10	25.4	1.00	2.54	0.10
150FN999	12.7	0.50	12.7	0.50	12.7	0.50
150FN019			25.4	1.00	12.7	0.50
200FN011			25.4	1.00	25.4	1.00
200FN919	12.7	0.50	25.4	1.00	12.7	0.50
250FN029			50.8	2.00	12.7	0.50
300FN021			50.8	2.00	25.4	1.00
300FN929	12.7	0.50	50.8	2.00	12.7	0.50
400FN022			50.8	2.00	50.8	2.00
400FN031			76.2	3.00	25.4	1.00
500FN131	25.4	1.00	76.2	3.00	25.4	1.00
600FN051			127	5.00	25.4	1.00

TI-NHTSA 018524



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

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

TI-NHTSA 018525

Safety and Handling

Safe handling of Type HN and VN Kapton® polyimide films at high temperatures requires adequate ventilation. Meeting the requirements of OSHA (29 CFR 1910.1000) will provide adequate ventilation. If small quantities of Kapton® are involved, as is often the case, normal air circulation will be all that is needed in case of overheating. Whether or not existing ventilation is adequate will depend on the combined factors of film quantity, temperature, and exposure time. For additional information on the Teflon® FEP coating used on Type FN Kapton®, refer to the booklet "Guide to the Safe Handling of Fluoropolymer Resins" (H-48633).

Soldering and Hot Wire Stripping

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

Welding and Flame Cutting

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

Scrap Disposal

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

Fire Hazards

Whether in storage or use, Kapton® is unlikely to add appreciably to the hazards of fire. Bulk quantities of Kapton® (over 100 lb) should be stored away from flammable materials.

In the event of fire, personnel entering the area should use a fresh air supply or a respirator. All types of chemical extinguishers may be used to fight fires involving Kapton®. Large quantities of water also may be used to cool and extinguish a fire.

Static Electricity

The processing of Kapton® can generate a strong static charge. Unless this charge is bled off as it forms by using ionizing radiation or tinsel, it can build to many thousand of volts and discharge to people or metal equipment. In dust- or solvent-laden air, a flash fire or explosion could result. Precautions for static charges should also be taken when removing plastic films used as protective packaging for Kapton®.

For additional information, users should refer to the bulletin "Kapton® Polyimide Film—Products of Decomposition" (H-16512).

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

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Reorder No.: H-[illegible]-2

DuPont High Performance Films

TABLE XVI

CHEMICAL RESISTANCE OF 1 AND 2 MIL KAPTON®

Chemical Resistance	Conditions Time	Conditions Temp.	% Prop. Retained Tens.	% Prop. Retained Elong.	% Prop. Retained Mod.	Conditions Time	Conditions Temp.	% Prop. Retained Tens.	% Prop. Retained Elong.	% Prop. Retained Mod.
Benzene	1 yr.	Rm.	100	82	100	56 days	80°C.	100	100	104
Hexane	1 yr.	Rm.	97	89	100	56 days	65°C.	100	100	114
Toluene	1 yr.	Rm.	94	66	97	28 days	110°C.	82	32	99
DMF	1 yr.	Rm.	81	65	88	1 " **	152°C.	0	0	0
Chloroform	1 yr.	Rm.	93	74	96	56 "	60°C.	100	100	100
Methanol	1 yr.	Rm.	100	73	140	56 "	64°C.	100	100	105
Chlorobenzene	1 yr.	Rm.	82	52	106	56 "	130°C.	100	100	98
Acetone	1 yr.	Rm.	67	72	160	56 "	80°C.	100	100	100
H_2O + Dupanol® (2%)	1 yr.	Rm.	89	22	130	7 "	100°C.	82	18	124
Sulfuric Acid (10%)	191 days	Rm.	78	71	83					
"Skydrol" (1)	191 days	Rm.	88	98	85	16 "	200°C.	76	93	78
Decomposed "Skydrol"						2 "	225°C.	51	10	62
JP-4 Jet Fuel	191 days	Rm.	86	92	84	30 "	100°C.	96	70	112
Ferric Chloride Etch. Soln.(3)						28 "	50°C.	98	94	99
Glacial Acetic						36 "	110°C.	85	62	102
Aniline						1 "	184°C.	0	0	0
Dimethyl Aniline						8 "	190°C.	81	59	102
p-Cresol						22 "	200°C.	100	77	102
Water						140 "	100°C.	52	26	120
Cellosolve						28 "	135°C.	100	53	102
"Arochlor" (4)						1 yr.	200°C.	100	53	142
"Transil" Oil (5)						6 mo.	150°C.	100	100	100
Water PH-10						100 hr.	100°C.		49	
Water PH-1						100 hr.	100°C.		51	
Sodium Hydroxide 10%	5 days	Rm.		Dissolves						
Ammonia Hydroxide (conc.)	2 days	Rm.		Dissolves						
Dow-Corning Silicone Varnish (1402)						48 hr.	250°C.		Varnish decomposes	
Dow-Corning Silicone Varnish (5651)						96 hr.	250°C.	100	96	114

**In air and in the presence of water. If water and air are excluded the film has considerably longer life. (3 weeks; 152°C.)

(1) Hydraulic Fluid (Phosphate) (2) Government specified jet fuel (3) Saturated solution of $FeCl_3$+0.3% Copper Powder
(4) Chlorinated biphenyl (Transformer Oil) (5) Hydrocarbon transformer oil

JPF/jes

AUTOMOTIVE FLUID TESTING
KAPTON® FILM AND LAMINATE TEST

- ATF • DEXRON ATF OFF SHELF • 300 DEGREE F
- GM SOUR GAS • INDOLENE H 03(AMOCO)/.0028% T-BUTYL HYDROPEROXIDE (90% PURE) • ROOM TEMP.
- BRAKE FLUID • BERKEBILE 2 + 2" DOT-3 • ROOM REMP.
- ANTIFREEZE • "PEAK" FULL CONCENTRATION • ROOM TEMP.
- DETERGENT • "JOY" DISH DETERGENT LIQUID 50% CONCENTRATION IN WATER • ROOM TEMP.
- SALT SOLUTION • SATURATED 1511.7 GRAMS NaCL/ 13602.3 GRAMS TAP WATER • ROOM TEMP.
- BATTERY ACID • OFF SHELF H2S04 - SP GRAV. = 1.265 • ROOM TEMP.
- ISOPROPYL ALCOHOL • FULL CONCENTRATION • ROOM TEMP.
- 1,1,1 TRICHLOROETHANE • FULL CONCENTRATION • ROOM TEMP.
- CAUSTIC CLEANER (PH > 10) • TAP WATER/ TRISODIUM PHOSPHATE 0.05% • ROOM TEMP.

PRODUCT AND TEST INFORMATION

- FILMS IN TEST
  1) 300HN
  2) 300EP
  3) 300HMK
  4) 100EP LF-0111 (5457-0616)
  5) 100HMK LF-0111 (5457-0677)
- LAMINATES IN TEST SEE CARL KILLIAN
- TESTS TO BE COMPLETED
  1) TENSILE
  2) ELONGATION
  3) MODULUS
  4) SWELL
  5) INITATION TEAR

GENERAL INFORMATION

- ALL CONTROL SAMPLES EXCEPT SWELL ARE THE AVERAGE OF FIVE DATA POINTS
- ALL TEST POINTS EXCEPT SWELL ARE THE AVERAGE OF THREE TEST POINTS
- SWELL DATA IS ONLY ONE TEST POINT, TWO POINTS WHERE RECORDED BUT DATA WAS SO REPRODUCABLE ONLY ONE WAS USED

TESTING RUN AT E.T.C.

	INITIAL	AVG. 3					
WATER	CONTROL	48HRS	100HRS	300HRS	500HRS	750HRS	1000HRS
300HMX	36872	34231	33968	32278	31974	31176	32070
300SP-X	38139	38390	38861	34697	33794	38453	37928
300ZRM06	30647	28128	31867	30718	28244	30349	32935
LP0616	15913	16861	16883	16486	18301	16483	18640
LP0677	14994	15256	13821	13371	14630	11246	13834
300FP019	34714						
180ZC	14763						
ATF							
300HMX	36872	33648	38174		34798	36382	35278
300SP-X	38130	38848	34825		36998	38231	34833
300ZRM06	30647	32384	32733		30781	1471	30136
LP0616	15913	16746	16874		18647	17383	19868
LP0677	14994	14868	16106		15968	18087	16718
300FP019	34714	14881	16886		18843	944	19481
180ZC	14763						18137
ACID							
300HMX	36872	33470	38638	38342	34486	33837	36310
300SP-X	38139	38881	40178	38389	36618	36370	40887
300ZRM06	30647		33168	31038	31414	34884	31801
LP0616	15913	16865	17244	18670	18750	18478	16774
LP0677	14994	15794	16882	15877	18288	18188	14877
300FP019	34714			40378			
180ZC	14763						
GUN-GAS							
300HMX	36872			33387	33413	1710	34816
300SP-X	38139			38883	38808	41448	38718
300ZRM06	30647				30384	31363	33411
LP0616	15913			18388	18806	18843	18834
LP0677	14994			14188	18384	14818	14483
300FP019	34714			18161	18488	18988	17621
180ZC	14763						
SALT							
300HMX	36872				33016	33788	33873
300SP-X	38139				31831	38878	37486
300ZRM06	30647				30118	30788	31817
LP0616	15913				24408	18840	18918
LP0677	14994				14884	13186	13483
300FP019	34714						
180ZC	14763						
JOT							
300HMX	36872	32870	34833		31483	31888	30784
300SP-X	38139	38833	41383		39813	38713	38887
300ZRM06	30647	28388	31734		30813	30878	27384
LP0616	15913	18848	18018		15788	18846	18888
LP0677	14994	14781	14988		13830	16888	18883
300FP019	34714						
180ZC	14763						

TI-NHTSA 018630

	VIRGIL CONTROL	AVG. 3 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ANTI-FR							
1000MX	36972	33728	31713	33908	33134	32930	33984
1000HP-X	38139	39838	48844	39936		38169	38090
3000MM064	30647	35803	30843	38897	39475	30341	30338
LF0816	18912	18492	17113	18075	14408	14158	15994
LF0677	14994	15306	13817		14400	13971	13906
3000TW610	24714						
1000XC	14763						
CLM-10							
1000MX	36972	38828	33904	33187	33876	34391	31444
1000HP-X	38139	34489	34809	38387	30314	34403	37821
3000MM064	30647	33118	30517	31064	29143	30483	27344
LF0816	18912	16471	16849	17842	16839	18932	18003
LF0677	.14994	18040	15786	18443	14339	13433	13781
3000TW610	24714						
1000XC	14763						
IPA							
1000MX	36972	38938	34404	34678	35168	33188	35961
1000HP-X	38139	34797	42982	38897	38434	38233	38184
3000MM064	30647	31380	33898	31827	30794	31849	31834
LF0816	18912	14885	17879	18048	16874	18883	15724
LF0677	14994	16174	18088	14761	14485	18121	14821
3000TW610	24714			38176			
1000XC	14763						
1,1,1,TRI							
1000MX	36972	34983	37380	34791	33117	38183	34841
1000HP-X	38139	38814	35388	33648	38344	38484	34349
3000MM064	30647	31161	31880	38713	33318	38146	38948
LF0816	18912	14884	18846	18003	15443	17818	18489
LF0677	14994	16383	18804	18418	18881	18897	18985
3000TW610	24714						
1000XC	14763						

