EA02025

TEXAS INSTRUMENTS, INC.'S

09/10/03 LETTER TO ODI

REQUEST 10

BOX 13

PART A – G

PART F

DUPONT

MATERIAL SAFETY DATA SHEET

IDENTIFICATION

NAME
HFC-134a

FORMULA
CH_2FCF_3

MANUFACTURER/DISTRIBUTOR
E. I. du Pont de Nemours & Co. (Inc.)

ADDRESS
Wilmington, DE 19898

CHEMICAL FAMILY
Halogenated Hydrocarbon

TSCA INVENTORY STATUS
Reported/Included

PRODUCT INFORMATION PHONE
(800) 441-9450

MEDICAL EMERGENCY PHONE
(800) 441-3637

TRANSPORTATION PHONE
CHEMTREC (800) 424-9300

PHYSICAL DATA

BOILING POINT
-26.5°C (-14.5°F) @ 736 mmHg

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

VAPOR DENSITY (AIR = 1)
3.18

FORM
Liquefied Gas

COLOR
Colorless

PERCENT VOLATILE BY VOLUME
100

VAPOR PRESSURE
96 psig @ 25°C (77°F)

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

APPEARANCE
Clear

ODOR
Slight Ethereal

DU PONT

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HAZARDOUS COMPONENTS

MATERIAL(S)	CAS NO.	APPROXIMATE %
Ethane,1,1,1,2-Tetrafluoro	811-97-2	100

HAZARDOUS REACTIVITY

STABILITY
Material is stable. However, avoid open flames and high temperatures.

INCOMPATIBILITY
Alkali or Alkaline earth metals—powdered Al, Zn, Be, etc.

DECOMPOSITION
HFC-134a can be decomposed by high temperatures (open flames, glowing metal surfaces, etc.) forming hydrofluoric acid—possibly carbonyl fluoride.

POLYMERIZATION
Will not occur.

FIRE AND EXPLOSION DATA

FLASH POINT
Will not burn. METHOD TOC

FLAMMABLE LIMITS IN AIR, % BY VOL.
LOWER Not applicable.
UPPER Not applicable.

AUTOIGNITION TEMPERATURE
Not determined.

FIRE AND EXPLOSION HAZARDS
Cylinders may rupture under fire conditions. Decomposition may occur.

EXTINGUISHING MEDIA
As appropriate for combustibles in area.

SPECIAL FIRE FIGHTING INSTRUCTIONS
Cool cylinders with water spray. Self-contained breathing apparatus (SCBA) may be required if cylinders rupture or release under fire conditions.

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HEALTH HAZARD INFORMATION

PRINCIPAL HEALTH HAZARDS

Inhalation of high concentrations of vapor is harmful and may cause heart irregularities, unconsciousness or death. Intentional misuse can be fatal. Vapor reduces oxygen available for breathing and is heavier than air. Liquid contact can cause frostbite

Inhalation 4 Hour ALC: 567,000 ppm in rats

The compound is untested for skin and eye irritancy and is untested for animal sensitization.

Acute Toxicity in Animals

The effects in animals from short exposure by inhalation include no toxic effects observed at vapor concentrations up to 81,000 ppm. Lethargy and rapid respiration were observed at a vapor concentration of 205,000 ppm.

Pulmonary congestion, edema, and central nervous system effects occurred at a vapor concentration of 750,000 ppm. Cardiac sensitization occurred in dogs at 75,000 ppm from the action of exogenous epinephrine.

Subchronic Toxicity in Animals

Inhalation: The effects in animals from exposure by inhalation for two weeks include no observable adverse effects. Ingestion: No adverse effects were observed in male and female rats administered 300 mg/kg/day of HFC-134a for 52 weeks.

No acceptable information is available to confidently predict the effects of excessive human exposure to this compound.

CARCINOGENICITY

HFC-134a is not listed as a carcinogen by IARC, NTP, OSHA, ACGIH, or Du Pont.

EXPOSURE LIMITS

PEL (OSHA): Not established.
TLV* (ACGIH): Not established.

SAFETY PRECAUTIONS

Avoid breathing vapor and liquid contact with skin or eyes. Provide adequate ventilation for storage, handling, and use, especially for enclosed and low spaces.

*TLV is a registered trademark of the American Conference of Governmental Industrial Hygienists.

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HEALTH HAZARD INFORMATION (con't)

FIRST AID

IF HIGH CONCENTRATIONS ARE INHALED: Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Call a physician.

IN CASE OF EYE CONTACT: Immediately flush eyes with plenty of water for at least 15 minutes. Call a physician.

IN CASE OF SKIN CONTACT: Flush skin with water after excessive contact. Wash contaminated clothing before reuse. Treat for frostbite if necessary.

IF SWALLOWED: Ingestion is not considered a potential route of exposure.

NOTE TO PHYSICIANS

Because of possible disturbances of cardiac rhythm, catecholamine drugs, such as epinephrine, should be considered only as a last resort in life-threatening emergencies.

PROTECTION INFORMATION

GENERALLY APPLICABLE CONTROL MEASURES

Normal ventilation for standard manufacturing procedures is generally adequate. Local exhaust should be used when large amounts are released. Mechanical ventilation should be used in low places.

PERSONAL PROTECTIVE EQUIPMENT

Lined butyl gloves and chemical splash goggles should be used when handling liquid. Under normal manufacturing conditions, no respiratory protection is required when using this product. Self-contained breathing apparatus (SCBA) is required if a large release occurs.

DISPOSAL INFORMATION

SPILL, LEAK OR RELEASE

Ventilate area—especially low places where heavy vapors might collect. Remove open flames. Use self-contained breathing apparatus (SCBA) if large spill or leak occurs.

WASTE DISPOSAL

Contaminated HFC-134a can be recovered by distillation or removed to a permitted waste disposal facility. Comply with Federal, State, and local regulations.

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DUPONT

DUPONT

SHIPPING INFORMATION

DOT (172.101)

PROPER SHIPPING NAME
Refrigerant Gas, N.O.S.
(Tetrafluoroethane)

HAZARD CLASS
Nonflammable gas

UN NO.
1078

DOT/IMO (172.102)

PROPER SHIPPING NAME
Refrigerant Gas, N.O.S.
(Tetrafluoroethane)

HAZARD CLASS
Nonflammable gas, 2.2

UN NO.
1078

IMO LABEL
Nonflammable gas

OTHER INFORMATION

SHIPPING CONTAINERS
Cylinders, ton tanks, tank cars and tank trucks

STORAGE CONDITIONS
Clean, dry area. Do not heat above 125°F.

ADDITIONAL INFORMATION AND REFERENCES

NFPA - HMIS RATINGS

Health	1
Flammability	0
Reactivity	1
Personal Protection	-

Personal Protection rating to be supplied by user depending on use conditions.

DATE OF LATEST REVISION/REVIEW: 4/88

PERSON RESPONSIBLE FOR MSDS:
K. P. BROWN
Du Pont Co.
C&P Dept., Chestnut Run-709
Wilmington, DE 19898
(302) 999-3018

138337A

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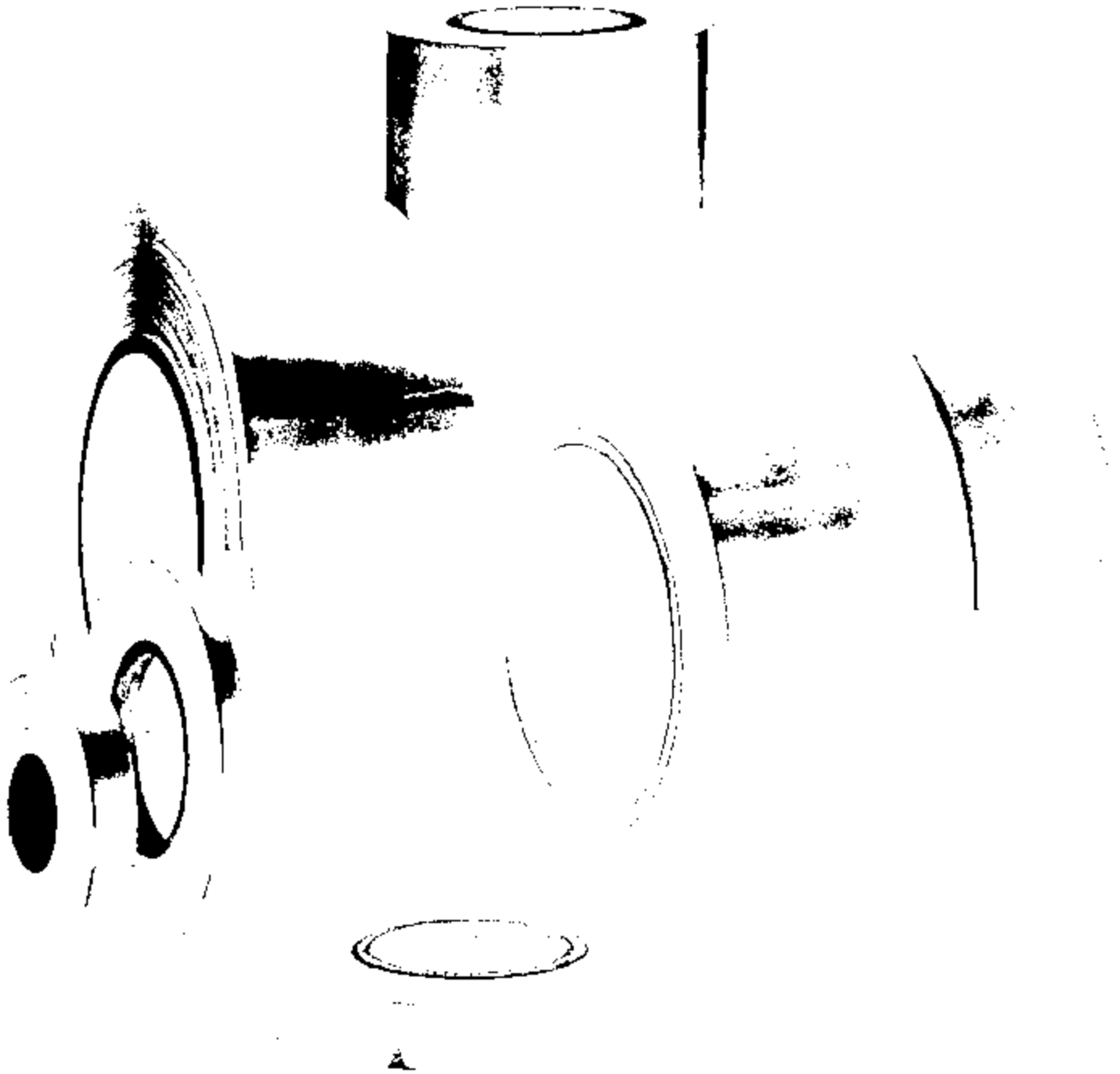
138337A

Kapton

POLYIMIDE FILM

SUMMARY OF PROPERTIES



DUPONT

CONTENTS

Kapton®

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 cryogenic 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.

PHYSICAL & THERMAL PROPERTIES

KAPTON® Type H Film

25 μm (1 mil)

PHYSICAL PROPERTIES

PHYSICAL PROPERTIES	TYPICAL VALUES 78K (−195°C)	296K (23°C)	473K (200°C)	TEST METHOD
Ultimate Tensile (MD) Strength, MPa (psi)	241 (35,000)	172 (25,000)	117 (17,000)	ASTM D-882-81
Yield Point (MD) at 3%, MPa (psi)		69 (10,000)	41 (6,000)	ASTM D-882-81
Stress to Produce (MD) 5% Elongation, MPa (psi)		90 (13,000)	59 (8,500)	ASTM D-882-81 ASTM D-882-81
Ultimate Elongation (MD)%	2	75	90	ASTM D-882-81
Tensile Modulus, GPa (MD) (psi)	3.5 (510,000)	3.0 (430,000)	1.86 (260,000)	ASTM D-882-81
Impact Strength, J/mm (kg-cm)		23 (6)		Du Pont Pneumatic Impact Test
Folding Endurance MIT		10,000 cycles		ASTM D-2176-69
Tear Strength—Propagating (Elmendorf), g		8		ASTM D-1922-67
Tear Strength—Initial (Graves), g (g/mil)		510 (510)		ASTM D-1004-66
Density, g/cm³		1.42		ASTM D-1505-68
Coefficient of Friction Kinetic (Film-to-Film)		.42		ASTM D-1894-78
Refractive Index (Becke Line)		1.78		Encyclopaedic Dictionary of Physics, Vol. 1
Poisson's Ratio		.34		Ave. 3 Samples Elongated at 5%, 7%, 10%

MD—Machine Direction

THERMAL PROPERTIES

THERMAL PROPERTIES	TYPICAL VALUES	TEST CONDITION	TEST METHOD
Melting Point	NONE		ASTM E-794-8
Zero Strength Temperature	1088K (815°C)	.14 MPa (20 psi) load for 5 seconds	Du Pont Hot Bar Test
Coefficient of Linear Expansion	2.0×10^{-5} m/m/K (2.0×10^{-5} in/in/°C)	259 to 311K (−14°C to 38°C)	ASTM D-696-44
Coefficient of Thermal Conductivity, W/m·K $\left(\frac{(cal)(cm)}{(cm^2)(sec)(°C)}\right)$	0.155 (3.72×10^{-4}) 0.163 (3.89×10^{-4}) 0.176 (4.26×10^{-4}) 0.189 (4.51×10^{-4})	296K (23°C) 348K (75°C) 473K (200°C) 573K (300°C)	Model TC-1000 Twin Heatmaster Comparative Tester
Specific Heat	1.09 (.261)	J/g·K (cal/g/°C)	Differential Calorimetry
Flammability	94 VTM-0		UL-94 (1-24-80)
Shrinkage	(See chart on Page 7)		IPC Method 2-2-2-A
Heat Sealability	Not Heat Sealable		
Limiting Oxygen Index	100H-38		ASTM D-2863-77
Smoke Generation	100H − DM = less than 1	NBS Smoke Chamber	NFPA-258 procedures
Glass Transition Temperature (Tg)	A second order transition occurs in KAPTON between 633K (360°C) and 683K (410°C). This is assumed to be the glass transition temperature. Different measurement techniques produce different results within the above temperature range.		

KAPTON® Type V Film

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

KAPTON® Type F Film

PROPERTY	TYPICAL VALUES Film Type* 120F616	150F019	250F029
Ultimate Tensile Strength (MD), MPa (psi)			
296K (23°C)	165 (24,000)	117 (17,000)	172 (25,000)
473K (200°C)	110 (16,000)	76 (11,000)	110 (16,000)
Yield Point at 3% (MD), MPa (psi)			
296K (23°C)	62 (9,000)	50 (7,300)	69 (10,000)
473K (200°C)	38 (5,500)	28 (4,000)	55 (8,000)
Stress at 5% Elongation (MD), MPa (psi)			
296K (23°C)	86 (12,500)	62 (9,000)	
473K (200°C)	52 (7,500)	36 (5,500)	
Ultimate Elongation (MD)			
296K (23°C)%	65	75	80
473K (200°C)%	95	85	
Tensile Modulus, MD GPa (psi)			
296K (23°C)	2.86 (415,000)	2.21 (320,000)	
473K (200°C)	1.48 (215,000)	1.19 (173,000)	
Impact Strength at 296K (23°C)			
g-m (Kg-cm/μm)	70 (7)	70 (7)	
g-m/μ (Kg-cm/mil)	2.3 (6.0)	1.8 (4.6)	
Tear Strength—Propagating (Elmendorf)			
g		20	
g/μm (g/mil)	0.39 (10)	0.53 (13.5)	0.47 (12)
Tear Strength—Initial (Graves)			
g		650	
g/μm (g/mil)	19 (750)	17 (435)	
Weight % Polyimide	80	57	73
Weight % FEP	20	43	27
Density			
Kg/m³x10⁻³	1.53	1.67	1.57

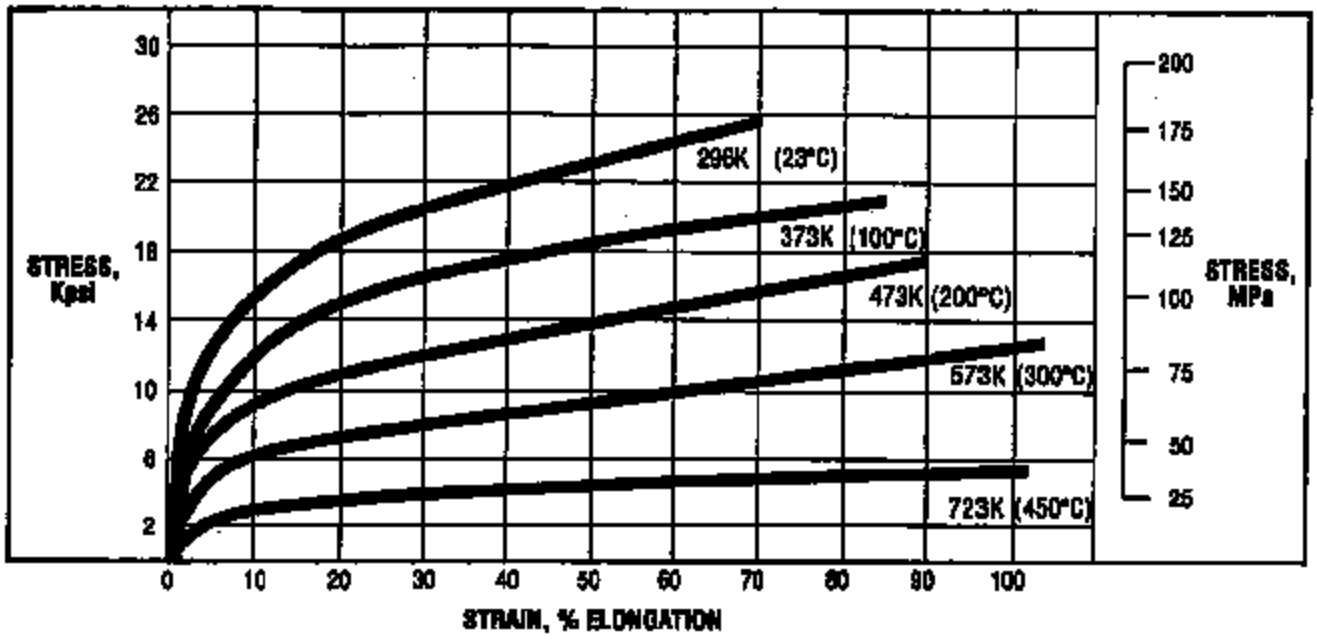
*Since a number of combinations of polyimide film and fluorocarbon coating add up to the same total gauge, it is necessary to distinguish among them. A three digit system is used in which the middle digit represents the nominal thickness of the base KAPTON film in mils. The first and third digits represent the nominal thickness of the coating of TEFLON FEP fluorocarbon resin in mils. The symbol 0 is used to represent 13 μm (½mil), and 6 to represent 2.5 μm (1/10 mil). Example: 120F616 is a 120-gauge structure consisting of a 25 μm (1-mil) base film with a 2.5 μm (1-10 mil) coating of TEFLON on each side. See page 22 for construction explanation.

MECHANICAL PROPERTIES

The usual values of tensile strength, tensile modulus, and ultimate elongation at various temperatures can be obtained from the typical stress-strain curves shown below. Such properties as tensile strength and modulus have an inverse relation with temperature, while elongation peaks to a maximum value at about 573K (300°C). Other factors such as humidity, film thickness, and Instron elongation rate were found to have only a negligible effect on the shape of the 296K (23°C) curve.

TENSILE STRESS STRAIN CURVES

(Type H Film 25 μm (1 mil))

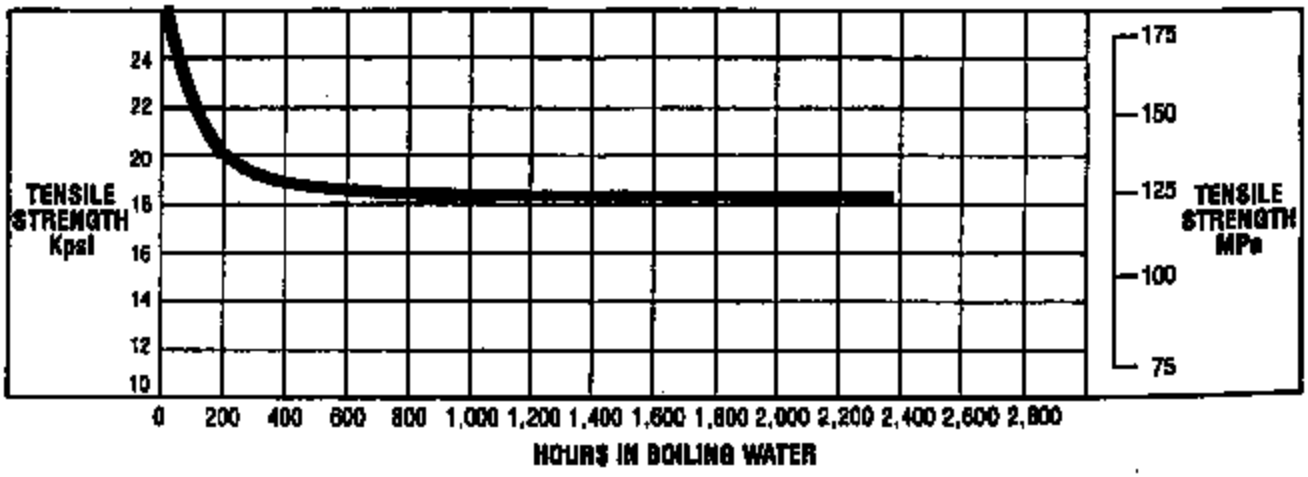


HYDROLYTIC STABILITY

KAPTON® polyimide film is made by a condensation reaction; therefore, its properties are affected by water. Although long-term exposure to boiling water, as shown in the curves below, will reduce the level of film properties, sufficient tensile and elongation remain to insure good mechanical performance. A decrease in the temperature and the water concentration will reduce the rate of KAPTON property reduction while higher temperatures and pressures will increase it.

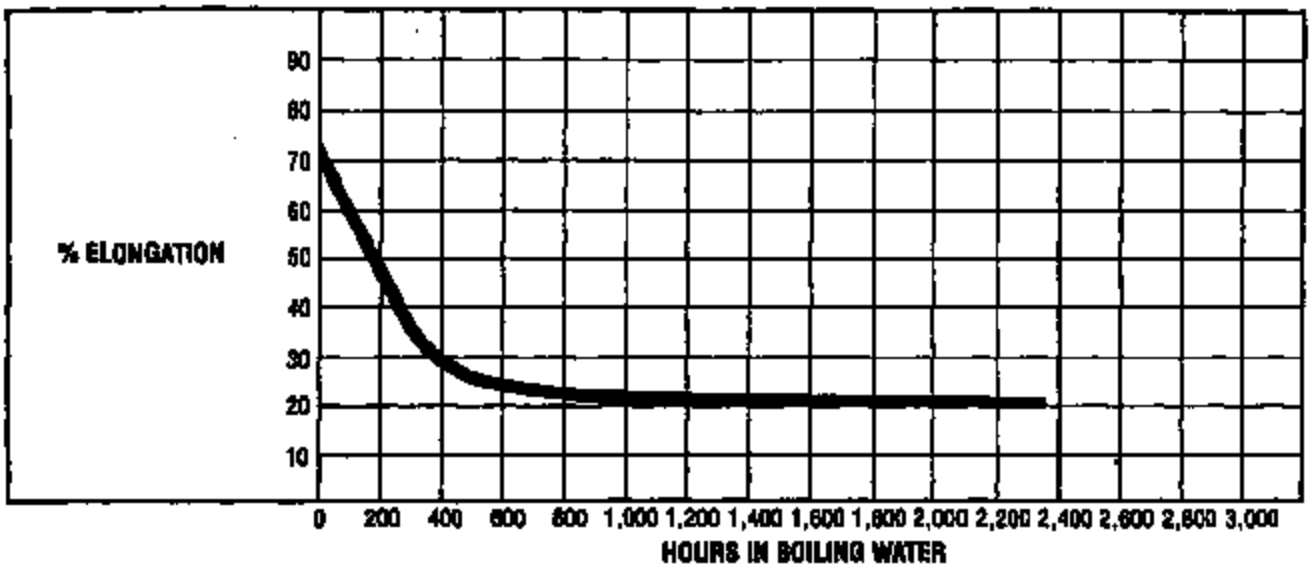
TENSILE STRENGTH AFTER EXPOSURE TO 373K (100°C) WATER

(Type H Film 25 μm (1 mil))



ULTIMATE ELONGATION AFTER EXPOSURE IN 373K (100°C) WATER

(Type H Film 25 μm (1 mil))

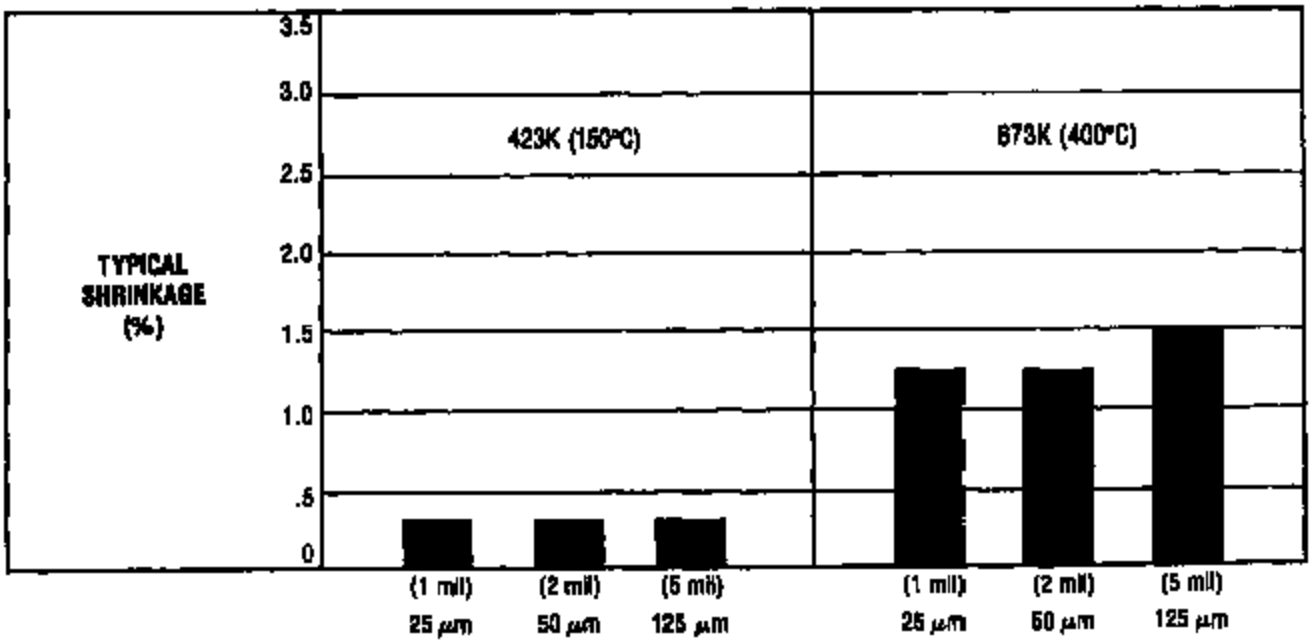


DIMENSIONAL STABILITY

The dimensional stability of KAPTON® polyimide film depends on two factors—the normal coefficient of thermal expansion and the residual stresses placed in the film during manufacture. The latter causes KAPTON to shrink on its first exposure to elevated temperatures as indicated in the bar graphs below. Once the film has been exposed, the normal values for thermal expansion listed on Page 6 can be expected.

RESIDUAL SHRINKAGE VS. EXPOSURE TEMPERATURE AND GAUGE

(Type H Film)



THERMAL COEFFICIENT OF EXPANSION

(Type H Film 25 μm (1 mil)) Thermally Exposed

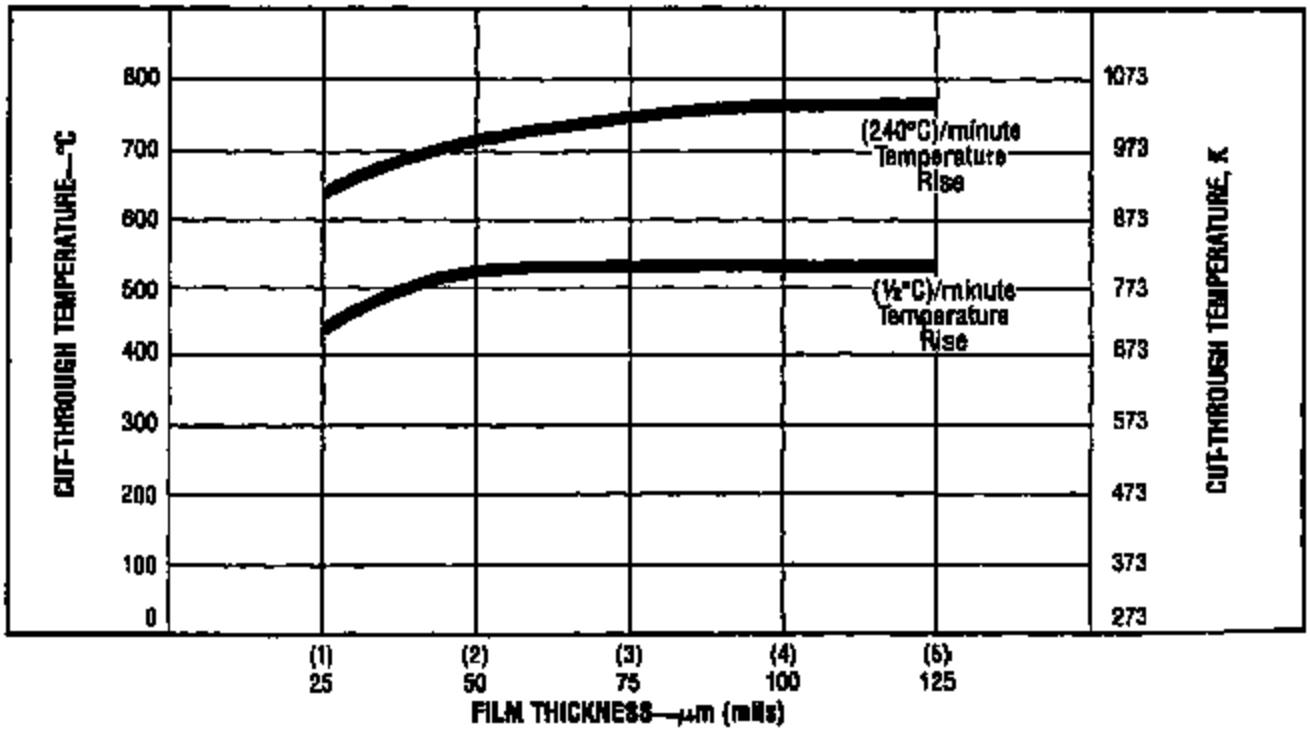
Temperature Range	"K" m/m-K x 10^{-6}
296-373K (23-100°C)	1.60
373-473K (100-200°C)	3.10
473-573K (200-300°C)	4.85
573-673K (300-400°C)	7.75
296-673K (23-400°C)	4.55