TI-NHTSA 018831

BRAKE	ELONG CONTROL	48HRS	100HRS	300HRS	500HRS	750HRS	1000HRS
300HNX	54.9	56.8	64.6	48	47.7	47.6	50
300FP-X	23.7	24.1	30.1	27	28.1	33.8	29.8
300FN904	67.4	48.3	71.8	46.4	54.2	61.4	38.3
LF0616	42.2	44.6	62.3	43.2	41.9	43.7	42.8
LF0677	56.2	50.8	63.1	56.3	50.4	48.7	54.8
300FN919	71.1						
100HC	13.8						
ATF							
300HNX	54.9	57.2	61.9		56.9	54.8	66.2
300FP-X	23.7	[illegible]	18.4		27.8	13	27.1
300FN904	67.4	78	73.7		73.1	61.8	80.3
LF0616	42.2	45.1	40.3		31.1	44.8	39.6
LF0677	56.2	46.8	57.9		43.8	53	45.8
300FN919	71.1	51.1	63.6		67.1	66	40.1
100HC	13.8						11.3
ACID							
300HNX	54.9	66.1	63.8	56.8	63.8	59.4	64
300FP-X	23.7	27	27.8	28.6	28	28.4	37.2
300FN904	67.4	66.1	63.9	63	66	68.2	64.5
LF0616	42.2	43.1	44.7	41.2	42.1	42.8	40.3
LF0677	56.2	53.8	66.6	56.3	56.7	48.9	52.9
300FN919	71.1			68.8			
100HC	13.8						
[illegible]-GAS							
300HNX	54.9			57.2	58.4	63.6	57.6
300FP-X	23.7			36.4	33.4	48.8	33.1
300FN904	67.4				57.2	61.3	58
LF0616	42.2			41.8	43	41.8	43.7
LF0677	56.2			49.2	56.8	58.3	47.3
300FN919	71.1			48.6	40.3	63	58.9
100HC	13.8						
SALT							
300HNX	54.9				56.9	58.7	50.8
300FP-X	23.7				19.4	27.1	38.1
300FN904	67.4				67.7	59.6	64.6
LF0616	42.2				40.1	41.6	48
LF0677	56.2				51.8	36.6	36.8
300FN919	71.1						
100HC	13.8						
JOY							
300HNX	54.9	41.6	54.2		41.3	37.8	39.7
300FP-X	23.7	27.3	41		38	28.3	28.7
300FN904	67.4	64.7	43		55.9	50.7	43.8
LF0616	42.2	33.1	38.4		34.8	34.1	32.1
LF0677	56.2	64.7	43.1		28	37.7	34
300FN919	71.1						
100HC	13.8						

ANTI-FR	ELONG CONTROL	48HRS	180HRS	260HRS	500HRS	750HRS	1000HRS
300HN	54.9	53.3	50.1	50.6	49.1	46	48.9
300HP-X	23.7	30.8	34.2	24.3		22.5	28.6
300[illegible]	67.4	56.5	51.1	60.8	58.4	61.8	48.0
LF0614	42.3	36.3	40.3	41.7	43.1	43.1	38.0
LF0477	50.3	56.0	52.7		52.2	40.5	43.9
300FN019	71.1						
100HN	13.0						
GLM-10							
300HN	54.9	55.8	58.4	48.2	57.8	58.3	40.9
300HP-X	23.7	28.6	26.8	19.3	26	25.6	33.2
300[illegible]	67.4	55.0	58.1	63	60.1	65.4	60.1
LF0614	42.0	46.9	41.8	41.1	48.4	40.5	48
LF0477	50.3	54	40.3	58	48.7	43.6	48.4
300FN019	71.1						
100HN	13.0						
TPA							
300HN	54.9	61.1	58.3	62	61.3	43.9	47.3
300HP-X	23.7	34.1	49	28.2	27.7	21.7	28.4
300[illegible]	67.4	68.8	63.3	67.7	62.2	61.2	78.0
LF0614	42.3	41.4	42.4	44	44.2	41.4	42.8
LF0477	50.3	60.1	48.4	47.8	46.3	53.7	60.4
300FN019	71.1			66.0			
100HN	13.0						
1,1,1-TRI							
300HN	54.9	56.2	40.7	51	47.6	42.0	61.4
300HP-X	23.7	24.8	21.2	19.0	28.0	24.7	20.1
300[illegible]	67.6	63.0	64.6	61.0	67.2	62.3	63
LF0614	42.3	40.3	37.9	42.8	36.8	30.1	40.3
LF0477	50.3	50.1	61.4	54.8	52.7	46.8	63.4
300FN019	71.1						
100HN	13.0						

TI-NHTSA 018533

[illegible]	[illegible] CONTROL	[illegible]	100[illegible]	[illegible]	[illegible]	750[illegible]	1000[illegible]
BRAKE							
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	818376	815107	[illegible]
[illegible]	781127	757482	742341	748182	768670	776798	774778
[illegible]	373734	410618	[illegible]	[illegible]	600140	419678	484709
LF0614	374386	403824	[illegible]	372830	347221	[illegible]	348164
LF0677	381037	330417	378197	[illegible]	[illegible]	337087	345488
[illegible]	[illegible]						
[illegible]	473690						
ATF							
[illegible]	[illegible]	[illegible]	520376		548204	[illegible]	[illegible]
[illegible]	781127	747812	788413		748073	783810	824841
[illegible]	373734	391411	418416		608480	NO DATA	[illegible]
LF0616	374386	[illegible]	430618		440108	431848	488204
LF0677	381037	338738	348818		398140	371788	[illegible]
[illegible]	386736	313490	353378		289301	13207	358470
[illegible]	473690						547137
ACID							
[illegible]	[illegible]	462751	[illegible]	[illegible]	508174	818401	840343
[illegible]	781127	738018	768411	786310	763730	783818	882324
[illegible]	373734		417[illegible]	637641	400882	388834	488376
LF0616	374386	368731	428048	318881	384427	372712	406381
LF0677	381037	311814	318480	328373	321889	338878	361314
[illegible]	386736			363484			
[illegible]	473690						
NON-GAS							
[illegible]	[illegible]			484847	488347	NO DATA	838115
[illegible]	781127			783114	788133	771877	[illegible]
[illegible]	373734				383413	488373	[illegible]
LF0616	374386			383284	387877	370703	344734
LF0677	381037			348382	319488	314884	380013
[illegible]	386736			[illegible]	384884	388370	384840
[illegible]	473690						
GAS							
[illegible]	[illegible]				487408	433398	831880
[illegible]	781127				753833	778188	781483
[illegible]	373734				388830	387487	437348
LF0616	374386				398384	384038	388830
LF0677	381037				318438	318183	337891
[illegible]	386736						
[illegible]	473690						
[illegible]							
[illegible]	[illegible]	[illegible]	844813		837400	878080	818808
[illegible]	781127	770217	778880		774818	768337	843883
[illegible]	373734	403843	417841		438804	433308	441131
LF0614	374386	438518	433138		408843	431834	431484
LF0677	381037	334180	343888		733181	333348	348488
[illegible]	386736						
[illegible]	473690						

TI-NHTSA 018534

ANTI-FR	MODULUS CONTROL	48HRS	100HRS	250HRS	500HRS	750HRS	1000HRS
[illegible]	[illegible]	[illegible]	[illegible]	474995	[illegible]	[illegible]	[illegible]
[illegible]	761127	[illegible]	781164	[illegible]		[illegible]	[illegible]
[illegible]	373724	[illegible]	378874	[illegible]	403431	410000	[illegible]
LF0616	374386	[illegible]	441789	[illegible]	[illegible]	[illegible]	[illegible]
LF0677	381037	311931	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]	[illegible]						
[illegible]	[illegible]						
CLR-10							
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	761127	[illegible]	[illegible]	787431	[illegible]	779307	777834
[illegible]	373724	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LF0616	374386	[illegible]	[illegible]	422827	[illegible]	[illegible]	[illegible]
LF0677	381037	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]						
[illegible]	473480						
IPA							
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	761127	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	373724	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LF0616	374386	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LF0677	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]			[illegible]			
[illegible]	[illegible]						
1,1,1,TRI							
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	761127	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LF0616	374386	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LF0677	381037	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]						
[illegible]	[illegible]						

TI-NHTSA 018536

MAKE	12-YEAR CONTROL	LBS/INCH STD.DV	6MONTH	STD.DV	100HRS	STD.DV	200HRS	STD.DV
BRAKE								
200HN	2304.1	79	2859.2	124.7	2644.8	88.0	2820.5	46.7
300HP-K	1820.9	89	2664.1	184.1	2730.9	89.1	2737.7	210.8
[illegible]	1821.6	48	2317.1	64.8	2440.2	207.4	2193.9	221.6
LF0616								
LF0677								
200FN919								
100XC								
ATF								
200HN	2304.1	79	2873.3	45.7	2828.9	48.4		
300HP-K	1820.9	89	2787.3	68.2	2811.4	84.6	2801.8	188.9
[illegible]	1821.6	48	2138.1	88.4	2263.2	234.1	2417.1	146.3
LF0616								
LF0677								
200FN919								
100XC								
ACID								
200HN	2304.1	79	2660	818	2632.1	161.1	2642.9	132.8
300HP-K	1820.9	89	2726.8	73.8	2074.3	77.1	2771.3	126
[illegible]	1821.6	48	2211.6	4.6	2119.4	81.4	2841.8	326
LF0616								
LF0677								
200FN919								
100XC								
[illegible]								
200HN	2304.1	79	2604.8	21.8	2921.6	94.2	2714.8	109
300HP-K	1820.9	89	2983.7	200.8	2648.4	11.5	2642.8	146.8
[illegible]	1821.6	48	2666.8	114.3	2207.6	77	2234.8	21.8
LF0616								
LF0677								
200FN919								
100XC								
[illegible]								
200HN	2304.1	79	2641.9	46	2281.1	52.4	2627.8	68.3
300HP-K	1820.9	89	2830.9	-6.4	2702.4	178.8	2730	69.4
[illegible]	1821.6	48	2184.1	121.8	2818.4	130.8		
LF0616								
LF0677								
200FN919								
100XC								
[illegible]								
200HN	2304.1	79	2484.4	42.1	2690	148.3	2880.7	38.2
300HP-K	1820.9	89	3043	488.9	2688.8	108.8	2702.4	58.8
[illegible]	1821.6	48	2181.8	71.8	2487.8	807	2212.3	184.4
LF0616								
LF0677								
200FN919								
100XC								

TI-NHTSA 018538

ATF[illegible]	IN-GEAR CONTROL	LBS/INCH STD.DV	[illegible]	STD.DV	[illegible]	STD.DV	[illegible]	STD.DV
300HN	2384.1	79	2318.6	71.1	2210.5	188.8	2614.6	16.2
100HN-X	1838.8	80	2384	203.3	2686.8	409.5	2448.9	84.7
200HN[illegible]	1821.6	40	2080.7	23.7	2018.2	26.8	2156	16.9
LF0616								
LF0677								
200FN919								
100HN								
OIL-10								
300HN	2384.1	79	2266	20.3	2430.8	300.6	3431.3	322.3
100HN-X	1838.0	80	2216	301.4	3188.4	130.3	3817.7	143.7
200HN[illegible]	1821.6	40	1940	44	3128.5	170.4	2340.8	480.9
LF0616								
LF0677								
200FN919								
100HN								
IPA								
300HN	2384.1	79	2000.2	30.6			2835.5	170.4
100HN-X	1880.8	80	2789.1	80.2	2921.3	94.1	2648.9	66.8
200HN[illegible]	1821.6	40	2301.6	178.9	3184.3	18.3	2380	43.6
LF0616								
LF0677								
200FN919								
100HN								
1,1,1,[illegible]								
300HN	2384.1	79	2218.8	34.1	2872.3	34.6	2844.4	46.8
100HN-X	1838.9	80	2897.8	142.6	2898.9	140.6	2487.8	121.4
200HN[illegible]	1821.6	40	2084.8	224	2203.4	98.4	2218	43.3
LF0616								
LF0677								
200FN919								
100HN								

TI-NHTSA 018537

	IN-LBS 500%MIN	LBS/INCH STD.DV	TENSILE	STD.DV	100%MOD	STD.DV
BRAKE						
300HN	2826.7	7.7	2628.4	78.2	2345.3	71.4
300HP-E	2581.6	167	2738.2	182.2	2188.3	144.6
300HN906	2090.2	112.2	2084	72.8	1811.6	72.7
LF0616						
LF0677						
300FN919						
100XC						
ATF						
300HN	2711.1	143.4	2780.1	146.8	2874.6	33.1
300HP-E	2687.9	148.9	2788	79.8	2776.4	210.7
300HN906	2298.3	118.8	2204.8	6.4	2299.2	116
LF0616						
LF0677						
300FN919						
100XC						
ACID						
300HN	2877.8	78.2	2888.2	84.7	2464.7	87.2
300HP-E	2787.8	173.6	2868.3	69.1	2843.9	128.1
300HN906	2186.7	103.4	2297	288.6	2098	73
LF0616						
LF0677						
300FN919						
100XC						
AIR-GAS						
300HN	2837.3	79.4	2831.7	134.8	2867.7	38.7
300HP-E	2844.8	487.1	2781.8	7.1	2810.1	261
300HN906	2231.8	88.2	2284.3	186.8	2171.4	13.8
LF0616						
LF0677						
300FN919						
100XC						
SALT						
300HN	2617.4	173.4	2878	137.8	2467.7	34.8
300HP-E	2742	93.9	2708.8	188.1	2648.1	180.2
300HN906	2207.4	167	2188.8	286	2128.4	819.8
LF0616						
LF0677						
300FN919						
100XC						
JP4						
300HN	2648.9	27.4	2629.4	99.8	2880.8	104.6
300HP-E	2721.1	28.8	2732.8	108.1	2818.6	128.4
300HN906	2484.4	494.8	2413.3	218.4	2826	77
LF0616						
LF0677						
300FN919						
100XC						