CUT-THROUGH AND COLD FLOW

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

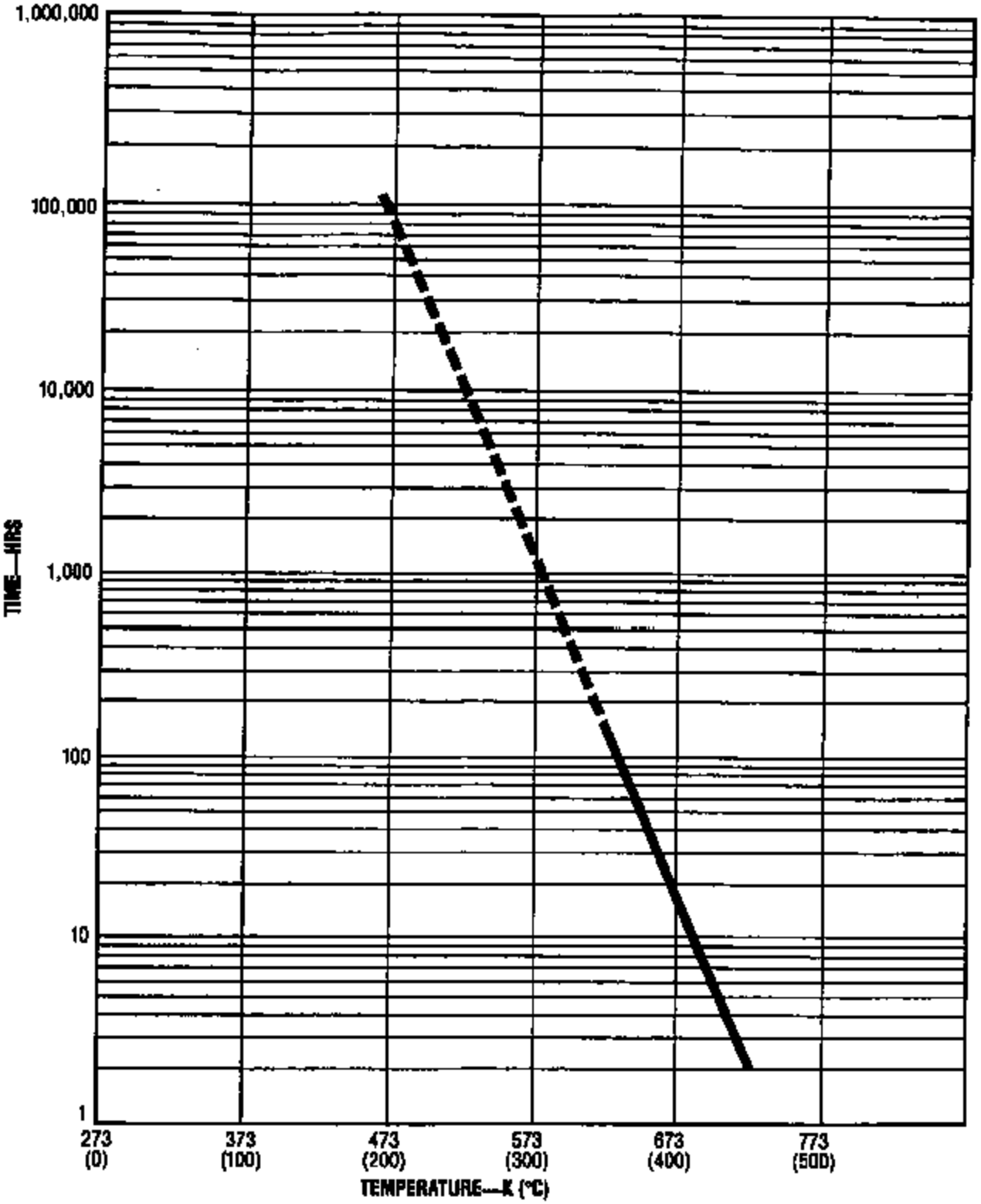
CUT-THROUGH TEMPERATURE VS. RATE OF TEMPERATURE RISE AND GAUGE

(Type H Film)



RESISTANCE TO CUT-THROUGH VS. TEMPERATURE

(Type H Film—25 μm (1 mil))



actual ——————

extrapolated — — — —

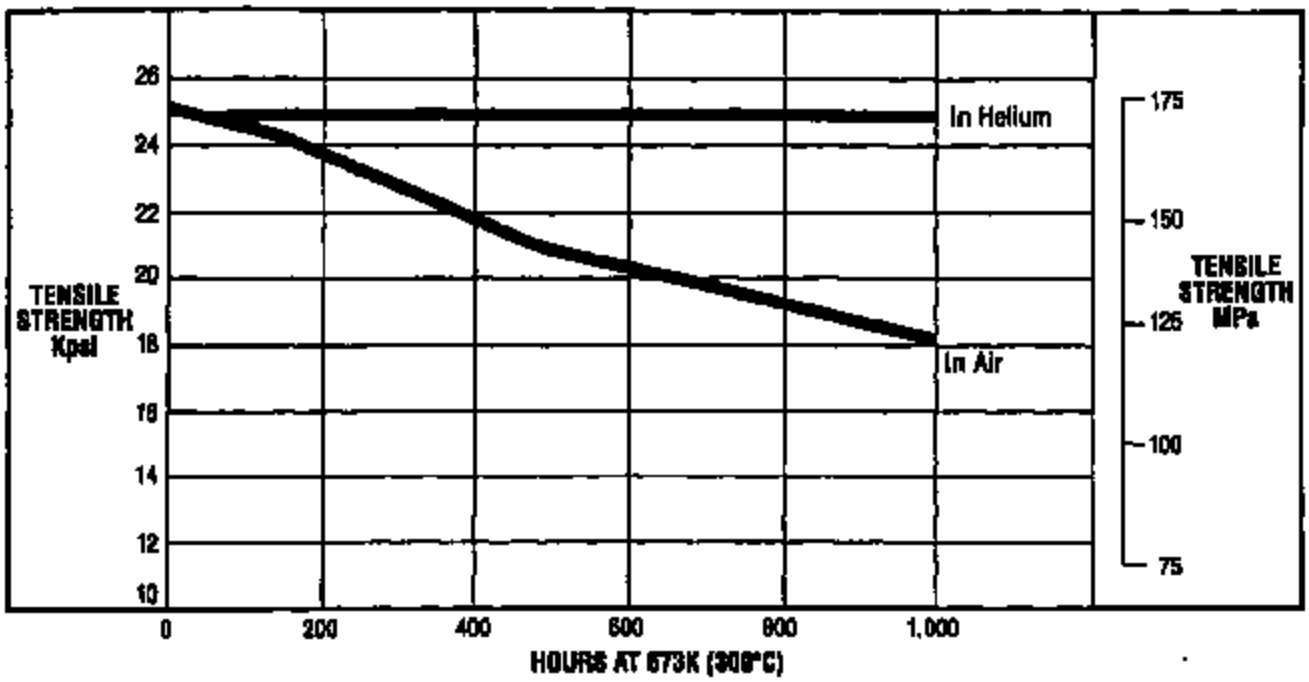
TI-NHTSA 018289

THERMAL AGING

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

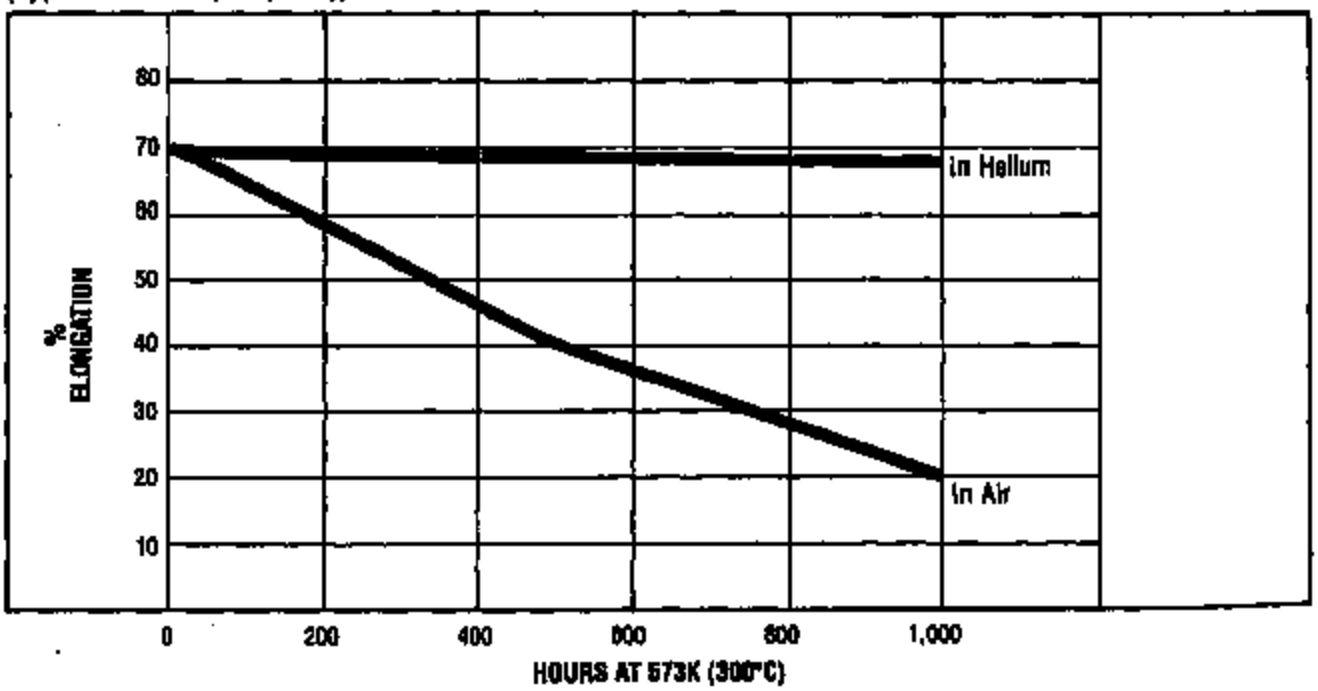
TENSILE STRENGTH VS. AGING AT 573K (300°C)

(Type H Film 25 μm (1 mil))



ULTIMATE ELONGATION VS. AGING AT 573K (300°C)

(Type H Film 25 μm (1 mil))



TI-NHTSA 018300

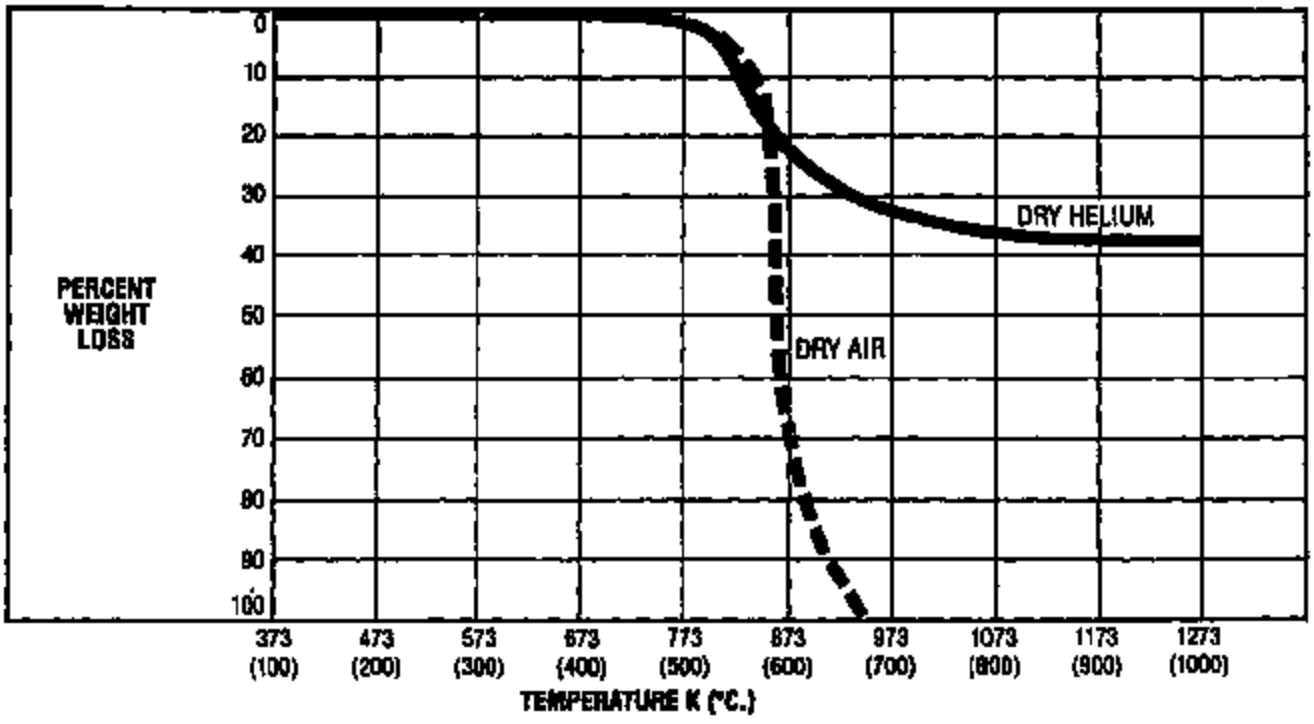
TIME REQUIRED FOR REDUCTION IN ULTIMATE ELONGATION FROM 70% to 1%

(Type H Film 25 μm (1 mil))

Temperature		Environment	
		Air	Helium
723K	(450°C)	2 hours	22 hours
698K	(425°C)	5 hours	3½ days
673K	(400°C)	12 hours	2 weeks
648K	(375°C)	2 days	2 months
623K	(350°C)	6 days	1 year
573K	(300°C)	3 months	—
548K	(275°C)	1 year	—
523K	(250°C)	8 years	—

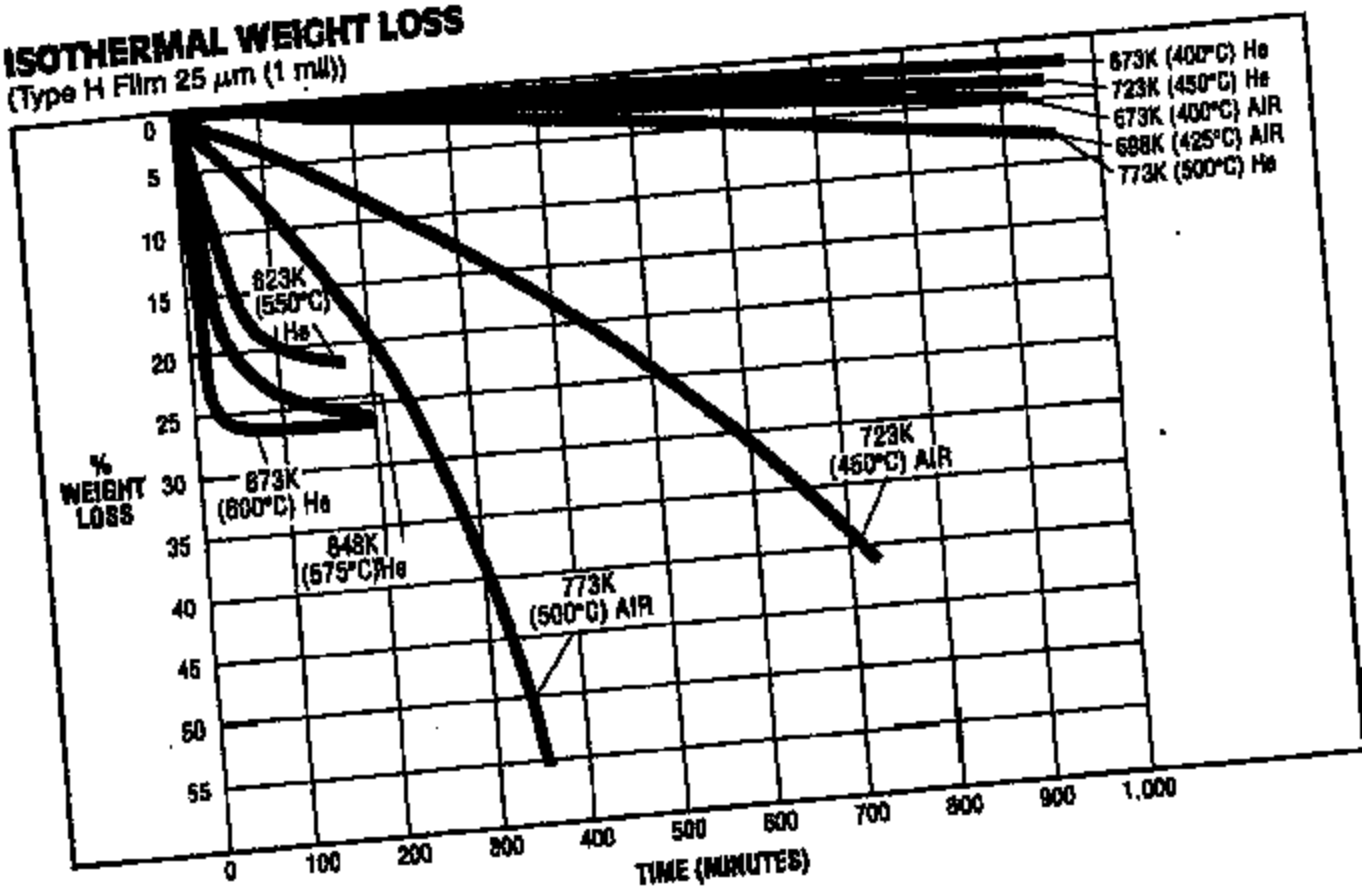
WEIGHT LOSS AT (5°C)/MINUTE TEMPERATURE RISE

(Type H Film 25 μm (1 mil))



ISOTHERMAL WEIGHT LOSS

(Type H Film 25 μm (1 mil))



ELECTRICAL PROPERTIES

KAPTON® Type H Film

TYPICAL ELECTRICAL PROPERTIES

PROPERTY	TYPICAL VALUE	TEST CONDITION	TEST METHOD
Dielectric Strength			
25 μm (1 mil)	276 v/μm (7,000 v/mil)	60 hertz	ASTM D-149-81
50 μm (2 mil)	213 v/μm (5,400 v/mil)	¼" electrodes	
75 μm (3 mil)	181 v/μm (4,600 v/mil)		
125 μm (5 mil)	142 v/μm (3,600 v/mil)		
Dielectric Constant			
25 μm (1 mil)	3.5	1 kilohertz	ASTM D-150-81
50 μm (2 mil)	3.6		
75 μm (3 mil)	3.7		
125 μm (5 mil)	3.7		
Dissipation Factor			
25 μm (1 mil)	.0025	1 kilohertz	ASTM D-150-81
50 μm (2 mil)	.0025		
75 μm (3 mil)	.0025		
125 μm (5 mil)	.0027		
Volume Resistivity			
25 μm (1 mil)	1×10^{18} ohm-m	125 volts	ASTM D-257-78
50 μm (2 mil)	6×10^{17} ohm-m		
75 μm (3 mil)	5×10^{17} ohm-m		
125 μm (5 mil)	1×10^{18} ohm-m		

KAPTON® Type V Film

TYPICAL ELECTRICAL PROPERTIES

PROPERTY	TYPICAL VALUE	TEST CONDITION	TEST METHOD
Dielectric Strength			
50 μm (2 mil)	213 v/μm (5,400 v/mil)	60 hertz	ASTM D-149-81
75 μm (3 mil)	181 v/μm (4,600 v/mil)	¼" electrodes	
125 μm (5 mil)	142 v/μm (3,600 v/mil)		
Dielectric Constant			
50 μm (2 mil)	3.6	1 kilohertz	ASTM D-150-81
75 μm (3 mil)	3.7		
125 μm (5 mil)	3.7		
Dissipation Factor			
50 μm (2 mil)	.0025	1 kilohertz	ASTM D-150-81
75 μm (3 mil)	.0025		
125 μm (5 mil)	.0027		
Volume Resistivity			
50 μm (2 mil)	6×10^{17} ohm-m	125 volts	ASTM D-257-78
75 μm (3 mil)	5×10^{17} ohm-m		
125 μm (5 mil)	1×10^{18} ohm-m		

KAPTON® Type F Film

TYPICAL ELECTRICAL PROPERTIES

PROPERTY	120F616	150F019	250F029
Dielectric Strength Total volts volts/μm (volts/mil)	 7,500 297 (6,900)	 6,300 165 (4,200)	 167 (4,000)
Dielectric Constant	2.8	3.0	
Dissipation Factor	.0022	.0014	
Volume Resistivity ohm-m @ 296K (23°C) (ohm-cm.) ohm-m @ 473K (200°C) (ohm-cm.)	 1.5×10^{14} (1.5×10^{16}) 5×10^{12} (5×10^{14})	 10^{16} (10^{18}) 10^{14} (10^{16})	 7×10^{15} (7×10^{17})

EFFECT OF HUMIDITY

(Type H Film 25 μm (1 mil))

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

The results of these measurements are given below.

RELATIVE HUMIDITY VS. ELECTRICAL PROPERTIES OF KAPTON

% RELATIVE HUMIDITY	AC DIELECTRIC STRENGTH V/μm	(V/mil)	DIELECTRIC CONSTANT	DISSIPATION FACTOR
0	307	(7,800)	3.0	.0018
30	287	(7,300)	3.3	.0021
50	276	(7,000)	3.5	.0025
80	256	(6,500)	3.7	.0037
100	244	(6,200)	3.9	.0047

For calculations involving absolute water content, 50% RH in our study is equal to 1.3% water in the film and 100% RH is equal to 2.9% water, the maximum adsorption possible regardless of the driving force.

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DUPONT

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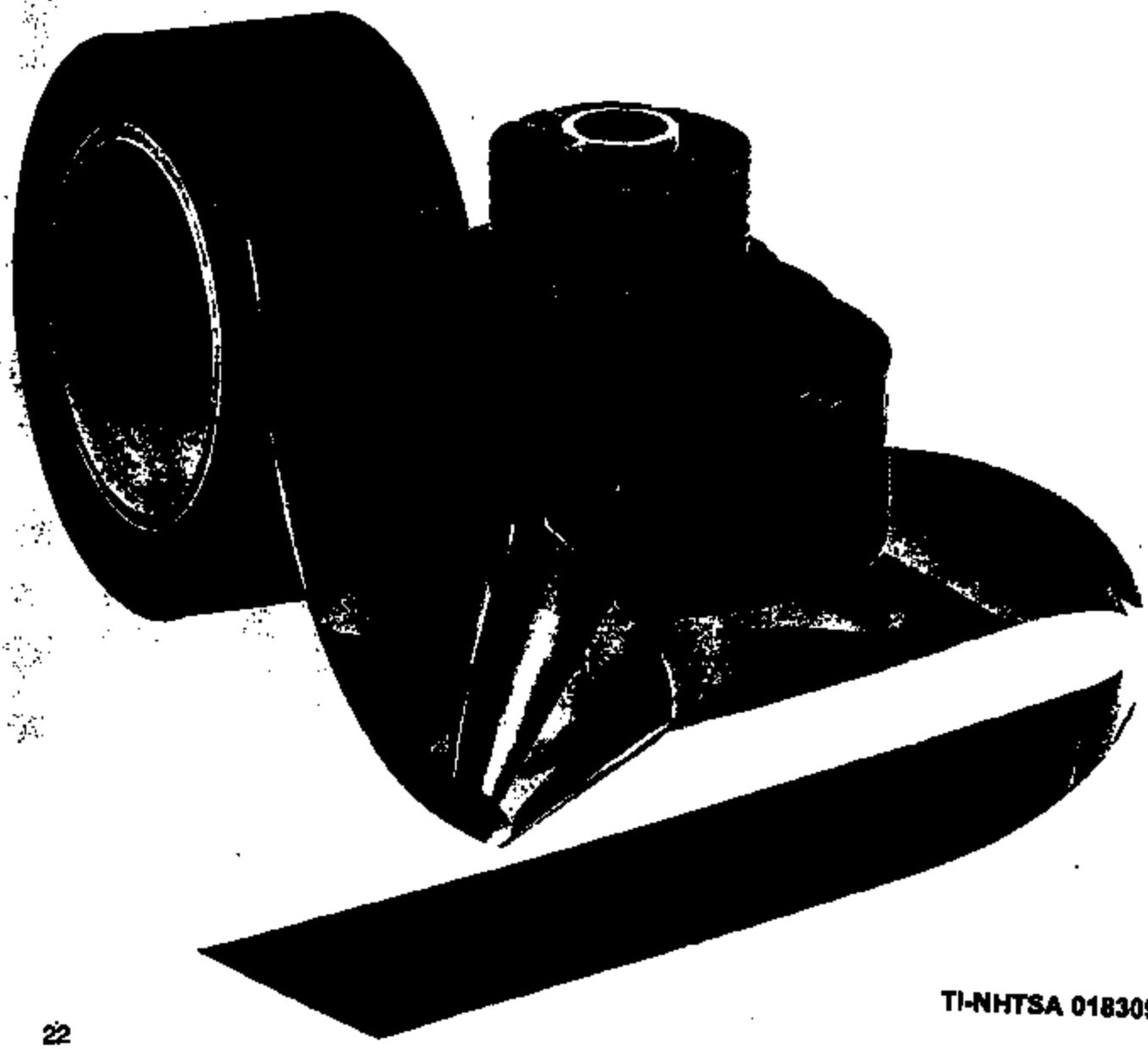
INQUIRIES

NOMINAL CONSTRUCTION, Type F Film

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

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

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



KAPTON® Type V Film

CHEMICAL PROPERTIES

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

KAPTON® Type F Film

CHEMICAL PROPERTIES

PROPERTY	120FB16	150FB19	400FB22
Moisture Absorption @ 298K (25°C), 50% R.H. 98% R.H.	1.3% 2.6%	.6% 1.7%	.4% 1.2%
Water Vapor Permeability g/m²-d (gm./(100 in²) (24 hrs.) g/m²-d-μm (g./(100 in²)(24 hrs./mil)	13.7 (0.89) 0.44 (1.07)	8.6 (0.57) 0.35 (0.85)	3.6 (0.23) 0.14 (0.92)

KAPTON® Type H Film

25 μm (1 mil)

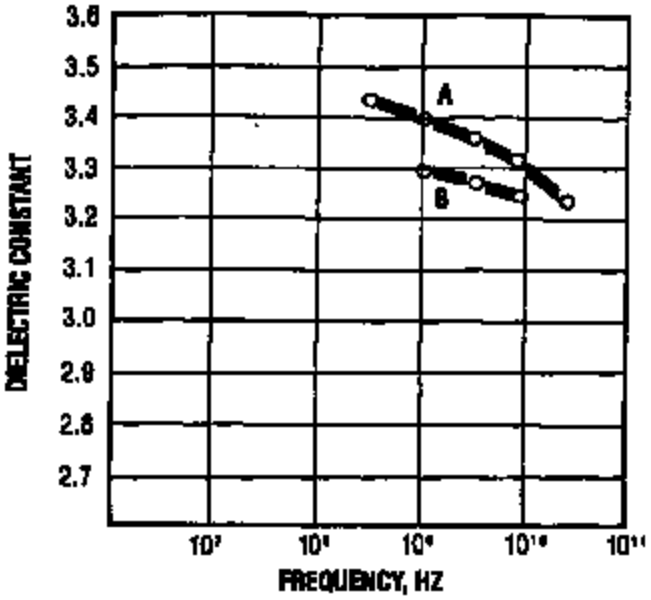
CHEMICAL PROPERTIES

PROPERTY	TYPICAL VALUES (~25 μm (1 mil)) % Tensile Retained	% Elongation Retained	% Modulus Retained	TEST CONDITION/METHOD
RESISTANCE TO:				Days Immersed at Room Temperature
Benzene	100	82	100	365
Toluene	99	91	97	365
Methanol	100	73	140	365
Acetone	67	62	160	365
10% Sodium Hydroxide		Degrades		5
Glacial Acetic Acid	85	62	102	36 days @ 383K (110°C)
p-Cresol	100	77	102	22 days @ 473K (200°C)
Transformer Oil	100	100	100	180 days @ 423K (150°C)
Water pH = 1	65	30	100	14 days @ 373K (100°C)
pH = 4.2	65	30	100	14 days @ 373K (100°C)
pH = 7.0	65	20	100	166 days @ 373K (100°C)
pH = 8.9	65	20	100	14 days @ 373K (100°C)
pH = 10.0	60	10	100	4 days @ 373K (100°C)
RADIATION RESISTANCE				
Gamma (Savannah River)		Still Flexible (180° Bend)		Exposure: 4.16×10^7 Gy
Electron (Van de Graaff)		Retains 50% of Original Elongation		Exposure: 6×10^7 Gy
Neutron plus Gamma (Brookhaven)		Darkened but tough		Exposure: 10^8 Gy
FUNGUS RESISTANCE		Inert		Soil Burial
MOISTURE ABSORPTION		1.3% Type H		50% Relative Humidity at 296K (23°C)
		2.9% Type H & V		Immersion for 24 hours at 296K (23°C)
HYGROSCOPIC COEFFICIENT OF EXPANSION		2.2×10^{-6} m/m/% Relative Humidity		295K (72°F) 20%-60% Relative Humidity
PERMEABILITY Gas		ml/m²·MPa·day (cc/(100 in²) (24 hrs.) (atm/mil))		
Carbon Dioxide		6.9 (45)		ASTM D-1434-63 @ 296K (23°C)
Hydrogen		38 (250)		
Nitrogen		0.9 (6)		
Oxygen		3.8 (25)		
Helium		63 (415)		
Water Vapor		g/m²·day 84 g/(100 in²) (24 hrs.)/mil 5.4		ASTM E-96-63T

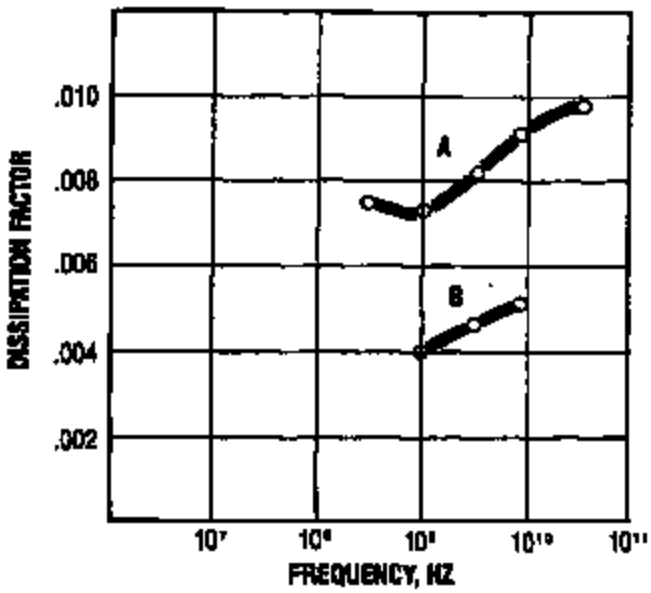
CHEMICAL PROPERTIES

DIELECTRIC PROPERTIES IN GIGAHERTZ FREQUENCY RANGE

(Type H Film, 125μm (5 mil))*



(Type H Film, 125μm (5 mil))*



*Technical Report AFML-TR-72-39—Curve A is 500H KAPTON as received and measured at 25°C and 45% RH with the electric field in the plane of the sheet. Curve B is the same measurement after conditioning the film at 100°C for 48 hours.

TRACKING RESISTANCE

A 125 μm (5 mil) KAPTON® polyimide film, Type H, has a tracking resistance of 183 seconds as measured by ASTM D-495-81. The failure was due to true tracking rather than erosion, etc.

CORONA LIFE

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

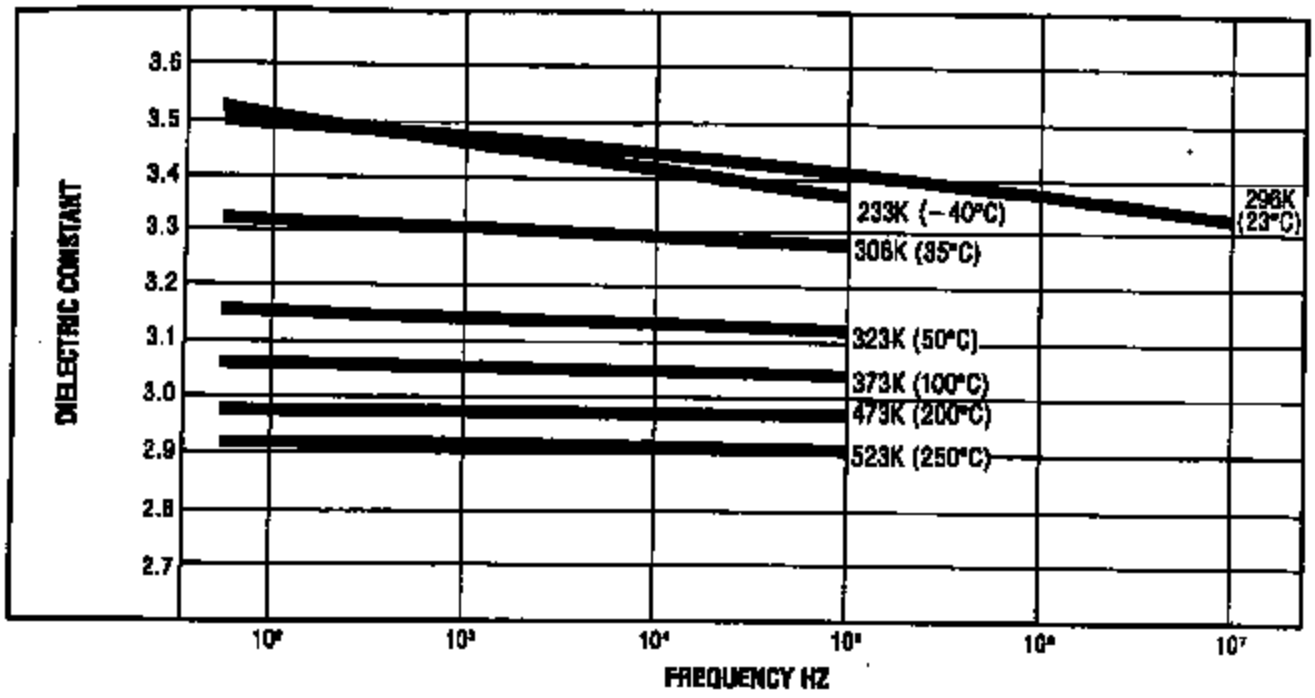
Corona inception voltage and corona intensity are functions of many parameters, including insulation thickness, air gap thickness, and device shape. Consult with a Du Pont technical representative on the suitability of KAPTON for specific applications where corona may be present.