TI-NHTSA 018538

	IN-TEAL 500HRS	LBS/INCH STD.DV	750HRS	STD.DV	1000HRS	STD.DV
ANTI-FR						
[illegible]	1849.1	1807.6	1979	104	2035.8	37
100HP-E	2460.8	89.3	2258.4	186.3	1877.8	149
[illegible]	2241.4	118.6	2082.1	89.4	1981.2	31
LF0416						
LF0677						
[illegible]						
100HC						
OIL-10						
[illegible]	2814.4	124.6	2446.7	74.7	2234.7	15
100HP-E	2884.3	63.7	2862.9	270	1843	194
[illegible]	2242.9	22.3	2228.8	61.8	1810.8	188
LF0416						
LF0677						
[illegible]						
100HC						
IPA						
[illegible]	2888.2	7.3	[illegible]	187.8	2281.8	64
100HP-E	2873.4	177.3	2772.4	278.5	1781.1	188
[illegible]	2866	808.8	2258.3	148.5	2281.3	98
LF0416						
LF0677						
[illegible]						
100HC						
1,1,1,TRI						
[illegible]	2697.1	323.8	2627.8	81.9	2473.8	29
100HP-E	[illegible]	88.8	2737.7	184.7	2181.2	88
[illegible]	2274.8	103	2188.7	4.3	1878.2	87
LF0416						
LF0677						
[illegible]						
100HC						

TI-NHTSA 018539

SHELL BRAND	INITIAL LENGTH	SMEAR WIDTH	[illegible] LENGTH	EXPOS. WIDTH	INITIAL LENGTH	SMEAR WIDTH	[illegible] LENGTH	EXPOS. WIDTH	INITIAL LENGTH	SMEAR WIDTH	1000HRS LENGTH	EXPOS. WIDTH
[illegible]	[illegible].027	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
300SP-X	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.5	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible].017	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LF0516	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.5	[illegible]	0.[illegible]
LF0477	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.[illegible]	[illegible].017	0.[illegible]	[illegible]	[illegible]
[illegible]												
ATF												
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible].033	[illegible]	[illegible]	[illegible]	[illegible].017	[illegible]
300SP-X	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.470
[illegible]	[illegible]	[illegible]	[illegible].037	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible].017	[illegible]
LF0516	[illegible].04	[illegible]	[illegible].04	0.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LF0477	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible].027	[illegible]
[illegible]	[illegible].11	[illegible]	[illegible].127	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.477
[illegible]												
[illegible]	[illegible]	[illegible]	[illegible].047	[illegible]	[illegible]	[illegible]	[illegible]	0.5	[illegible]	[illegible]	[illegible]	[illegible].5
300SP-X	[illegible]	[illegible]	[illegible]	0.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LF0516	[illegible]	0.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible].037	[illegible]	[illegible]	[illegible]
LF0477	[illegible].01	[illegible]	[illegible].027	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]												
[illegible]												
[illegible]	[illegible].017	0.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible].014	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
300SP-X	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LF0516	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LF0477	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible].027	[illegible]	[illegible].01	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]												
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible].02	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
300SP-X	[illegible]	0.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible].02	[illegible]
LF0516	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LF0477	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible].011	[illegible]
[illegible]												
[illegible]												
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.5	[illegible]	[illegible]
300SP-X	[illegible]	[illegible]	[illegible]	0.473	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible].027	[illegible]	[illegible]	[illegible].5	[illegible].044	[illegible]	[illegible].047	[illegible]
LF0516	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LF0477	[illegible]	[illegible]	[illegible]	[illegible]	[illegible].014	0.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible].04	[illegible]
[illegible]												

TI-NHTSA 018640

FLUID ANTI-FR	INITIAL LENGTH	INITIAL WIDTH	48 HRS LENGTH	[illegible] WIDTH	INITIAL LENGTH	[illegible] WIDTH	[illegible] LENGTH	[illegible] WIDTH	INITIAL LENGTH	[illegible] WIDTH	1000HRS LENGTH	[illegible] WIDTH
300MMX	1.048	0.5	1.038	0.501	1.034	0.5	1.039	0.5	1.038	0.498	1.03	0.501
300HP-X	1.037	0.499	1.04	0.499	1.03	0.502	1.037	0.5	1.048	0.501	1.031	0.5
300HN006	1.024	0.5	1.024	0.5	1.035	0.498	1.034	0.499	1.014	0.498	1.014	0.499
LP0414	1.034	0.5	1.031	0.502	1.047	0.501	1.088	0.499	1.012	0.498	1.014	0.498
LP8477	1.038	0.499	1.08	0.501	1.036	0.497	1.053	0.499	1.084	0.498	1.041	0.498
300VW019 1400C												
GEN-10												
300MMX	1.031	0.5	1.037	0.501	1.032	0.501	1.031	0.5	1.036	0.501	1.037	0.501
300HP-X	1.014	0.498	1.018	0.5	1.022	0.501	1.037	0.5	1.027	0.5	1.034	0.501
300HN006	1.083	0.499	1.036	0.5	1.048	0.481	1.083	0.493	1.122	0.5	1.034	0.501
LP0414	1.018	0.5	1.046	0.5	1.035	0.5	1.08	0.5	1.038	0.5	1.007	0.502
LP8477	1.024	0.498	1.044	0.498	1.038	0.5	1.04	0.501	1.039	0.5	1.018	0.5
300VW019 1400C												
IPA												
300MMX	1.019	0.501	1.018	0.5	1.01	0.504	1.018	0.501	1.034	0.501	1.046	0.501
300HP-X	1.017	0.499	1.018	0.5	1.018	0.498	1.019	0.499	1.038	0.499	1.037	0.499
300HN006	1.033	0.441	1.027	0.44	1.032	0.5	1.039	0.499	1.038	0.498	1.034	0.5
LP0414	1.034	0.5	1.083	0.5	1.014	0.503	1.014	0.5	1.031	0.502	1.031	0.502
LP8477	1.037	0.5	1.023	0.5	1.088	0.501	1.038	0.501	1.084	0.501	1.078	0.5
300VW019 1400C												
1,1,1,TRI												
300MMX	1.019	0.499	1.038	0.5	1.014	0.5	1.023	0.5	1.088	0.5	1.026	0.501
300HP-X	1.01	0.5	1.011	0.501	1.02	0.499	1.018	0.499	1.017	0.5	1.017	0.502
300HN006	1.019	0.499	1.084	0.499	1.02	0.499	1.028	0.5	1.027	0.5	1.028	0.5
LP0414	1.028	0.505	1.023	0.502	1.088	0.5	1.088	0.5	1.014	0.499	1.014	0.5
LP8477	1.036	0.501	1.041	0.501	1.033	0.499	1.044	0.497	1.084	0.493	1.028	0.494
300VW019 1400C												

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

KAPTON® a versatile space-age material with down-to-earth applications.

The space shuttle's solar array; the Lunar Excursion Module; miniaturized electronic components; more efficient oil well pump motors; reliable flexible circuits; thin, lightweight electrical heaters; precise electrothermal fuel level sensors; high-temperature electrical insulation. For the past twenty years, KAPTON has contributed to the innovative design and commercial success of a wide variety of new and improved products. The reason KAPTON was selected for such demanding applications is its unique *combination* of outstanding mechanical, electrical and chemical properties *and* its ability to retain these properties over a wide range of temperatures where other engineering materials do not function.

KAPTON has proved itself as *the* material of choice in applications that involve very high or low operating temperatures.

Designers are finding that the application potential for this unique industrial material has barely been tapped.

A variety of new application possibilities for KAPTON are now being explored by Du Pont and its customers, including semiconductor pads and microprocessor chip carriers. However, a number of uses for KAPTON are well established. Some examples from the electrical and electronics industries are: field coil insulation; substrates for flexible printed circuits; motor and generator armature slot liners; magnet wire insulation; transformer and capacitor insulation; magnetic recording and pressure-sensitive tapes and tubing; and wire and cable insulation.

Three types of KAPTON are commercially available.

■ KAPTON Type H is an all-purpose, all-polyimide film that has been used successfully in applications reaching temperatures as low as −269°C and as high as 400°C. Type H film can be laminated, metallized, diecut, slit, formed, or adhesive-coated. It is available as 0.3, 0.5, 1, 2, 3, and 5 mil film.

■ KAPTON Type V is an all-purpose, all-polyimide film with all of the properties of Type H film, plus *superior dimensional stability*. It is available in 1, 2, 3, and 5 mil thickness.

■ KAPTON Type F is a Type H film coated on one or both sides with TEFLON® FEP fluoropolymer resin to impart *heat sealability*, provide a moisture barrier, and enhance chemical resistance. It is available in a variety of constructions.

One of the important benefits of KAPTON polyimide film is its ability to be bonded, laminated, coated, and otherwise converted to fulfill a broad range of high-performance operating requirements. This outstanding versatility — and the fact that all three types share the same unique balance of properties inherent in the basic material — allows KAPTON to be *custom-tailored* to fit an almost endless variety of applications.

Armed with 20 years' experience with a high-quality material and backed by the considerable resources of the Du Pont Company, we are committed to remaining the world leader in the manufacture and diversification of polyimide films. In response to the needs of our customers and their interest in films that can insulate or conduct electricity, heat shrinkable films, pigmented films, heat conductive films and new adhesive systems, we are making a significant investment in research, development and equipment — aimed at delivering higher quality, improved productivity and better end use products, to our customers.

When sufficient business potential exists, our resources can be made available for the joint development of custom-tailored products and programs to fulfill your most stringent design requirements — during the Eighties and beyond.

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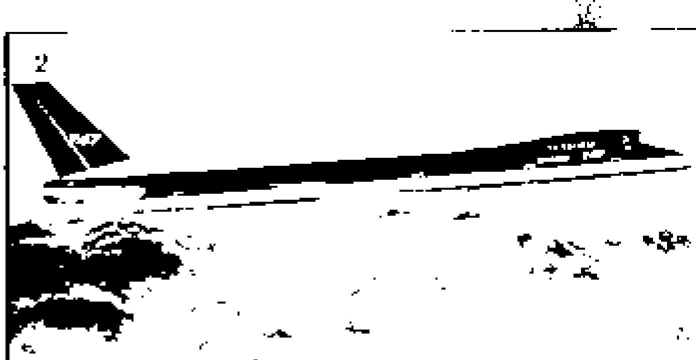

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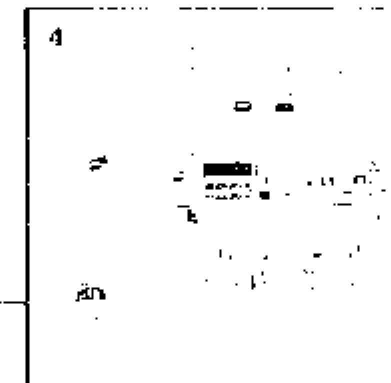

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KAPTON® offers inherent heat and flame resistance and excellent thermal performance.

For all of its outstanding properties, KAPTON is probably best known for its ability to "take the heat." With a UL-94 rating of V-O for flammability — the best possible — KAPTON polyimide film will not sustain or propagate flame. Nor will it melt, drip or produce any significant smoke when exposed to flame.

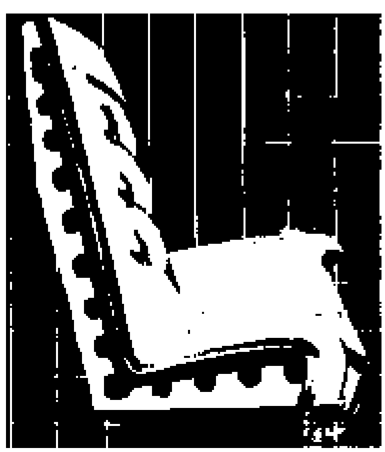
Rated at 240°C for continuous service, KAPTON can still function after exposure to temperatures up to 400°C for brief periods. Best of all — it retains its high dielectric strength even at elevated temperatures — 2,500 volts/mil at 300°C.

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

KAPTON polyimide film is compatible with a number of high-temperature impregnating varnishes used in modern electrical equipment manufacture — including polyimides, esterimides, epoxies, silicones, amides-imides, and organo-silicones. Magnet wire made with certain combinations of polyimide film and varnishes has a IEEE #57 thermal stability rating of 260°C.

But flame and heat resistance aren't the only thermal advantages of KAPTON. It also performs very well at the other end of the temperature scale. KAPTON film retains its flexibility at -269°C without embrittlement or significant loss of other properties.

Keeping people and equipment warm is a natural for KAPTON. As a strong, lightweight, flexible laminated sheet, it can be used to insulate and protect embedded heater wires for such diverse applications as car seat or ski-lift chair heaters, aircraft wing deicers, engine warmers, hot trays and electric blankets.



7. A strip of KAPTON Type H film is positioned over the pins in this IC socket to prevent wicking during wave soldering. The strip also provides a dielectric barrier between the leads and printed circuit.

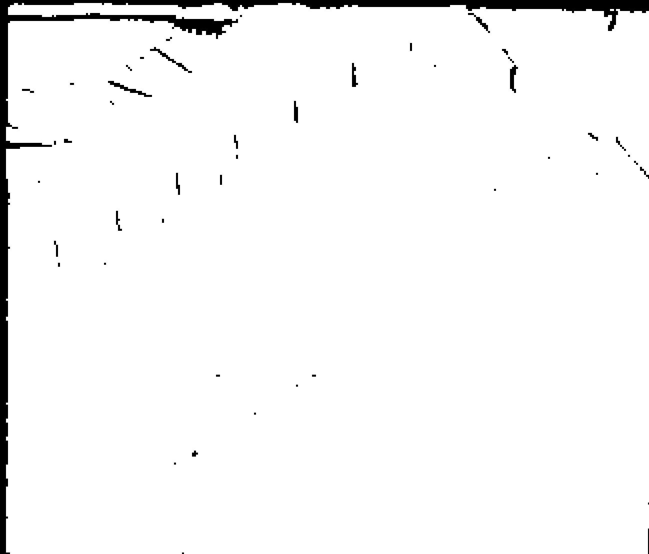
8. A steel mill now gets 3,000 extra horsepower from the same size motor thanks to KAPTON as the coil insulation. The motor manufacturer reports that insulated windings of KAPTON last as much as 50 times longer at the 200°C rated operating temperature versus those with previously used insulations.

9. Used as insulation in rotor and stator windings, KAPTON reduced the weight of traction motors in the world's fastest train by 5%. It also helped reduce motor production costs and increased horsepower.

10. The low smoke properties of insulation of KAPTON permit its use as a cable jacket for plenum cable, eliminating the need for expensive metal conduit.

11. As a pin grid array, KAPTON allows insertion of *all* pins into a circuit board in a single, high-speed operation. Registration is perfect, and the need for expensive loading machinery is eliminated. KAPTON withstands the high temperatures of wave soldering and allows visual inspection of completed connections. After soldering, KAPTON can either be peeled away or left in place as additional support for pins during further processing and handling.

12. PC boards are identified for quality control and inventory purposes by bar code labels using an overlay of KAPTON. Since KAPTON can withstand the temperatures of wave soldering without significant shrinkage or distortion, it can be used for labelling on the *underside* of printed circuit boards where space is not at a premium.



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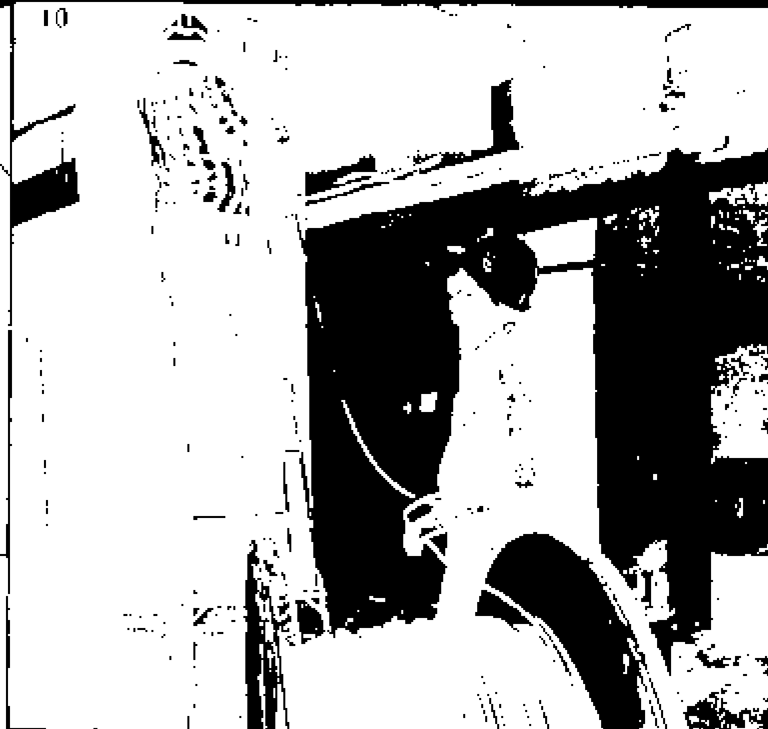

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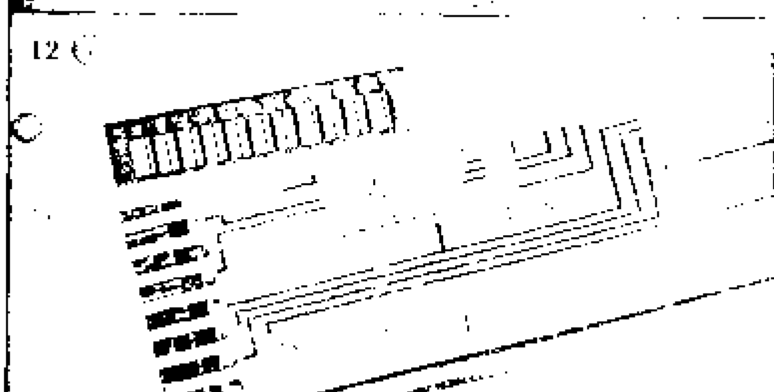

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TI-NHTSA 018546

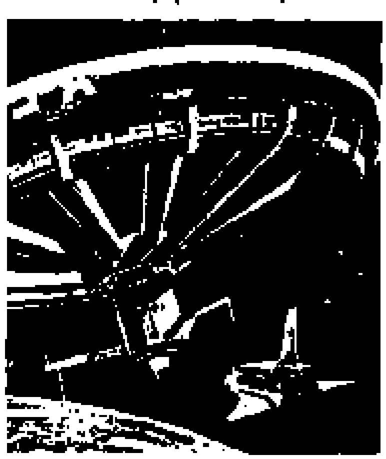
KAPTON® has superior strength, toughness, abrasion resistance and workability.

KAPTON polyimide film can solve a host of parts' performance problems that fibers, resins, metals, composites, glass, ceramics, mica or asbestos and conventional films cannot. The high tensile strength and initial tear resistance of KAPTON provide the mechanical durability necessary for many critical manufacturing operations, such as printed circuit processing and installation. Its exceptional toughness and resistance to cut-through and abrasion make it especially useful as insulation for aerospace communications wire and cable where it can be pulled through even the tightest routing.

Since the outside diameter of a wire or cable insulated with KAPTON is smaller than conventional wiring using extruded insulations, more cables can be run through a given size conduit or plenum. Stripping and termination are easier, too.

The strength, toughness, flexibility and wear resistance of KAPTON film are leading to greater numbers of non-electrical applications as well. Applications such as drive belts, pressure switch diaphragms, wear strips, washers, and seals.

As a material for use in space, KAPTON has virtually no limitations. Designers already envision huge inflatable structures that could be used for a variety of purposes, including space station repairs, energy collection and transmission, and temporary protection of unassembled equipment components.



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

14. KAPTON protects plenum cables from damage by abrasion, kinking and snagging during installation when it is "fished" over sharp places in plenums and through ducting and conduit.

15. Automotive pressure sensing switches use KAPTON for the diaphragm because it is flexible, easily fabricated and withstands the dramatic temperature changes under the hood. KAPTON also resists most organic solvents, oils and greases.

16. KAPTON is an ideal material for tractor belts on high-speed computer printers. Because of its excellent toughness, dimensional stability and thermal properties, KAPTON stands up to the shock of abrupt start and stop operation and the heat of high-speed operation. The tractor belt teeth are injection molded directly into KAPTON film.

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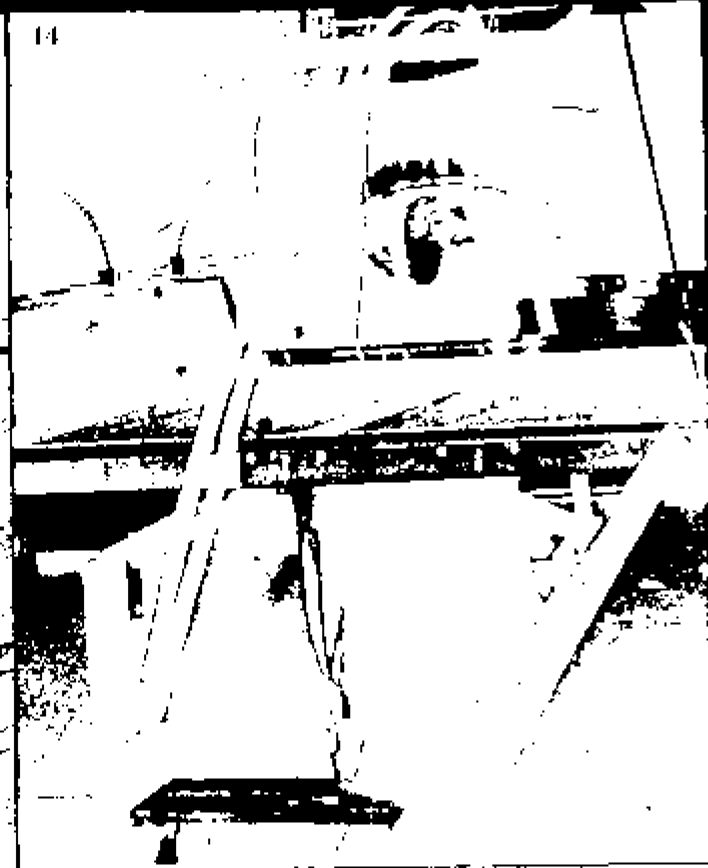

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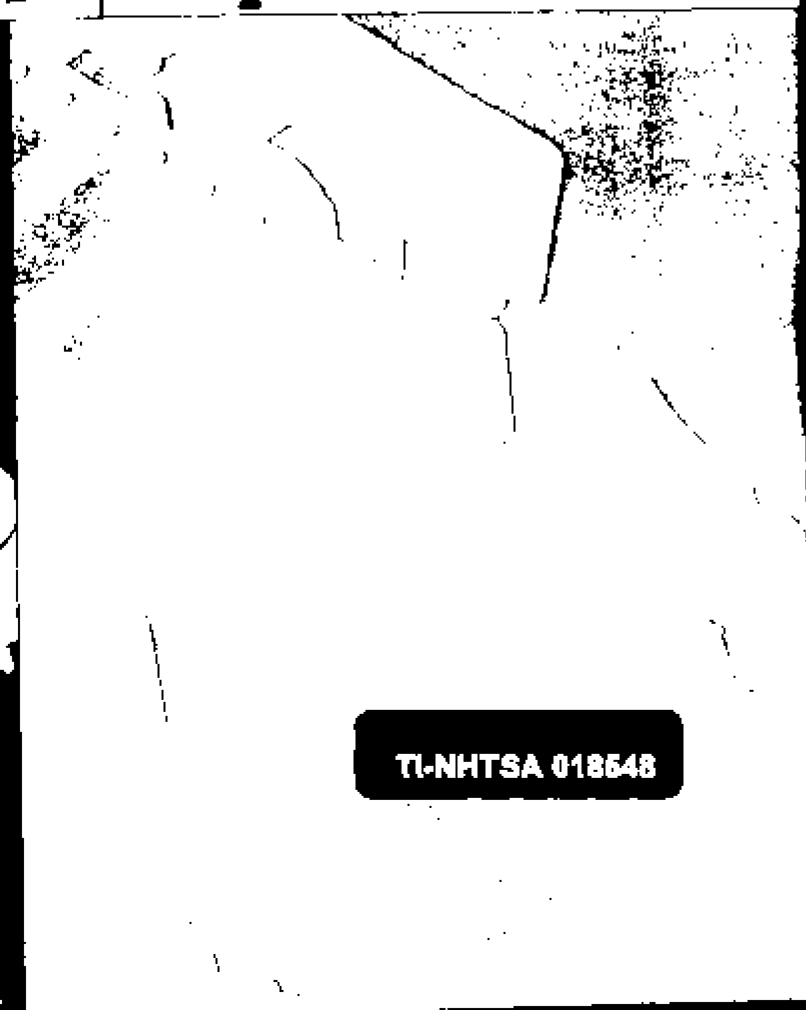


TI-NHTSA 018548

KAPTON® has outstanding electrical properties.