EFFECT OF FREQUENCY

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

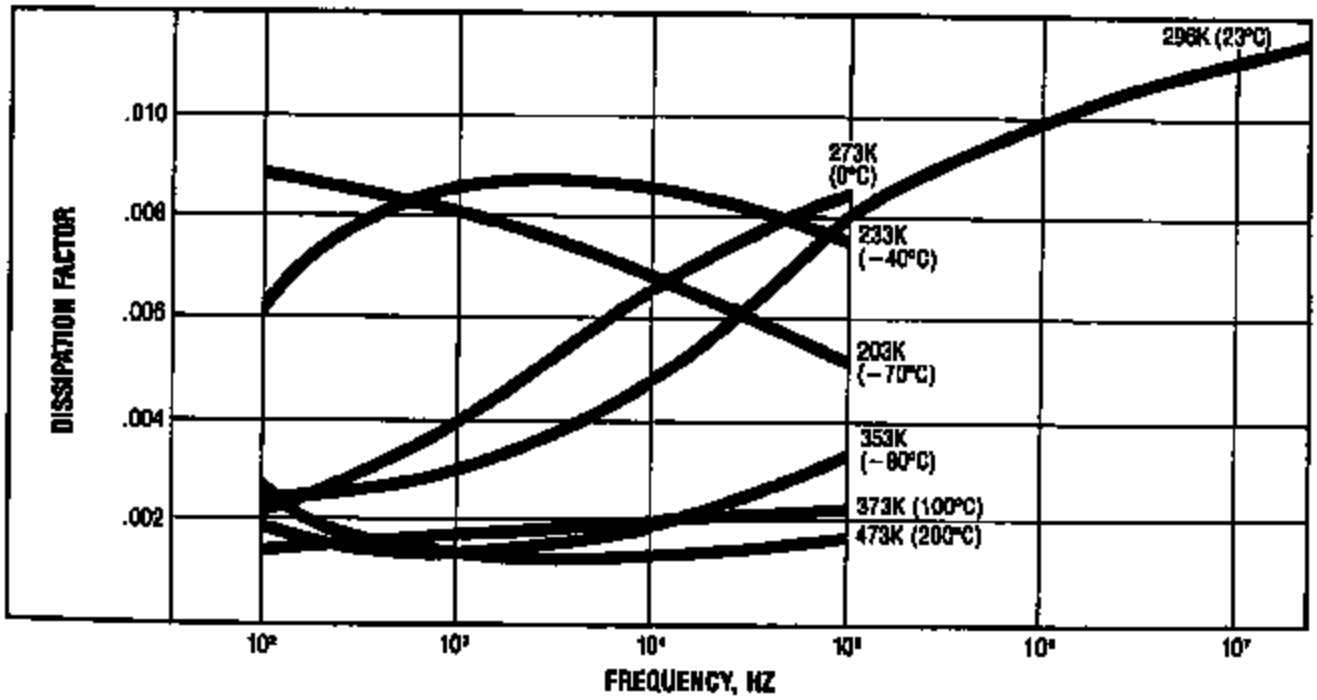
DIELECTRIC CONSTANT VS. FREQUENCY

(Type H Film 25 μm (1 mil))



DISSIPATION FACTOR VS. FREQUENCY

(Type H Film 25 μm (1 mil))

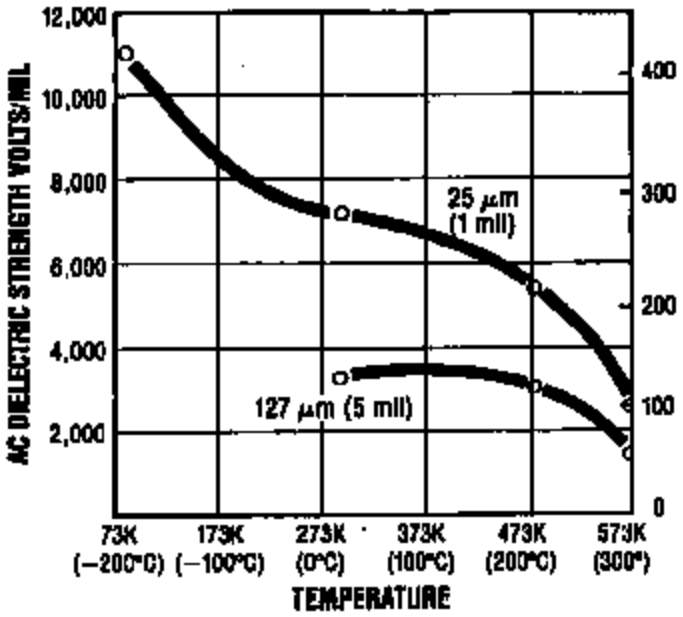


EFFECT OF TEMPERATURE

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

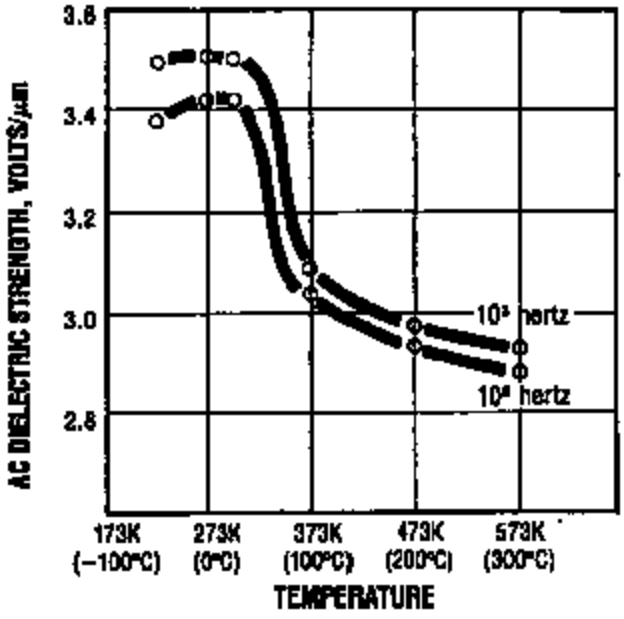
AC DIELECTRIC STRENGTH VS. TEMPERATURE

(Type H Film)



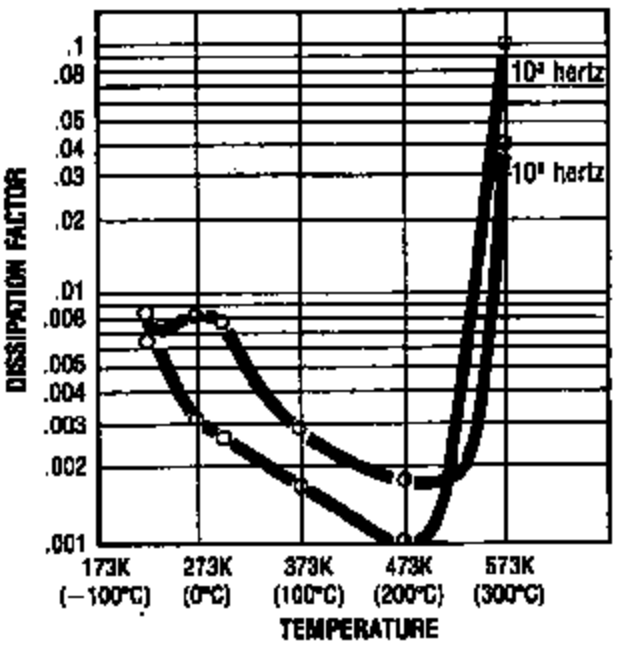
DIELECTRIC CONSTANT VS. TEMPERATURE

(Type H Film—25 μm (1 mil))



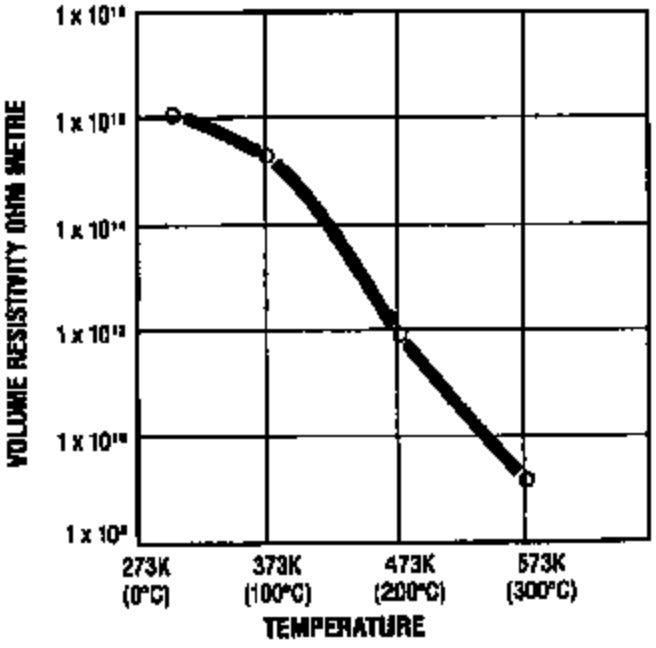
DISSIPATION FACTOR VS. TEMPERATURE

(Type H Film 25 μm (1 mil))



VOLUME RESISTIVITY VS. TEMPERATURE

(Type H Film 25 μm (1 mil))



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CHEMICAL PROPERTIES

Kapton

POLYIMIDE FILM

ADHESION TO KAPTON®

KAPTON® polyimide film, made only by Du Pont, is available in three basic film types. Type H KAPTON is 100% polyimide film. Type F is coated on one or both sides with a TEFLON® FEP fluorocarbon adhesive and Type V is a plain polyimide film having superior dimensional stability properties. Typical property information for KAPTON is found in Bulletin E-72087, "Summary of Properties." Specifications are found in Bulletin E-67624, "Industry Specifications Bulletin FC-66-2." For flexible printed circuit applications the trade specification IPC-FC-231/Sheet 1, applies to KAPTON.

ADHESIVE SELECTION

For some applications KAPTON must be bonded to other materials, such as copper foil, which requires the use of an adhesive. Optimum adhesion results are usually obtained from commercially coated KAPTON which is available from a variety of suppliers such as those listed in Bulletin E-72091, "Suppliers of Adhesive Coatings on KAPTON." This listing represents most of those companies offering coated KAPTON but should not be regarded as a complete listing. Detailed information on the use of these adhesive coated products can be obtained from the supplier's bulletins. Specific requirements for copper laminates produced as substrates for flexible printed circuits are outlined in trade specifications:

- USA: IPC-FC-241
- British: BS-4584
- German: DIN-40802

When commercially coated film is not suitable for an application, most vendors offer a dry film form of their adhesives for use as a bonding film in laminations. However, better adhesion is normally obtained from commercial solution coatings than from the dry bonding film. The dry film adhesive does have the advantage that it can be cut to shapes which cover only that portion of the polyimide film where adhesion is desired.

If neither commercially coated polyimide film nor adhesive bonding film is suitable for the application, the remaining option is for the user to apply a solution adhesive. Some generic classes of adhesives which bond KAPTON include acrylics, epoxies, butyral-phenolics, polyesters, silicones, urethanes, fluorocarbons and blends of these materials.

Selection of an adhesive is usually dependent on the properties required of the adhesive and the demands of the application. Property considerations are the thermal rating, chemical resistance, fill and flow characteristics, flexibility, peel strength, flammability, moisture resistance and insulation resistance. Also to be considered is the ease of processing, lamination temperature and whether the lamination is to be made in continuous roll equipment or in a platen press.

ADHESIVE PROPERTIES

Adhesives used with KAPTON Type H are usually a modified version of the generic adhesive family (e.g., modified-epoxy). These formulations are proprietary to the suppliers of coated KAPTON and require specific processing conditions to achieve the maximum bond strength. Always use the supplier's recommended lamination conditions for the specific adhesive you select.

Listed in Table I are several adhesive types along with information on typical lamination temperatures and maximum operating temperatures (short term exposure). When using an epoxy adhesive, anhydride curing agents are preferred. If an amine curing agent must be used, avoid an excess of curing agent as the free alkaline materials can degrade the polyimide.

TABLE 1

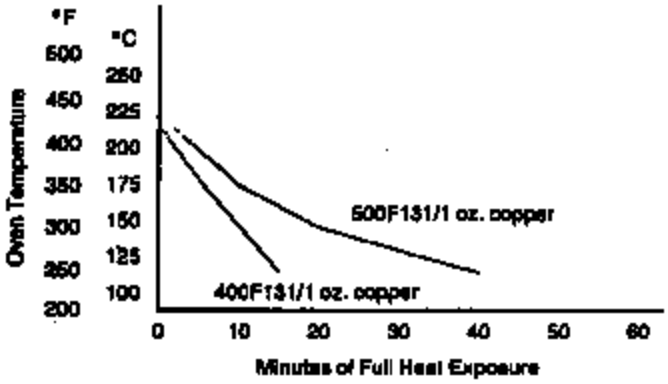
Adhesive Types	Lamination Temperatures °F (°C)	Maximum Operating Temperature °F (°C)
Fluorocarbons	550-600 (290-315)	to 500 (260)
Polyimides	500-700 (260-370)	to 650 (345)
Epoxies	73-450 (23-230)	to 600 (315)
Pressure Sensitive Silicones	73-300 (23-150)	to 500 (260)
Rubber-Phenolics	300-400 (150-205)	to 500 (260)
Acrylics	350-375 (175-190)	to 550 (290)
Polyesters	275-300 (135-150)	to 220 (105)

Solution forms of most of the adhesives above are available from suppliers of adhesives to the electronics industry. Listings of suppliers can be found in buyer's guides for electronic products. Bulletin E-74149, "Suppliers of Adhesives to the Electronics Industry," provides a representative listing of adhesive suppliers who can be consulted with for specific adhesive needs.

DUPONT

Given in Figure 3 are minimum times to dry laminates of Type F to copper prior to dip soldering. The times are different than in Figure 2 due to the presence of the copper foil.

FIGURE 3
DRYING CONDITIONS FOR KAPTON TYPE F LAMINATES PRIOR TO DIP SOLDERING



SOLDERING AND PRESS CONDITIONS FOR TYPE H LAMINATES

The recommended predrying conditions prior to dip soldering and platen pressing laminates based on type H film will vary according to type of thermoset adhesive used in addition to factors mentioned for Type F laminates. The moisture retention and permeability of the film and adhesive must be considered along with the impermeability of the copper foil layers. Consult your laminate supplier for recommended predrying conditions specific to the combination of materials supplied.

EFFECTS OF HUMIDITY ON PEEL STRENGTH

Humidity can have a large effect on peel strength with certain adhesive systems, and RH ought to be controlled in peel strength measurements. A summary of our investigation into this phenomenon is given in Table III. Results show that those adhesives having functional groups capable of absorbing water vapor will promote high peel strengths at high RH and low peel strengths at low RH. Between an RH of 10% and an RH of 70%, the effect can be as large as 6 lbs. per lineal inch (10.5 N/cm). Those adhesives which do not have hygroscopic functional groups are not affected by RH changes in terms of peel values.

TABLE III
EFFECTS OF RELATIVE HUMIDITY ON PEEL STRENGTH

Adhesive Type	Peel Strength, lb./in. (N/cm) 10% RH	70% RH
Acrylic	5.8 (10.2)	11.5 (20.1)
Epoxy-Amide	5.4 (9.5)	10.0 (17.5)
Epoxy-Novolac	2.0 (3.5)	2.1 (3.7)
Phenolic-Butyral	3.8 (6.7)	5.2 (9.1)
Phenolic-Nitrile	4.7 (8.2)	4.3 (7.5)

EFFECT OF SURFACE ON PEEL STRENGTH

The top surface of KAPTON is referred to as the "bright" or "shiny" side. The bottom side is "dull" and purposely roughened in the manufacture of the film to improve film handling characteristics. Most adhesives bond better to the dull side of the film. The effect is generally 1-2 lbs. per lineal inch (1.8-3.5 N/cm) but can be as high as 4 lbs. per inch (7.0 N/cm) or negligible depending on the adhesive system used.

Experience has also shown that peel strength normally increases with the thickness of the film. Within a laminate based on a given film thickness, a range of peel strengths can also be expected, which is inherent in the film surface, the adhesive system and the test method applied. For example, a typical peel strength range for an acrylic adhesive is 6 lbs./in. (10.5 N/cm). For 100H this range can result in values as low as 2 lbs./in. (3.5 N/cm).

Unless specifically recommended by the adhesive supplier, the surface of KAPTON should be used as received. If the film has been contaminated with grease or oils, it should be cleaned with solvent (such as methylethyl ketone or toluene). Metal surfaces should be thoroughly cleaned. For best adhesion, they should be roughened mechanically or by chemical treatment.

When higher adhesion levels are required for a given adhesive system, the range of the peel strength values for the laminate may usually be reduced if the surface of the film is mechanically or chemically abraded, light pumice scrubbing or caustic etching. Caution must be exercised with any such treatment to avoid damaging the film.

EFFECT OF THERMAL TREATMENT ON PEEL STRENGTH

High thermal treatment of KAPTON will often improve bondability. Temperatures of about 400°C for as long as 5-10 minutes are required, and structural changes probably occur.

Studies of adherability of typical printed circuit adhesives to heat treated KAPTON and standard KAPTON have shown that heat treatment provides an advantage with most adhesives. The greatest advantage was gained with acrylic, epoxy, phenolic butyrals and phenolic nitriles. Improvement over standard film averaged from 40% to 97% for these adhesive types.

KAPTON® Type H Film

25 μm (1 mil)

CHEMICAL PROPERTIES

PROPERTY	TYPICAL VALUES (~25 μm (1 mil)) % Tensile Retained	% Elongation Retained	% Modulus Retained	TEST CONDITION/METHOD
RESISTANCE TO:				Days Immersed at Room Temperature
Benzene	100	82	100	365
Toluene	99	91	97	365
Methanol	100	73	140	365
Acetone	67	62	160	365
10% Sodium Hydroxide		Degrades		5
Glacial Acetic Acid	85	62	102	36 days @ 383K (110°C)
p-Cresol	100	77	102	22 days @ 473K (200°C)
Transformer Oil	100	100	100	180 days @ 423K (150°C)
Water pH = 1	65	30	100	14 days @ 373K (100°C)
pH = 4.2	65	30	100	14 days @ 373K (100°C)
pH = 7.0	65	20	100	166 days @ 373K (100°C)
pH = 8.9	65	20	100	14 days @ 373K (100°C)
pH = 10.0	60	10	100	4 days @ 373K (100°C)
RADIATION RESISTANCE				
Gamma (Savannah River)		Still Flexible (180° Bend)		Exposure: 4.16×10^7 Gy
Electron (Van de Graaff)		Retains 50% of Original Elongation		Exposure: 6×10^7 Gy
Neutron plus Gamma (Brookhaven)		Darkened but tough		Exposure: 10^8 Gy
FUNGUS RESISTANCE		Inert		Soil Burial
MOISTURE ABSORPTION		1.3% Type H		50% Relative Humidity at 296K (23°C)
		2.9% Type H & V		Immersion for 24 hours at 296K (23°C)
HYGROSCOPIC COEFFICIENT OF EXPANSION		2.2×10^{-6} m/m/% Relative Humidity		295K (72°F) 20%-80% Relative Humidity
PERMEABILITY Gas		ml/m²·MPa·day (cc/(100 in²) (24 hrs.) (atm/mil))		
Carbon Dioxide		6.9 (45)		ASTM D-1434-63 @ 296K (23°C)
Hydrogen		38 (250)		
Nitrogen		0.9 (6)		
Oxygen		3.8 (25)		
Helium		63 (415)		
Water Vapor		g/m²·day 84 g/(100 in²) (24 hrs.)/mil 5.4		ASTM E-96-63T

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KAPTON® Type V Film

CHEMICAL PROPERTIES

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

KAPTON® Type F Film

CHEMICAL PROPERTIES

PROPERTY	120F616	150F619	400F022
Moisture Absorption @ 298K (25°C), 50% R.H. 98% R.H.	 1.3% 2.5%	 .8% 1.7%	 .4% 1.2%
Water Vapor Permeability g/m²·d (gm./(100 in²) (24 hrs.) g/m²·d·μm (g./(100 in²)(24 hrs./mil)	 13.7 (0.89) 0.44 (1.07)	 8.8 (0.57) 0.35 (0.85)	 3.6 (0.23) 0.14 (0.92)

Kapton®
Polymide Film

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High Performance Films

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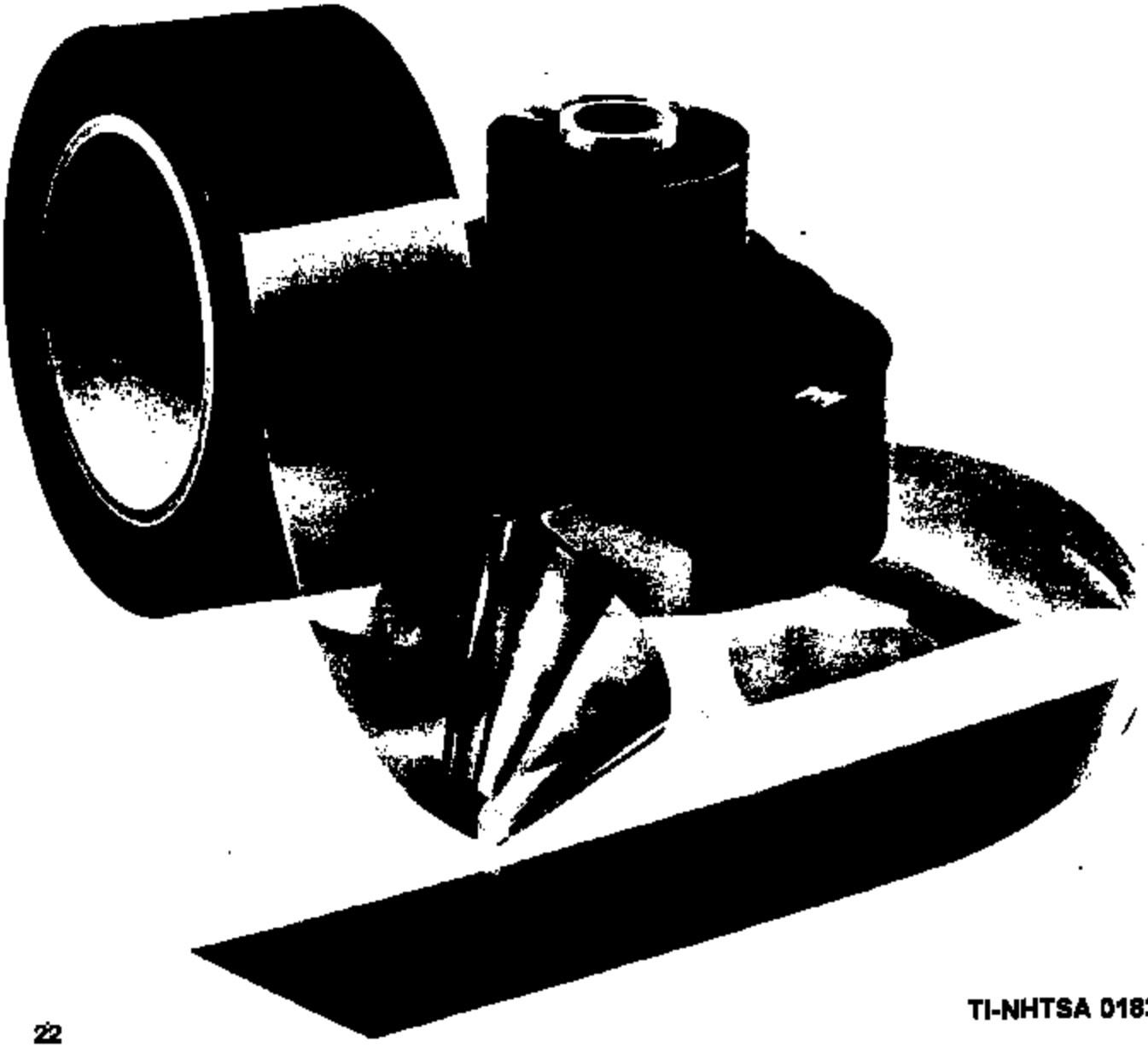
NOMINAL CONSTRUCTION, Type F Film

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

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

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



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Summary of Properties

DuPont High Performance Films

Kapton® polyimide film

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:

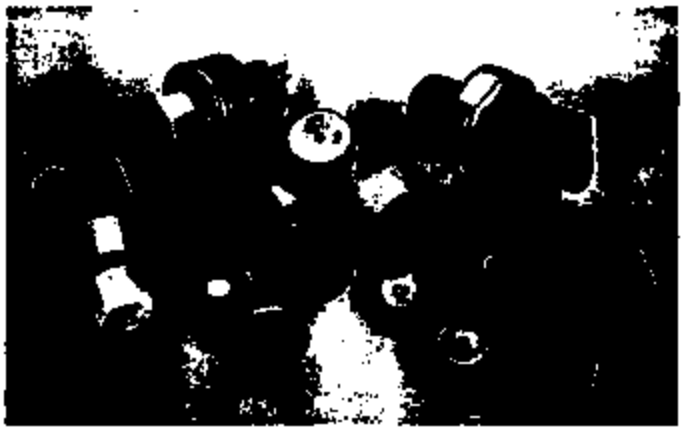
- Kapton® Type HN, all-polyimide film, has been used successfully in applications at temperatures as low as −269°C (−452°F) and as high as 400°C (752°F). Type HN film can be laminated, metallized, punched, formed, or adhesive coated. It is available as 7.5 µm (0.3 mil), 12.5 µm (0.5 mil), 19 µm (0.75 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:

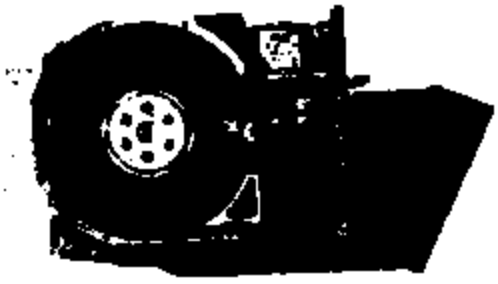
- antistat
- thermally conductive
- polyimides for fine line circuitry
- cryogenic insulation
- corona resistant
- pigmented for color
- conformable
- other films tailored to meet customers' needs

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].



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



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

Physical and Thermal Properties

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

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

Physical Property	Typical Value at 23°C (73°F)	Typical Value at 200°C (392°F)	Test Method
Ultimate Tensile Strength, MPa (psi)	231 (33,500)	139 (20,000)	ASTM D-882-91, Method A*
Yield Point at 3%, MPa (psi)	69 (10,000)	41 (6000)	ASTM D-882-91
Stress to Produce 5% Elongation, MPa (psi)	90 (13,000)	61 (9000)	ASTM D-882-91
Ultimate Elongation, %	72	83	ASTM D-882-91
Tensile Modulus, GPa (psi)	2.5 (370,000)	2.0 (290,000)	ASTM D-882-91
Impact Strength, N-cm (ft-lb)	78 (0.69)		DuPont Pneumatic Impact Test
Folding Endurance (MIT), cycles	286,000		ASTM D-2176-69
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-542-50
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)e1
$\frac{cal}{cm \cdot sec \cdot °C}$	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 (2-6-96)
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-2863-97
Solder Float	Pass		IPC TM 650, Method 2.4.13A
Smoke Generation	DM = <1	NBS Smoke Chamber	NFPA-258
Glass Transition Temperature (T_g)	A second order transition occurs in Kapton® between 360°C (680°F) and 410°C (770 F) and is assumed to be the glass transition temperature. Different measurement techniques produce different results within the above temperature range.		

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

Property	Typical Value for Film Thickness 25 µm (1 mil)	50 µm (2 mil)	75 µm (3 mil)	125 µm (5 mil)	Test Method
Ultimate Tensile Strength, MPa (psi)	231 (33,500)	234 (34,000)	231 (33,500)	231 (33,500)	ASTM D-882-91
Ultimate Elongation, %	72	82	82	82	ASTM D-882-91
Tear Strength—Propagating (Elmendorf), N	0.07	0.21	0.38	0.68	ASTM D-1922-89
Tear Strength—Initial (Graves), N	7.2	16.3	26.3	48.9	ASTM D-1004-90
Folding Endurance (MIT), x 10^3 cycles	285	86	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 (2-6-85)
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** 120FN819	150FN019	200FN529
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)	56 (8500)
200°C (392°F)	42 (6000)	43 (6000)	36 (5000)
Stress at 5% Elongation, MPa (psi)			
23°C (73°F)	79 (11,500)	66 (9,500)	76 (11,000)
200°C (392°F)	53 (8000)	41 (6000)	48 (7000)
Ultimate Elongation, %			
23°C (73°F)	75	70	85
200°C (392°F)	80	75	110
Tensile Modulus, GPa (psi)			
23°C (73°F)	2.48 (360,000)	2.28 (330,000)	2.62 (380,000)
200°C (392°F)	1.62 (235,000)	1.14 (165,000)	1.38 (200,000)
Impact Strength at 23°C (73°F), N-cm (ft-lb)	78 (0.58)	68.6 (0.51)	156.8 (1.16)
Tear Strength—Propagating (Elmendorf), N (lbf)	0.08 (0.02)	0.47 (0.11)	0.57 (0.13)
Tear Strength—Initial (Graves), N (lbf)	11.8 (2.6)	11.5 (2.6)	17.8 (4.0)
Polyimide, wt%	80	87	73
FEP, wt%	20	43	27
Density, g/cc or g/mL	1.53	1.87	1.57

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

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

Mechanical Properties

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

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

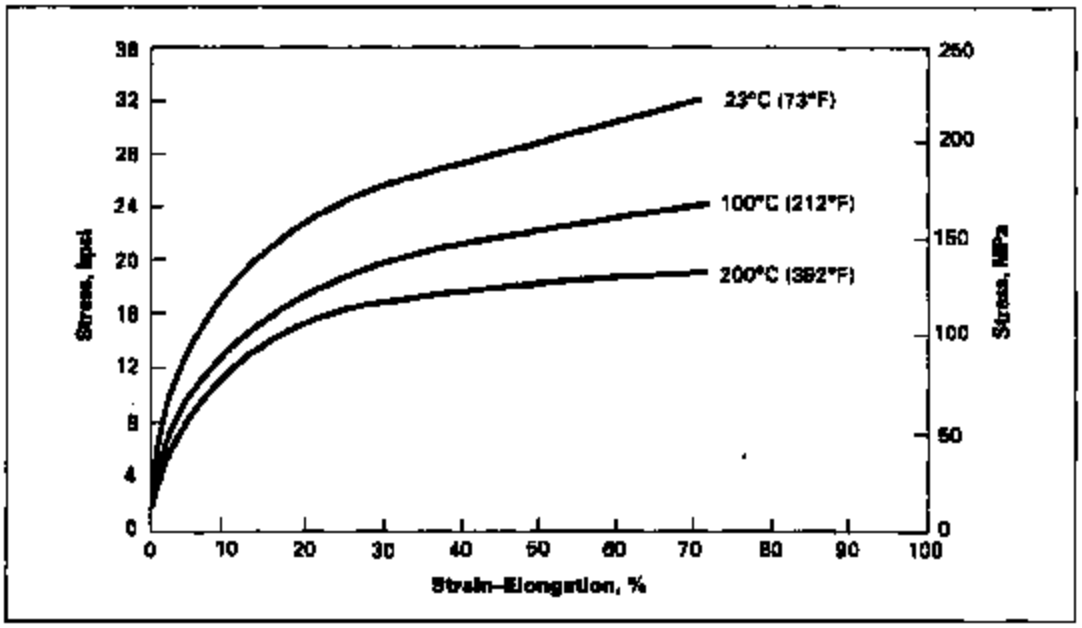


Figure 2. Tensile Creep Properties, Type HN Film, 25 µm (1 mil)