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

The combination of high dielectric strength, thermal stability, uniform thickness and excellent mechanical properties allows designers of electrical equipment to specify thinner insulation on coils for transformer, generator or motor windings. This is very important because more conductors can be physically located within a given space, yielding greater power per unit. Or, if the power requirement is constant, the weight and dimensions of a given coil, stator or rotor can be substantially reduced.

In flexible circuits, the high dielectric constant of KAPTON and low dissipation factor combine to reduce signal loss to a minimum at relatively low operating voltages.

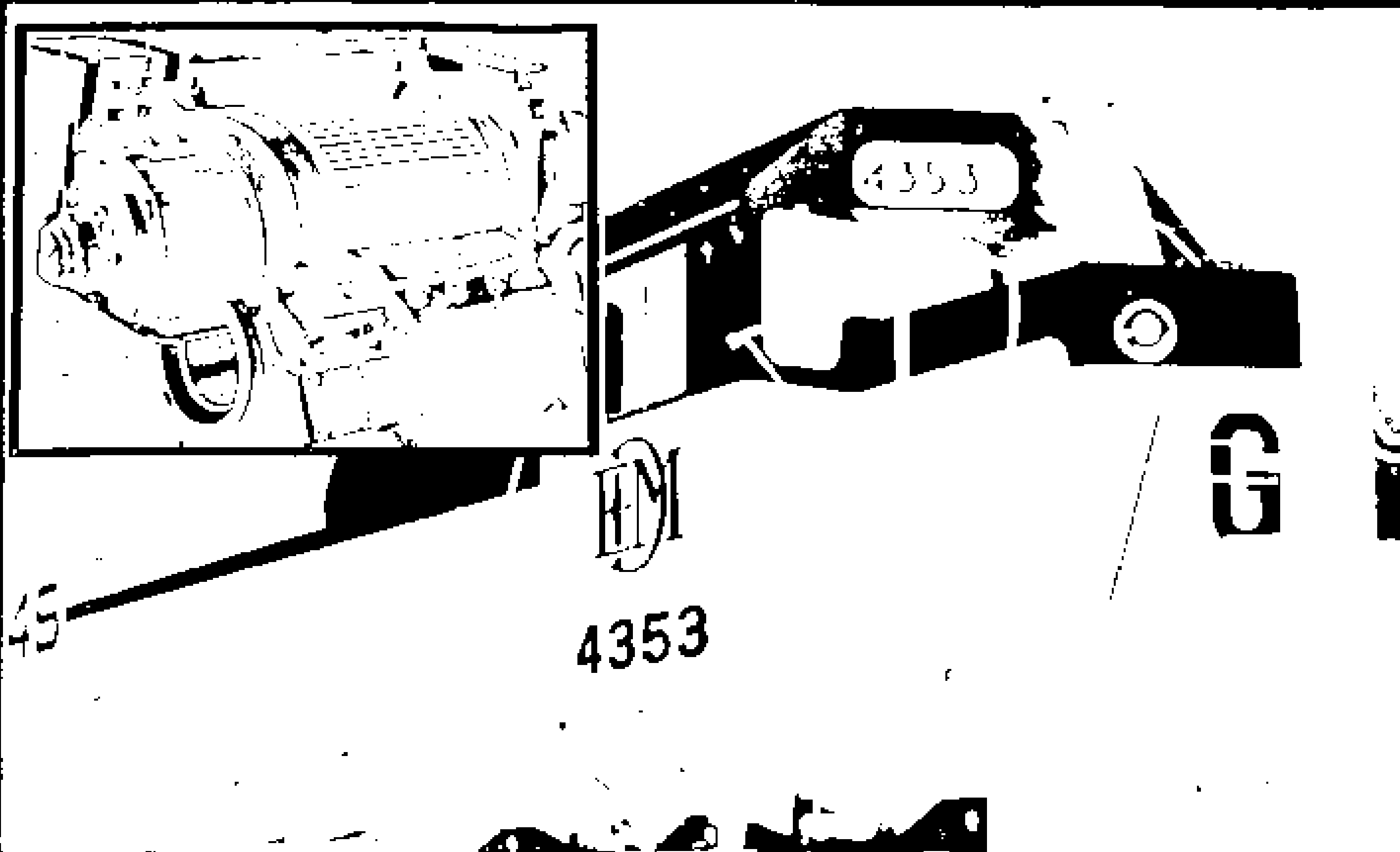
KAPTON film will play a major role in the world's largest linear particle accelerator. Proposed as the insulation for the research instrument's superconductive magnet wire, KAPTON is the only material — repeat, the only material — that can provide the extremely close tolerances, excellent dielectric strength and resistance to the liquid helium temperatures that are required for this unique application.

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

18. A thin, circular band of KAPTON provides outstanding electrical and thermal insulation for this high-frequency "super-tweeter" voice coil. KAPTON resists distortion at high operating temperatures, and is fully compatible with the epoxies, resins and paints used in speaker manufacture.

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

20. By utilizing KAPTON on the coil winding of this electric utility line trap, the size and weight of the device can be reduced 30% — a significant advantage for substations in locations where real estate is at a premium.



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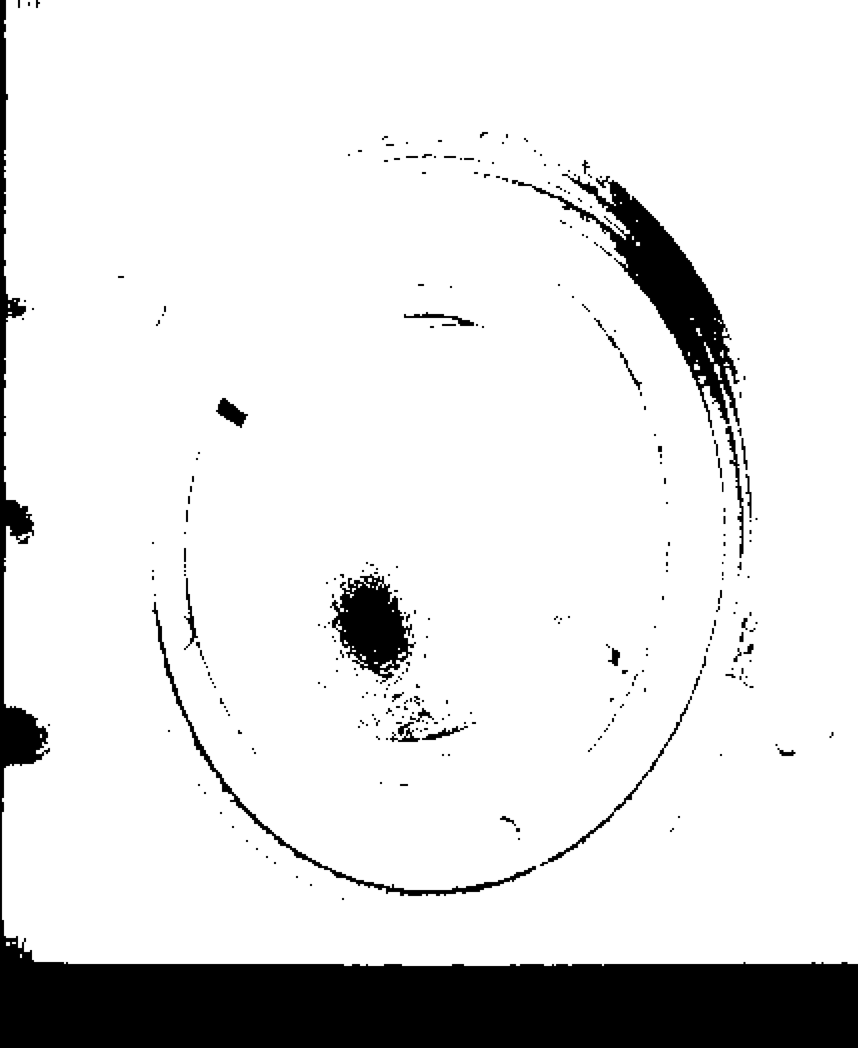

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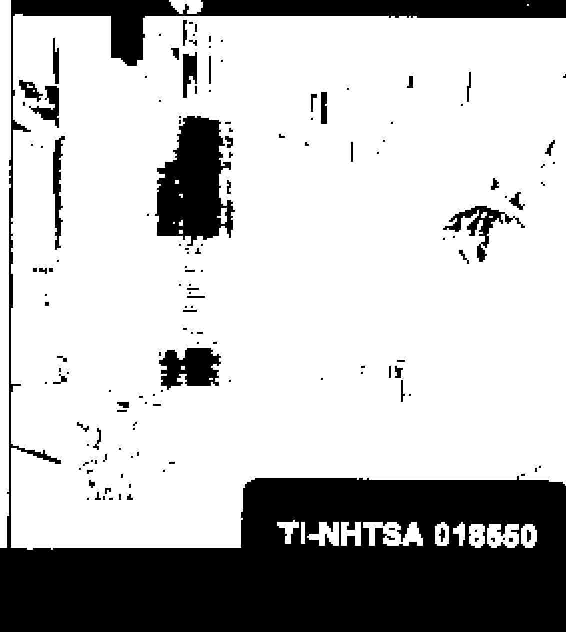
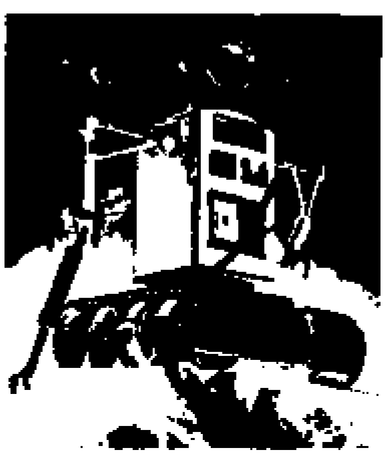


KAPTON® has outstanding resistance to most chemicals, solvents, lubricants and fuels.

KAPTON is an ideal material for use in demanding environments in which a combination of hostile elements such as chemicals, gasses, radiation and high temperature is present. No matter whether you're talking about the motor windings insulation in an oil well pump operating in a pit of gas and brine 20,000 feet below the surface of the earth, a protective layer for a liquid level sensor submerged in an organic solvent, or in a pressure switch in the cooling system of an automobile — KAPTON can take the punishment and still deliver reliable performance.

In flexible circuitry, conductors bonded between layers of KAPTON polyimide film are protected against chemicals, moisture, gasses and foreign materials so they can operate reliably in demanding environments. In military and industrial applications, KAPTON film remains tough and flexible even after exposure to 10^6 RADS of gamma radiation. And, although it is unaffected by most organic chemicals, solvents, fuels and lubricants, KAPTON can be dissolved by certain strong bases — a fact that printed circuit manufacturers use to advantage in the chemical milling of holes in printed circuits.

As mobile research vehicles brave the hostile environments of distant planets and traverse their rugged surfaces gathering samples and data, they will undoubtedly have the protection of KAPTON film. In applications ranging from wire and cable insulation to surface protection — from tractor belts to solar panels — KAPTON will make these robot explorers lighter, stronger, more resistant to chemicals, radiation and abrasion, and ultimately — more reliable.

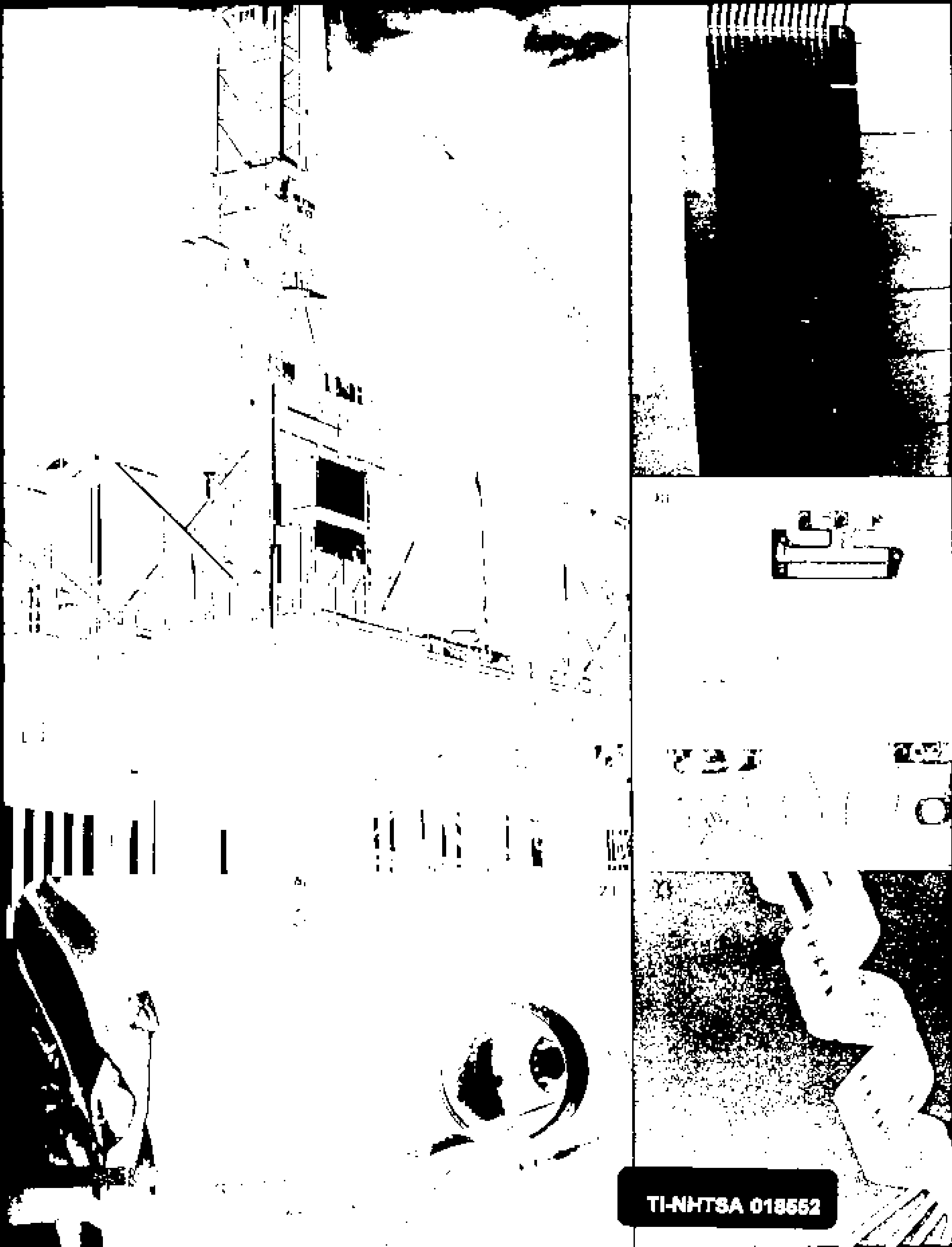


21. This 2,300 VAC submersible oil well pump uses KAPTON polyimide film in the magnet wire and slot liner insulation system. Motors of this type often operate at depths of 20,000 feet or more in hostile, high-temperature environments which contain brine, petrochemicals and hydrogen sulfide. Manufacturers report a 50% improvement in service life using motors insulated with KAPTON.

22. Specialty conductors metallized between sheets of KAPTON comprise a highly reliable and accurate automotive electrothermal fuel level sensor developed in Germany by VDO. In addition to its outstanding thermal and dielectric properties, KAPTON can be directly immersed in a wide variety of fuels, including blended ethanol and methanol.

23. KAPTON is an ideal substrate for this CTS throttle position transducer. Not only is it resistant to automotive chemicals and lubricants; it can also withstand both high underhood temperatures, and cold winter mornings while still performing reliably.

24. Critical fuel lines of satellites in space are kept from freezing at ultra-low temperatures by heater cables insulated with KAPTON. Nickel-chromium heating elements are encapsulated in a sandwich of KAPTON which provides both superior dielectric properties and full protection against the thermal shock of extremely high and extremely low temperatures.



Kapton ... only from Du Pont

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DU PONT

TI-NHTSA 018553

Texas Instruments

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TI-NHTSA 018654

Teflon Films

Teflon is Du Pont's trademark for their fluoropolymer materials. Teflon refers to both polytetrafluoroethylene (PTFE) and fluorinated ethylene propylene (FEP), and other fluoropolymers.

FEP is a copolymer of tetrafluoroethylene and hexafluoropropylene. It has the chemical repeat structure of $-CF_2CF_2CF(CF_3)CF_2-$. The parentheses indicate that the CF_3 unit is a side group pendant from the third C in the repeat unit.

FEP is melt processable. It was developed to achieve the propeties of PTFE with the added bonus of being manufacturable on conventional polymer processing equipment. FEP film is produced by melt extrusion. Air is easily removed from the thin polymer layer, so microvoids or porosity is not an issue with FEP film.

FEP is one of the least permeable of all polymer materials. Among common polymers, only polyvinylidene chloride (Saran) has a smaller moisture vapor transmission rate than FEP. More information on water permeability through FEP and FEP/Kapton laminates can be obtained from the work of Sacher and Susko (J. Appl. Poly Sci., 27, 3893 (1982) and J. Appl. Poly Sci, 30, 1393 (1985)).

PTFE has the chemical repeat unit of $-CF_2CF_2-$. PTFE is so viscous when molten that it cannot be processed by conventional injection molding or melt extrusion. PTFE can only be manufactured by sintering or by casting. Both sintering and casting can be used to produce PTFE films.

Sintering is accomplished in a manner similar to powder metallurgical techniques. Fine PTFE powders are compressed and heated. This sintering causes the powders to coalesce into a solid billet. Films can be made from this billet by cutting thin sections from it. This is called skiving.

Casting is done by dispersing fine PTFE powders into a liquid. The dispersion is deposited as a thin layer. The liquid is driven off, and the powders coalesce under heat. A PTFE film results.

Skived film and cast film are easily distinguishable. Cast film is clear, whereas skived film is white. The PTFE film removed from Wako switches are skived films.

Both processing techniques create microvoid porosity in the final PTFE product. This is a bigger problem in skived film than in cast film. In sintering, it is difficult to remove air from the thick billet. Small air bubbles are trapped in the billet. When the billet is cut during skiving, the bubbles are cross-sectioned, creating microvoid porosity in the film. Skived film is more permeable than cast film as a result. The permeability of cast PTFE film is approximately equivalent to that of FEP.

This information is based on conversation with Maurice Baumann of Du Pont, and from material in Engineering Polymer Sourcebook by Raymond B. Seymour.

TEFLON FEP FILM

- Melt processable
- Microvoids and porosity not a problem
- Very low permeability
- Film is clear

TEFLON PTFE FILM

- Not melt processable
- Cast film--clear
- Skived film--white
- Microvoid porosity in skived film
- Higher permeability in skived film

PROPERTIES OF TYPE HN FILM

MECHANICAL

[illegible]

ELECTRICAL

[illegible]

*1 hour for 30 and 60 gauge film.

Thermal Durability

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

Sheets of film 8½" x 11" are freely suspended in an oven at 400°C. The temperature of the oven is monitored with a thermocouple to insure a temperature accuracy of ±2°C. Sheets are removed after 2 hours* and tested on an Instron Tensile Tester as described above under "Elongation." The elongation (at 23.5°C.) of the film should not be less than 10% after this aging at 400°C. This conforms to the "Elongation after Aging at 400°C." test (paragraph

4,4,5) and "Elongation, percent, after 2 hour 400°C."* requirement (Table 1) of MIL-P-46112 B (MR).

Underwriters Laboratories Inc. lists a thermal index of 200°C.–220°C. (depending on gauge and type) for mechanical properties and 220°C.–240°C. (depending on gauge and type) for electrical properties under their file no. E39505 for "Kapton" polyimide film.

*1 hour for 30 & 50 gauge film.

PROPERTIES OF TYPE FN FILM

A. Heat Seal Strength

1. Film to Film Seals

The heat seal peel strength between the coated and uncoated side of one side coated Kapton® polyimide film or the coated to coated side of one or two side coated "Kapton" is measured in the following manner: Seals are made in a jaw sealer at 350°C., 20 psi, 20 sec. dwell time. After cooling, the seals are cut to 1" wide strips using a Thwing-Albert JDC sample cutter or equivalent. The strength of the seal is measured with an Instron type tensile tester. Seal strength is defined as the peak instantaneous strength occurring in each seal. Five specimen values are averaged.

The minimum peel strength between the coated sides of one or two side coated "Kapton" polyimide film will be 600 gms./inch except for 120FN616 which will be 450 gms./in. The minimum peel strength between the coated and uncoated side of one side coated "Kapton" will be 450 gms./inch.

2. Film to Copper Seals for 120FN616 Film

The ability of 120FN616 film to adhere to copper is measured by using the same heat seal peel strength technique as described above.

The peel strength obtained when 120FN616 is sealed to the untreated side of ¼ oz. GT copper foil (1 mil) will be a minimum of 250 gms./in.

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

The bond between the Type HN "Kapton" and Teflon® fluorocarbon resin layers on all type FN products except 120FN616 will have a minimum peel strength of 225 gms./in. as measured using an Instron type tensile tester and a 180° peel.

B. Dielectric Strength

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PROPERTIES OF TYPE VN FILM

MECHANICAL

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ELECTRICAL

[redacted]

Thermal Durability

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

Sheets of film 8½" × 11" are freely suspended in an oven at 400°C. The temperature of the oven is monitored with a thermocouple to insure a temperature accuracy of ±2°C. Sheets are removed after 2 hours and tested on an Instron Tensile Tester as described above under "Elongation." The elongation (at 23.5°C.) of the film should not be less than 10% after this aging at 400°C. This conforms to the "Elongation after Aging at 400°C." test (paragraph 4,4,5) and "Elongation, percent, after 2 hour 400°C." requirement (Table 1) of MIL-P-46112 B(MR).

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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 ¾" wide. Core material will be fibre for 3" I.D. cores wider than ¾" and 6" I.D. cores. A split 3" I.D. fibre core is standard for all universal rolls. Core width for universal wind is 2¾".

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

D. WIDTH TOLERANCE

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

Slit Width Range	Tolerance
⁷/₈" or less Universal only	± 7 mils
1" or less	± 15 mils
1¹/₁₆"–4"	± 30 mils
4¹/₁₆" or wider	± 60 mils

E. ROLL TYPES

"Kapton" film is supplied in two types of rolls, pad and universal wind. Available film widths and roll O.D.'s are specified on the next page.

[redacted]

(1) 3" x 6" pad roll is available in widths up to [illegible] only in 100HN, 200HN, 300HN, 500HN, 150FN019, 200FN011, 500FN919, 250FN029, 300FN021, 300FN[illegible].

* O.D. Tolerance is ± [illegible] for pads and ± [illegible] for universal.

* Type HN, FN and VN films in pads are supplied in width increments of [illegible]. Most films are supplied in width increments of [illegible] in widths [illegible] to 2".

* All universal rolls are available in [illegible] width increments with [illegible] maximum widths. The minimum width is [illegible] for 3" x 8" (I.D. x O.D.); the minimum width is [illegible] for 3" x 8", and 3" x 12" (I.D. x O.D.).