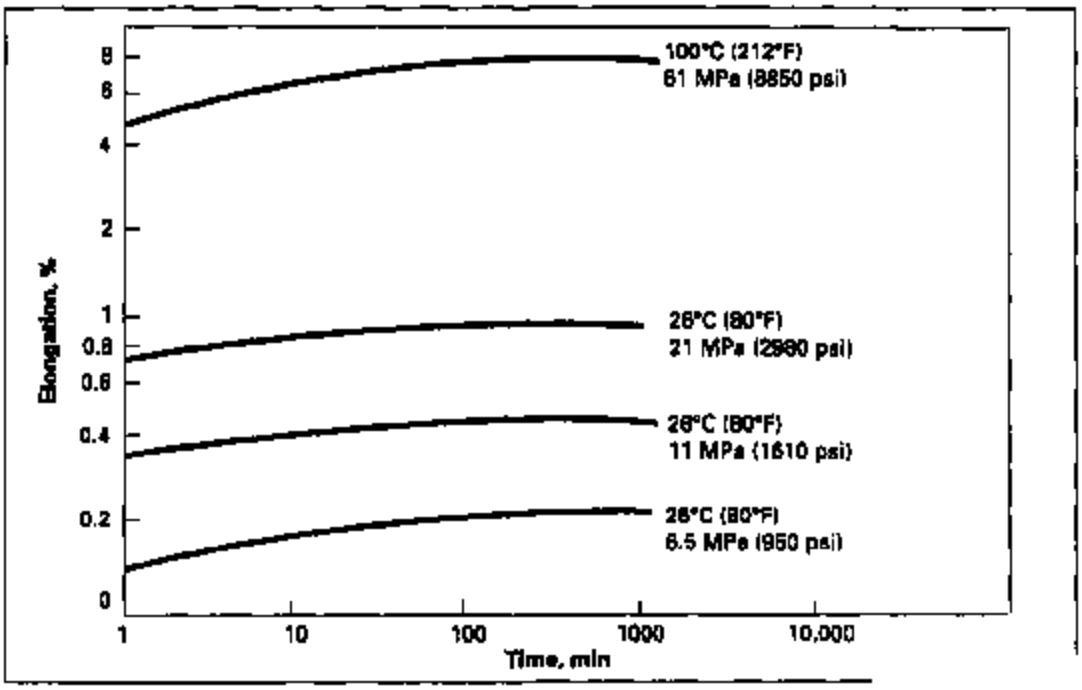
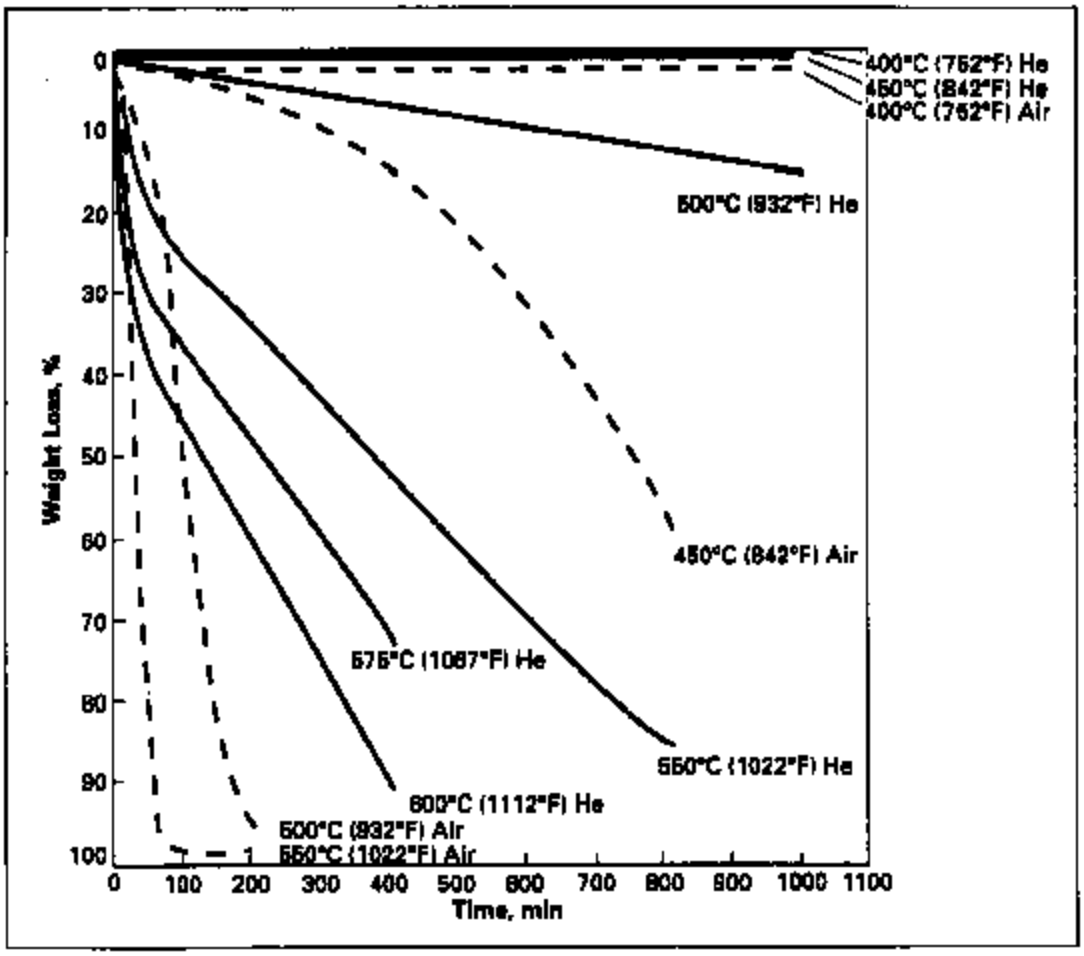


Table 6
Time Required for Reduction in Ultimate Elongation from 70% to 1%, Type HN Film, 25 μm (1 mil)

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

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



Electrical Properties

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

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

Property Film Gauge	Typical Value		Test Condition	Test Method
Dielectric Strength	V/µm (kV/mm)	(V/mil)	60 Hz	ASTM D-149-91[1]
25 µm (1 mil)	303	(7700)	1/4 in electrodes	
50 µm (2 mil)	240	(6100)	500 V/sec rise	
75 µm (3 mil)	205	(5200)		
125 µm (5 mil)	154	(3900)		
Dielectric Constant			1 kHz	ASTM D-150-92
25 µm (1 mil)	3.4			
50 µm (2 mil)	3.4			
75 µm (3 mil)	3.6			
125 µm (5 mil)	3.6			
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)	1.6×10^{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	200FN029
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}	3.8×10^{14}	3.7×10^{14}

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)

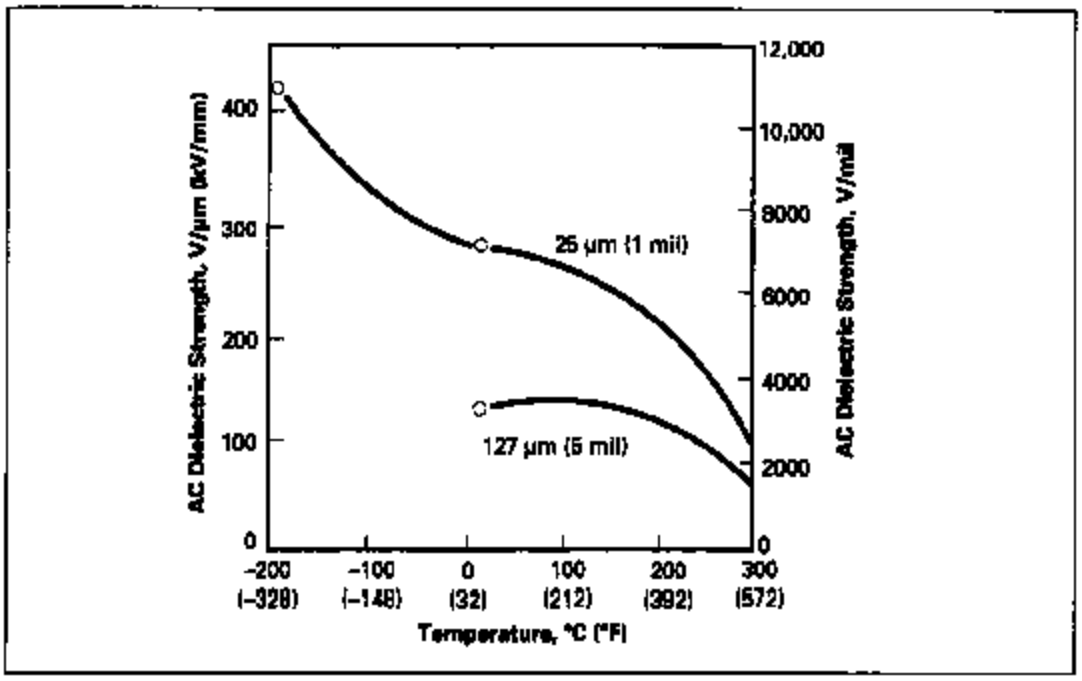


Figure 15. Dielectric Constant vs. Temperature, Type HN Film, 25 µm (1 mil)

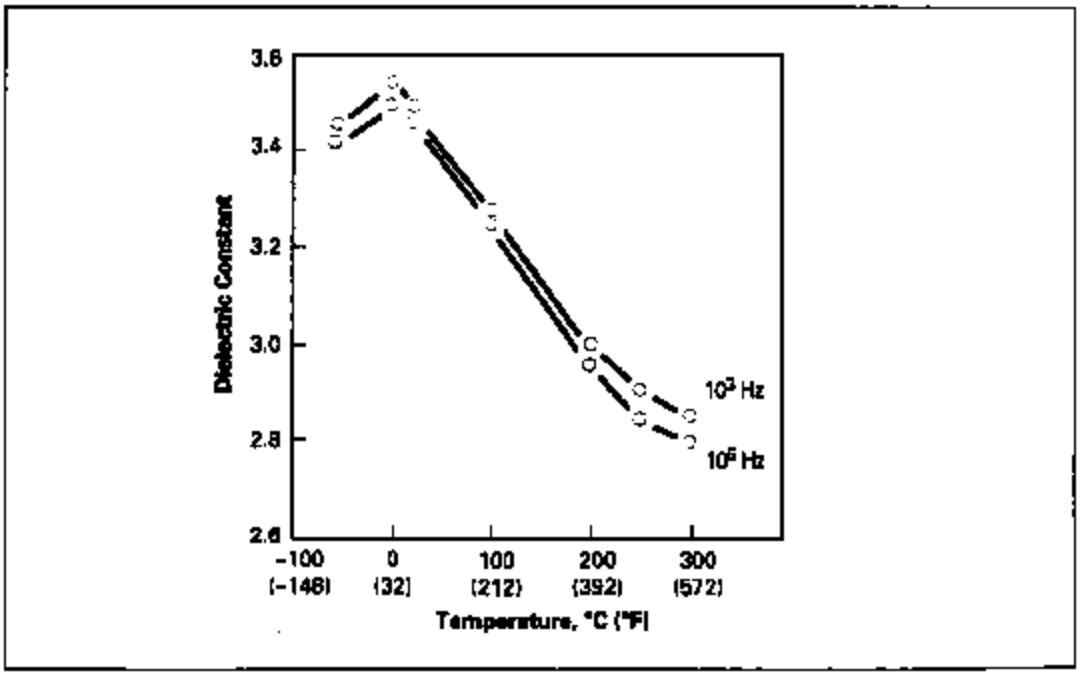


Figure 16. Dissipation Factor vs. Temperature, Type HN Film, 25 µm (1 mil)

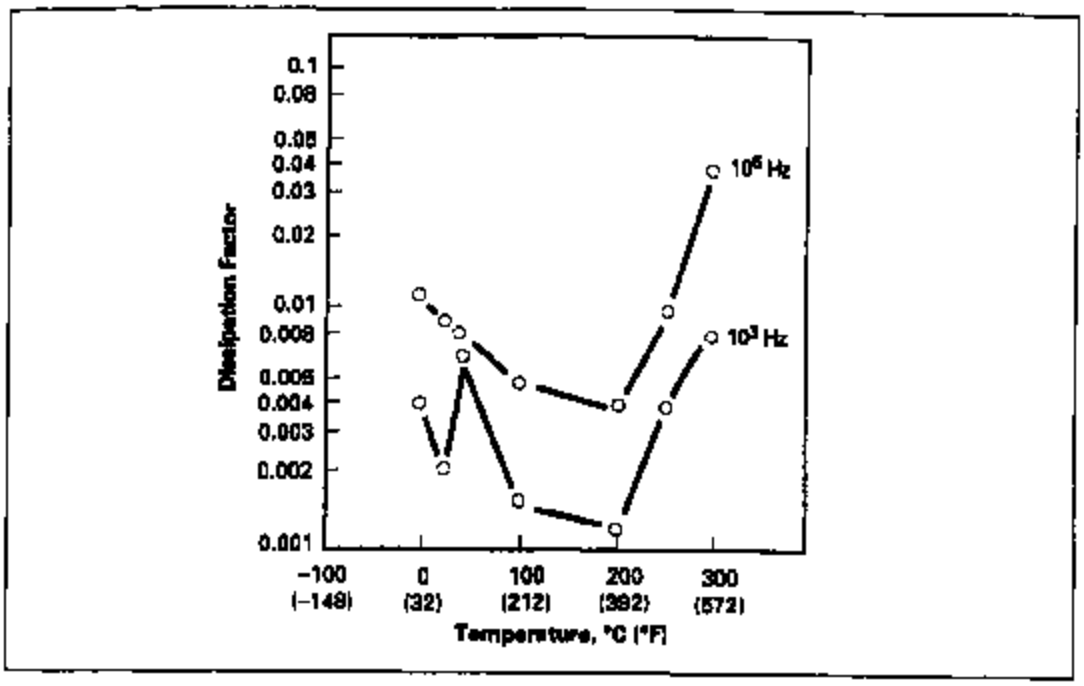
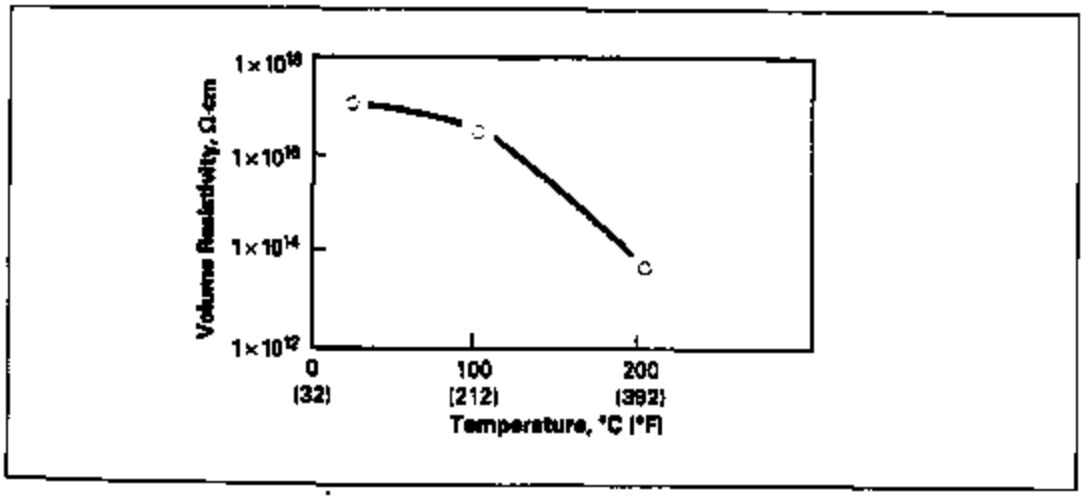


Figure 17. Volume Resistivity vs. Temperature, Type HN Film, 25 µm (1 mil)



Effect of Frequency

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

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

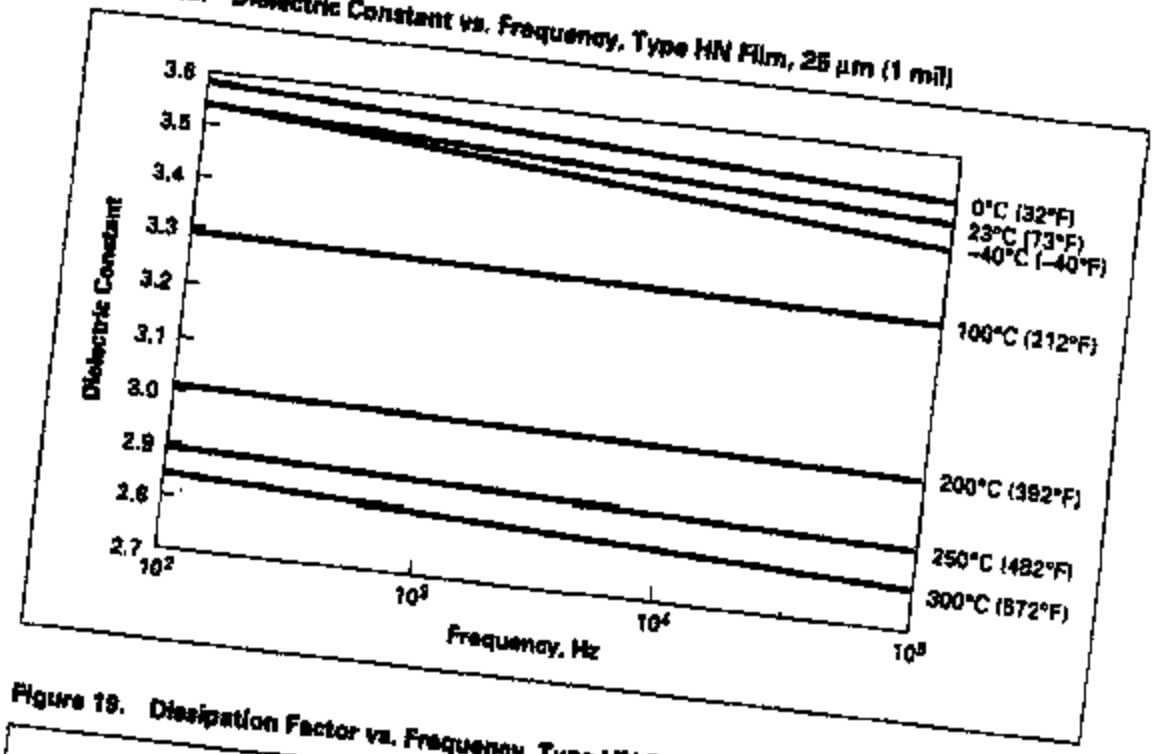


Figure 19. Dissipation Factor vs. Frequency, Type HN Film, 25 µm (1 mil)