Specifications for pad rolls are:

1. Core width will be film width + ⅛", −0".
2. Core edges shall not project more than 1/16" beyond roll face on either side.
3. Core shall not be recessed on either side.
4. The outside and starting ends of the film shall be fastened in such a manner as to prevent unwinding.
5. "Dishing" or "cupping" may not exceed 1/16" measured with a straight edge across the diameter of the roll.

Specifications for the universal rolls are:

1. The difference between the length of projecting core on each side shall not exceed 3/16".
2. Film shall not project from the main body of the roll more than ⅛".
3. The outside and starting ends of the film shall be fastened in such a manner as to prevent unwinding.
4. Roll face depression, the difference between the highest and lowest points unstressed, shall not exceed 3/16".
5. Width of traverse is 1¾", −¼", +⅛".

F. SPLICES

1. Description

Three types of splice are available.

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

Splices will be sufficiently smooth and wrinkle-free so as not to distort adjacent layers of film and approximately centered to ± ¼".

Tape splices are standard on all gauges of "HN" and "VN" film and also on all gauges of "FN" film more than 12" wide.

Tape splices are made as follows. A butt splice with film ends covered on both sides of the film with splice tape. For films less than 0.002" thick a 1" wide pressure sensitive tape is used. For films 0.002" thick and greater a 2" wide pressure sensitive tape will be used.

Heat seal splices are made as follows. On all films but 250FN029 the splice is an overlap splice a minimum of ⅛" long. On 250FN029 a butt splice is made using 120FN616 as the joining tape applied on the FEP surface.

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

The 250FN029 butt splice is oriented with the 120FN616 tape on the top of the film as it unwinds from a universal put-up and on the bottom as it unwinds from a pad.

2. Maximum Splices per Slit Roll

The minimum average footage between splices for most rolls is shown in Table I. To calculate the maximum number of splices in a roll divide the nominal feet per roll by the minimum average length between splices and subtract one.

3. Splice Placement

Table I shows the minimum length between splices and from the beginning and end of a roll, for most "Kapton" rolls. No splice is allowed, however, once a roll has reached the minimum O.D.

TABLE I

MINIMUM AVERAGE SPLICE FREE LENGTH (FEET)

[illegible]

NOTES: [1] To 50" wide for 30HN, 52" wide for 50HN
[2] To 60" wide
[3] To 6" wide
[4] To 18" wide. For widths greater than 18" to the maximum, the minimum average footage will be one half that shown in the table.
[5] ½" to ¾" wide

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

[illegible]

G. AVERAGE THICKNESS TOLERANCES (UNIT WEIGHT)

[illegible]

*Applies to Type VN films also.

[illegible]

Test Method and Sampling Procedure

Weigh test specimens equal to the width of slit roll and not less than ½ meter long to the nearest 0.10 gram on a torsion balance.

To confirm average thickness tolerances, obtain a sample consisting of a minimum of one specimen from each of several randomly selected slit rolls as follows:

Slit Roll Width	Minimum Number of Slit Rolls to be Sampled
Under 6"	25 ÷ slit roll width (in.)
6" and Over	4

TI-NHTSA 016562

H. MICROMETER THICKNESS

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

[redacted]

*Applies to Type VN films also.

[redacted]

Test Method

Make the following measurements to confirm that film from a single slit roll meets the micrometer tolerances:

1. Measure in accordance with ASTM-D-374-79, Method A or C.
2. Obtain the average of 10 randomly selected readings from a minimum area of 12 square inches. Recheck before rejecting any slit roll. Abnormal readings may occasionally result from dust particles or spot surface imperfections. Discard such readings as they will adversely affect the accuracy of measurements designated to indicate general sheet thickness.

Gauge Depression

To reduce web handling difficulties which would occur if film representing thickness extremes were shipped in the same roll, a gauge depression standard is applied.

Roll depression is the difference in diameter between the hardest and softest part of the roll or the difference between the undepressed and depressed (finger pressure) diameter at the softest part, whichever is greater.

Table II lists the maximum allowable depression for most pad rolls. There is no gauge depression standard for universal wind since that roll is limited to a maximum of 7/8" wide.

TABLE II

KAPTON® POLYIMIDE FILM GAUGE DEPRESSION STANDARDS—PAD ROLLS
(Maximum allowable depression in 1/32" increments)

[redacted]

TI-NHTSA 018563

Kapton

POLYIMIDE FILM

GENERA
SPECIFICATION
BULLETIN GS-87-

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

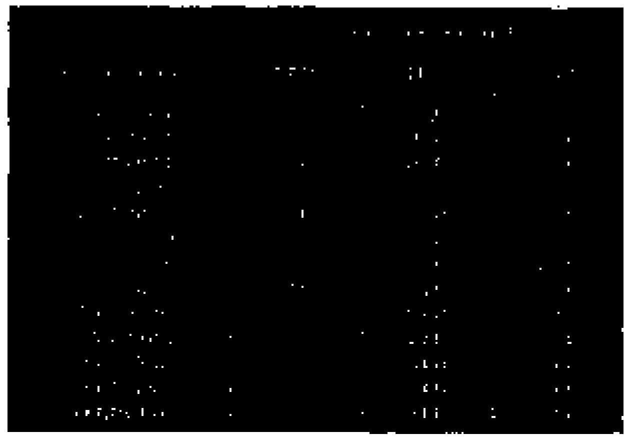
Du Pont makes three types of "Kapton" polyimide film, Type HN, Type FN and Type VN.

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.



Type VN Film

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

Certification

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

DU PONT

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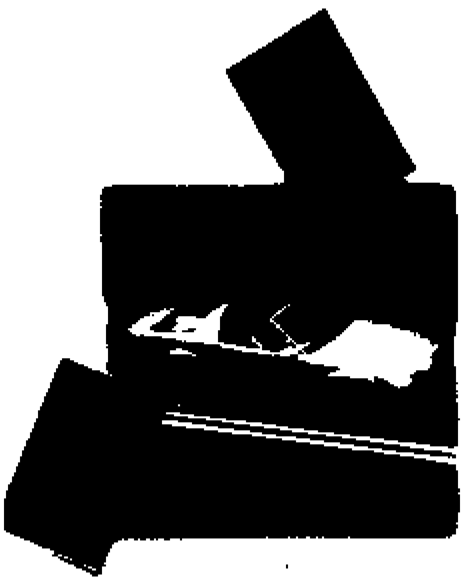
DuPont KAPTON®



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

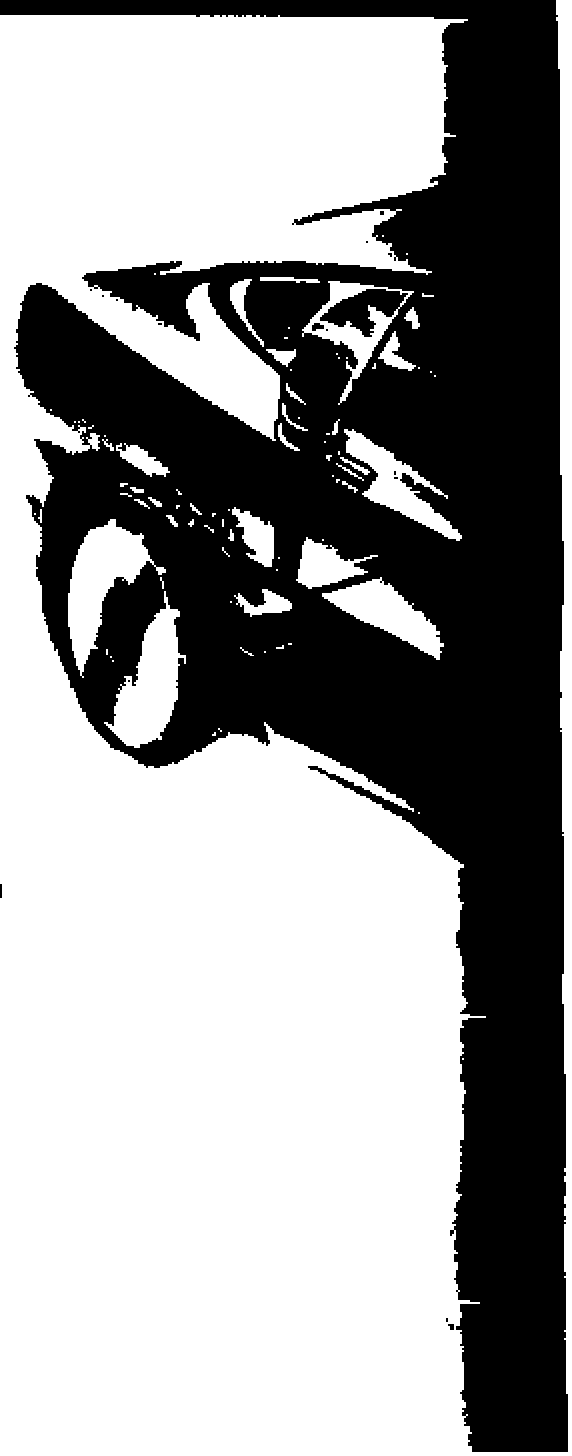
And, KAPTON is backed by a team of DuPont experts who are ready to provide technical support to designers, fabricators and original equipment manufacturers. In addition, the DuPont KAPTON Marketing Development Group offers a unique opportunity to form partnerships in selling products to the automotive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

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

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

rent and Potential

of KAPTON®



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

Typical

# of KAPTON®

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

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

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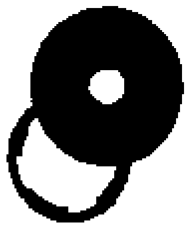
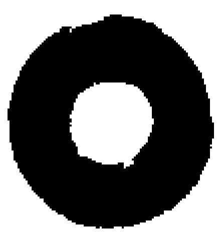


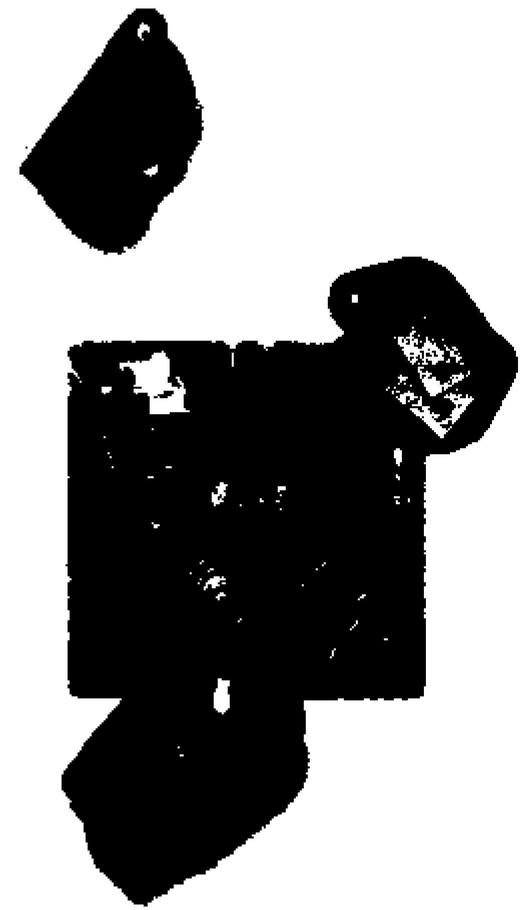


KAPTON® is used in fuel pulsation dampeners, fuse planes, wiring harnes replacements, power steering switches, EGR sensors, ABS components and a host of other automotive applications. In addition to outstanding chemical resistance, KAPTON features a UL®-94 V-O rating for flammabili

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

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

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



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

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

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

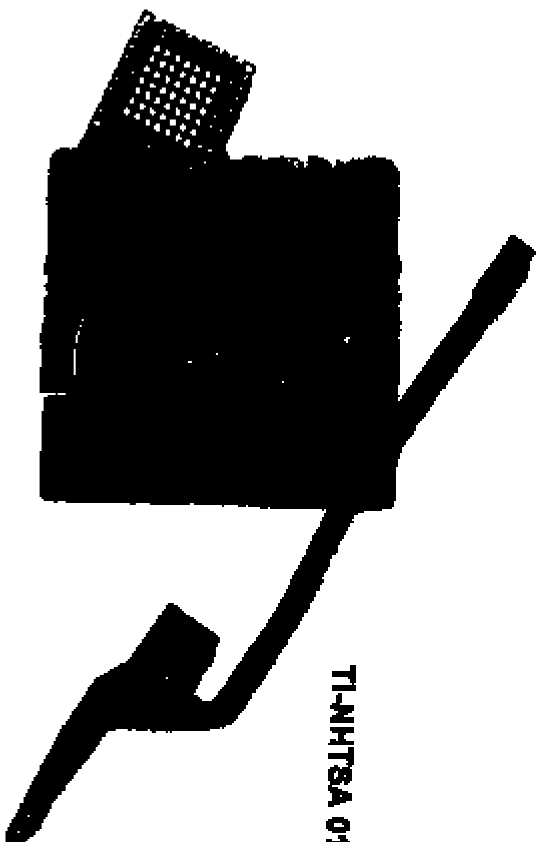
For example, automotive engineers have used KAPTON in a newly designed throttle position sensor that helps maximize fuel efficiency.

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

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

n Up Your

with DuPont KAPTON®



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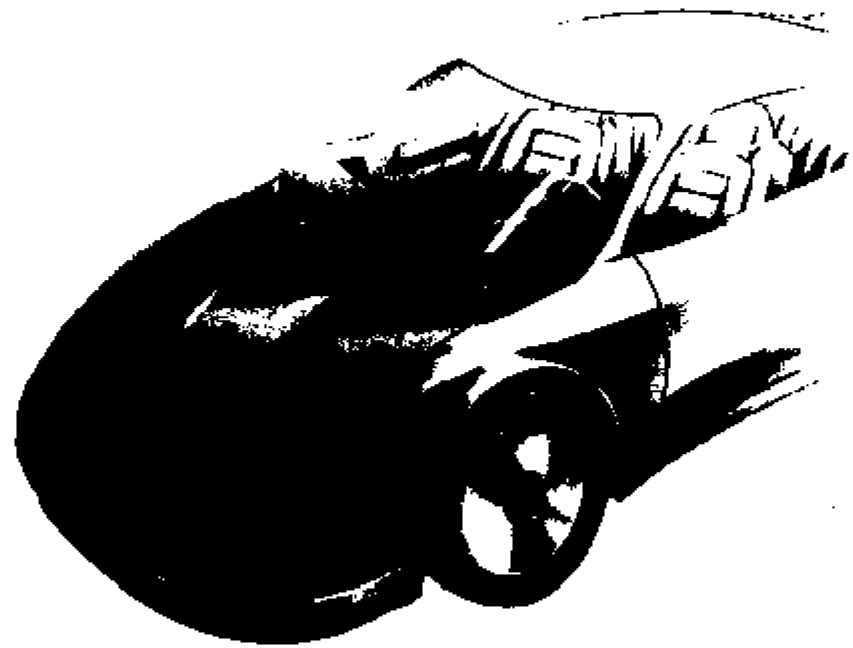
When you take a look into the future of the automotive industry, what do you see? Engines that will run hotter than ever before? Extended factory warranties? Stricter safety and emissions requirements? More and more challenges?

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

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

How to

with **DuPont KAPTON®**



KAPTON
Only by DuPont

DuPont Electronics

DuPont Company
Barley Mill Plaza
P.O. Box 80019
Wilmington, Delaware 19880-0019

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.

DJF/ tlp
Enclosures

®Du Pont Registered Trademark

TI-NHTSA 018575

KAP002

MATERIAL SAFETY DATA SHEET

E. I. DUPONT DE NEMOURS & CO
POLYMER PRODUCTS DEPARTMENT
ELECTRONICS DEPARTMENT
1007 MARKET STREET
WILMINGTON, DE 19898

TELEPHONE NUMBERS
MEDICAL EMERGENCY 800-441-3637
PRODUCT INFORMATION 800-441-7515
TRANSPORTATION EMERGENCY 800-424-9300

MATERIAL IDENTIFICATION

PRODUCT NAME	Kapton® Polyimide Film, coated types F, FN, XP, ZN	<
CHEMICAL NAME	Aromatic Polyimide plus up to 1 % dimethyl acetamide and a polyfluorocarbon coating.	
CAS REGISTRY NUMBER	NA	
TSCA INVENTORY STATUS	All reportable ingredients are listed in the TSCA Chemical Substance Inventory.	<
DOT HAZARD CLASS	Not regulated	
SHIPPING NAME	NA	
PREPARER	C. B. Stouffer DATE September 27, 1989	<

HAZARDOUS COMPONENTS

MATERIAL	Dimethyl acetamide	
CAS NO.	127-19-5	
CONCENTRATION %	Up to 1%	
OSHA PEL	10 ppm (skin)*	<
ACGIH TLV	10 ppm (skin)*	
DUPONT AEL	10 ppm (skin)*	

*The "skin" notation serves as a reminder that exposure can result through skin absorption as well as through inhalation, and that appropriate precautions should be taken to prevent both types of exposure.

SUBSTANCES PRESENT AT A CONCENTRATION OF 0.1% OR MORE CLASSIFIED AS A CARCINOGEN BY IARC, NTP OR OSHA: None

PHYSICAL/CHEMICAL DATA

APPEARANCE	Transparent film, light amber color
ODOR	None
MELTING POINT	None
SOLUBILITY IN WATER	Insoluble
VOLATILE CONTENT	1% max
SPECIFIC GRAVITY	>1.4

FIRE AND EXPLOSION HAZARD DATA

FLASH IGNITION TEMPERATURE NA

UNUSUAL FIRE, EXPLOSION HAZARDS Chars but does not burn. Static charge may build up during handling of Kapton® film.

HAZARDOUS COMBUSTION PRODUCTS Hydrogen fluoride, carbon monoxide, carbonyl fluoride.

SPECIAL FIRE FIGHTING INSTRUCTIONS Wear self-contained breathing apparatus and clothing to protect from hydrogen fluoride, which react with water to form hydrofluric acid. Wear Neoprene gloves when handling refuse from a fire involving fluorocarbon resins.

EXTINGUISHING MEDIA Water, carbon dioxide, foam, dry chemical.

HAZARDOUS REACTIVITY

CONDITIONS TO AVOID Temperatures above 260°C without adequate ventilation. Coated types of Kapton® will burn in an atmosphere of 95% oxygen.

MATERIALS TO AVOID Alkali metal and interhalogen compounds.

HAZARDOUS DECOMPOSITION PRODUCTS Above 260°C coated types of Kapton® can evolve toxic gaseous materials such as hydrogen fluoride and perfluoroolefins. Major off-gases are carbon monoxide and carbon dioxide.

HEALTH HAZARD DATA

Read "Safety in Handling and Use" Bulletin E-72084 before using Kapton®. Avoid contamination of tobacco products.

ACUTE OR IMMEDIATE EFFECTS: ROUTES OF ENTRY AND SYMPTOMS

INGESTION Not a probable route of exposure.

SKIN No irritation expected. Less than 1 ppm dimethyl acetamide was extracted from film by distilled water at 40°C for 4 hours.

EYE Not a probable route of exposure. Mechanical irritation.

INHALATION Vapors and fumes liberated above 260°C or from smoking tobacco or cigarettes contaminated with coated types of Kapton® film may cause influenza type symptoms (polymer fume fever) with chills fever and sore throat, which may not occur until several hours after after exposure, and pass within 36-48 hours, even without treatment.

Inhalation is not a probable route of exposure for film. For the polymer from which this film is made, du Pont recommends treating polymer dust as a nuisance particulate, and has established an AEL of 10 mg/m^3 total dust, the same as the TLV for nuisance particulates.

EMERGENCY FIRST AID

- If exposed to fumes from overheating or combustion, move to fresh air. Consult a physician if symptoms persist.
- For prolonged skin contact, wash with soap and water. In case of skin irritation, consult a physician.
- Flush eyes with plenty of water. Consult a physician if symptoms persist.

CHRONIC EFFECTS None known.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE None known.

PROTECTION INFORMATION

EYE Safety glasses recommended.

SKIN Gloves recommended.

VENTILATION Local exhaust for operation above 200°C.

RESPIRATOR Not required for normal processing.

DISPOSAL

SPILL, LEAK OR RELEASE Sweep up to avoid slipping hazard.

WASTE DISPOSAL Landfill or incinerate in compliance with federal, state, and local regulations. Incinerator should be equipped with scrubber to remove acidic hydrogen fluoride from off-gases.

AQUATIC TOXICITY Insoluble

STORAGE CONDITIONS Store away from flammable materials.

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

NA = Not applicable
NE = Not established
AEL = Du Pont Company's Acceptable Exposure Limit
> = New or revised information in this section when " > " is in left margin

SECTION 313 SUPPLIER NOTIFICATION

This product contains no known toxic chemicals subject to the reporting requirements of section 313 of the Emergency Planning and Community Right-To-Know Act of 1986 and of 40 CFR 372.

STATE RIGHT TO KNOW LAWS

No substances on the state hazardous substances list, for the states indicated below, are used in the manufacture of products on this Material Safety Data Sheet, with the exceptions indicated. While we do not specifically analyze these products, or the raw materials used in their manufacture, for substances on various state hazardous substances lists, to the best of our knowledge the products on this Material Safety Data Sheet contain no such substances except for those specifically listed below:

SUBSTANCES ON THE PENNSYLVANIA HAZARDOUS SUBSTANCES LIST PRESENT AT A CONCENTRATION OF 1% OR MORE:
Dimethyl acetamide (1% maximum)

SUBSTANCES ON THE PENNSYLVANIA SPECIAL HAZARDOUS SUBSTANCES LIST PRESENT AT A CONCENTRATION OF 0.01% OR MORE: None known.

NON-HAZARDOUS INGREDIENTS PRESENT AT A CONCENTRATION OF 3% OR MORE REQUIRED TO BE LISTED BY PENSYLVANIA:

	CAS No.
Polyimide film	25038-81-7
Polyfluorocarbon coating	25067-11-2 or 26655-00-5 or 25038-71-5.

WARNING: SUBSTANCES KNOWN TO THE STATE OF CALIFORNIA TO CAUSE CANCER: None known.

WARNING: SUBSTANCES KNOWN TO THE STATE OF CALIFORNIA TO CAUSE BIRTH DEFECTS OR OTHER REPRODUCTIVE HARM: None known.

SUBSTANCES ON THE NEW JERSEY WORKPLACE HAZARDOUS SUBSTANCE LIST PRESENT AT A CONCENTRATION OF 1% OR MORE (0.1% FOR SUBSTANCES IDENTIFIED AS CARCINOGENS, MUTAGENS OR TERATOGENS):
Dimethyl acetamide (1% maximum).

Kapton
POLYIMIDE FILM

GENERA
SPECIFICATIO
BULLETIN GS-87

GENERAL

INTRODUCTION

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

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Type FN Film

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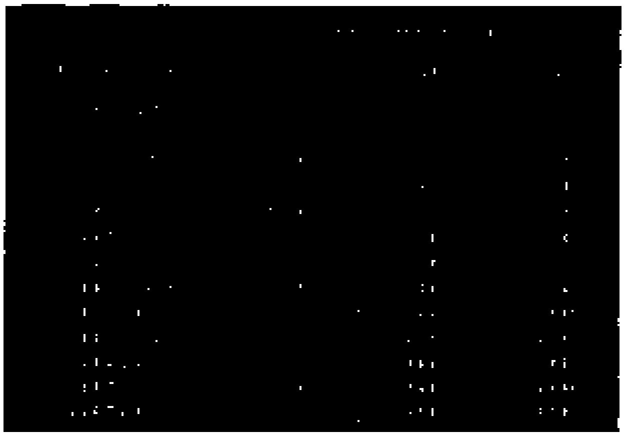

Type VN Film

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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.

DUPONT

2/6 DUPONT

Emmett Miller
ED McKENZIE @ TI

~~ISO9002~~

FN ⟹ has ~~[illegible]~~ FEP in it

- E Kanban (From line)
- Endurance Testing on TP Film
- Oasis Film - Now
- XP 131 ⟹ has PFA in it
  - Sample roll 6 to 8 yrs ago
  - Did ~~Kapton~~ Dupont Kapton ever make this

- Worldwide resin markets are short thru end of '96 ~~for~~ early '97

- Samples of XP929 given to Richard Standard
  baseline 500 FN131

  Oasis 250
  2 mil kapton / .25 mil on each side

- Color discussion
  Light vs. Dark

- TDC ⟹ JV in Japan
  Torre' + Dupont