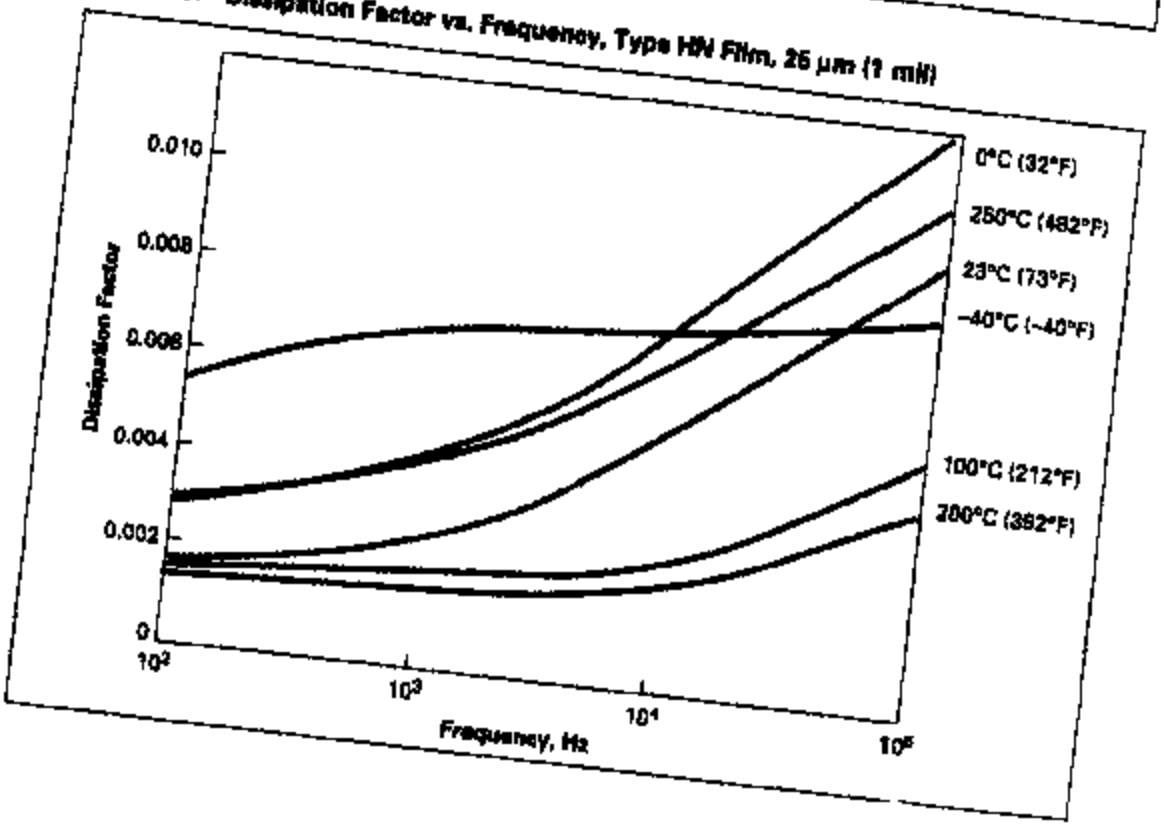


Figure 20. Dielectric Constant vs. Frequency, Type HN Film, 125 µm (5 mil)*

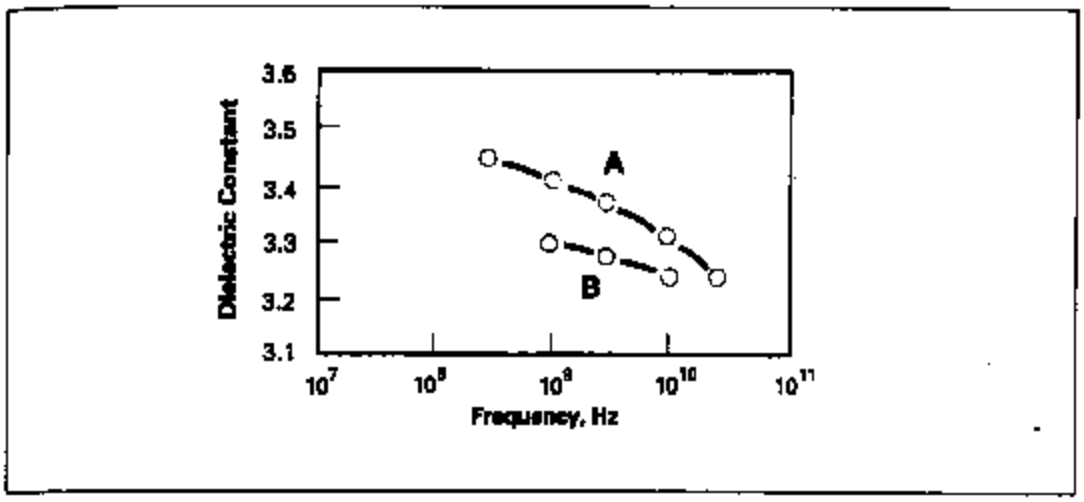
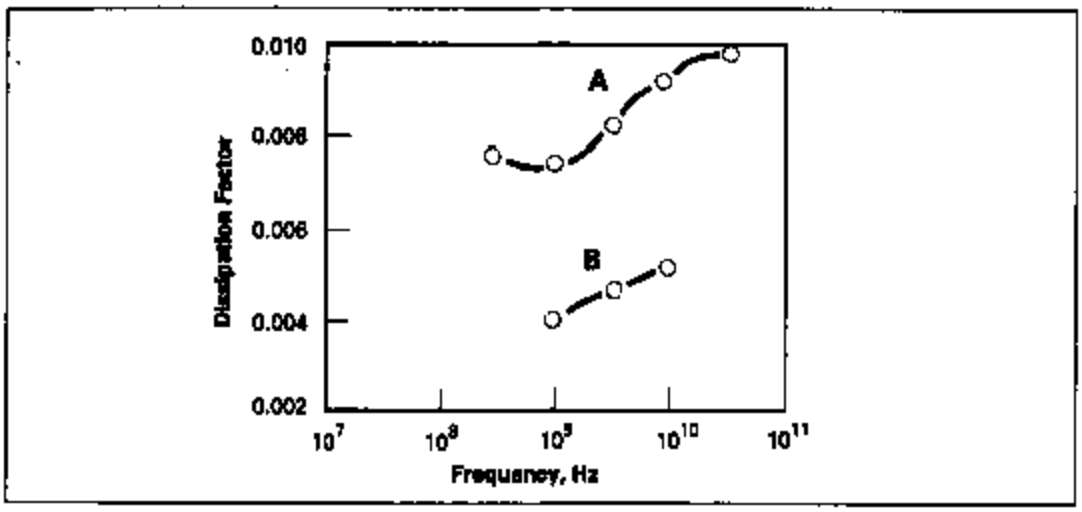


Figure 21. Dissipation Factor vs. Frequency, Type HN Film, 125 µm (5 mil)*



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

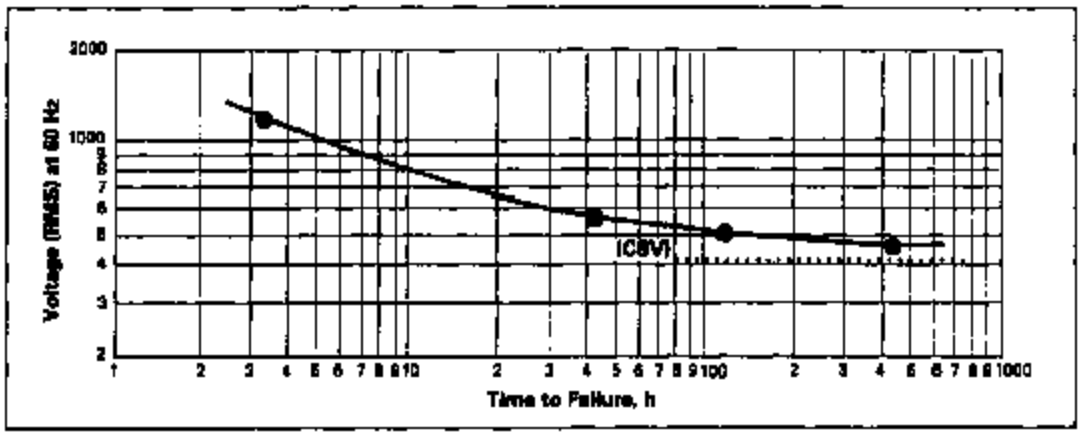
Corona Life

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

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

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

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



*Corona Starting Voltage (CSVI = 428 V

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 2.3.38
Toluene	98	91		
Methyl Ethyl Ketone	89	90		
Methylene Chloride/ Trichloroethylene (1:1)	88	85		
2 N Hydrochloric Acid	88	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	120FN619	150FN019	480FN022
Moisture Absorption, %			
at 23°C (73°F), 50% RH	1.3	0.8	0.4
98% RH	2.8	1.7	1.2
Water Vapor Permeability,			
g/(m²·24 h)	17.6	8.8	2.4
g/(100 in²·24 h)	1.13	0.62	0.16

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

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

Kapton® Film Type Information

Table 15
Type and Thickness

Type	Nominal Thickness µm	Nominal Thickness mil	Area Factor m²/kg	Area Factor ft²/lb
30HN	7.6	0.3	83	456
50HN	12.7	0.5	66	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	48
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
600FN131	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
600FN131	25.4	1.00	76.2	3.00	25.4	1.00
600FN051			127	5.00	25.4	1.00

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

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

Safety and Handling

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

Soldering and Hot Wire Stripping

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

Welding and Flame Cutting

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

Scrap Disposal

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

Fire Hazards

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

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

Static Electricity

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

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

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DUPONT

DuPont High Performance Films

Specification Bulletin

T 62-1

High Performance Films

DuPont FEP

fluorocarbon film

Types A, C, C-20, and L

Introduction

This specification covers FEP fluorocarbon film sold by DuPont Films.

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

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

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

Current product availability is shown in **Table 1.**

Manufacturing

Material

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

Color

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

Defects

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

Cores

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

Order Tolerance

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

Splices

Description

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

Frequency

See **Table 2.**

Thickness and Coverage

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

Width

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

Teflon® is a registered trademark of DuPont.

General

Packaging

DuPont FEP fluorocarbon film is wound on 3-in (76.2-mm) or 6-in (152.4-mm) cores and is overwrapped in polyethylene. The film is then boxed to prevent loss of contents or damage during shipment. Each container is labeled with DuPont and customer's name, purchase order number, film thickness, type, mill roll number, and shipping date. A label containing similar information is also affixed to the core for roll widths 2⅛ in (54 mm) and above; for rolls less than 2⅛ in (54 mm) wide, the core label is in the package.

Assurance

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

Table 1
Availability of DuPont FEP Fluorocarbon Film

	Gauge																
Type	50	100	175	200	300	500	750	1000	1500	2000	3000	4500	6000	7500	9000	12500	19000
A	*	*	*	*	*	*	*	*	—	*	—	—	—	—	—	—	—
C	*	*	*	*	*	*	—	*	—	—	—	—	—	—	—	—	—
C-20	—	—	—	*	—	*	—	—	—	—	—	—	—	—	—	—	—
L	—	—	—	—	—	*	—	*	*	*	*	*	*	*	*	*	*

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

Table 2
Maximum Allowable Splices/Roll

Types: A, C, and C-20

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

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

Type: L

	Roll, in	
Gauge	8 × 9½	8 × 11
500	3	3
1000	—	3
1500	—	3
2000	—	2
3000	—	2
4500	—	2
6000	—	1
7500	—	1
9000	—	1

Note: Minimum distance between the end of a splice and the end or start of a slit roll shall not be less than 100 ft for 500L, 80 ft for 1000L, 60 ft for 2000L and 3000L, 30 ft for 6000L, and 14 ft for 9000L.

Table 3
DuPont FEP Fluorocarbon Film Thickness Tolerance

Nominal Gauge	Nominal Thickness, in	A				B		C		
		Average Thickness Unit Weight, g/m²				Single Point Thickness[a]		Area Factor, ft²/lb		
		Nom.	Min.	Max.	% Var.	Min.	Max.	Nom.	Min.	Max.
Types: A, C, and C-20										
50	0.0005	27.29	24.55	30.01	±10	0.00035	0.00065	176.97	162.70	198.87
100	0.0010	54.56	49.10	60.02	±10	0.00070	0.00130	88.49	81.35	99.43
175	0.0017	95.48	85.93	105.03	±10	0.00130	0.00220	51.14	46.00	56.25
200	0.0020	109.12	98.20	120.03	±10	0.00160	0.00250	44.74	40.67	49.72
300	0.0030	163.68	147.31	180.05	±10	0.00225	0.00375	29.83	27.11	33.14
500	0.0050	272.80	253.70	291.90	±7	0.00400	0.00600	17.90	16.72	19.25
750	0.0075	409.20	380.55	437.84	±7	0.00622	0.00877	11.93	11.16	12.83
1000	0.0100	545.60	507.40	583.79	±7	0.00850	0.01150	8.95	8.36	9.62
2000	0.0200	1091.20	1014.82	1167.58	±7	0.01700	0.02300	4.47	4.18	4.81
Type: L										
500	0.0050	272.80	245.52	300.08	±10	0.0040	0.0060	17.90	16.27	19.69
1000	0.0010	545.60	491.04	600.16	±10	0.0085	0.0115	8.95	8.13	9.94
1500	0.0015	818.40	736.56	900.24	±10	0.0128	0.0173	5.97	5.42	6.63
2000	0.0200	1091.20	982.08	1200.32	±10	0.0170	0.0230	4.47	4.06	4.97
3000	0.0300	1636.80	1473.12	1800.48	±10	0.0255	0.0345	2.98	2.71	3.31
4500	0.0400	2455.20	2209.68	2700.72	±10	0.0383	0.0518	1.99	1.80	2.20
6000	0.0600	3273.60	2946.24	3600.24	±10	0.0540	0.0660	1.49	1.35	1.66
7500	0.0750	4092.00	368.28	4501.20	±10	0.0639	0.0963	1.19	1.07	1.31
9000	0.0900	4910.40	4419.36	5401.44	±10	0.0810	0.0990	0.99	0.90	1.10
12500	0.125	6820.00	6480.00	7160.00	±10	0.108	0.144	0.72	0.68	0.76
19000	0.190	10366.00	9895.00	10947.00	±10	0.161	0.218	0.47	0.45	0.49

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

Table 4
Roll Width Tolerance, in

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

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

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

Property	Film Gauge									Method
	50	100	200	300	500	750	1000	1500	2000	
Dielectric Strength, V/mil, AC	4000	4000	3500	3000	2500	2000	1800	1500	1400	Average of ten samples tested per ASTM D-149 Method A. Flat sheets in air placed between ¼ in diameter brass electrodes with 1/32 in edge radius and subjected to 60 Hz AC voltage rise at 500 V/sec to the breakdown voltage.
Dielectric Constant (at 25°C, 1000 Hz) Max.	2.18									ASTM D-150. Result is average of five tests using measured sample thickness.
Dissipation Factor (at 25°C, 1000 Hz) Max.	0.0003									ASTM D-150, same as above.
Volume Resistivity, ohm·cm at 170°C, Min.	1×10^{17}									ASTM D-257.
Surface Resistivity, ohm (per sq.) at 23°C, 38% RH, Min.	1×10^{15}									ASTM D-257.

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

Property	Film Gauge								Method
	50	100	200	300	500	750	1000	2000	
Tensile Strength, psi, 25°C, Min.	2000	2500	2500	2500	2500	2500	2500	2500	ASTM D-882 for ≤10 mil thickness. ASTM D-638 for >10 mil thickness. 2 in/min testing speed.
Elongation at Break, %, Min.	175	200	250	250	250	250	250	250	Same as above method.
Shrinkage, %, Max. at 200°C									Average of five measurements on room temperature samples before and after each test. Each specimen, 4 in × 4 in freely suspended in an oven controlled to 200°C ±1°C. Exposure time 0.5 hr.
MD	±5	±5	±3	±2	±2	±2	±2	±2	
TD	±5	±5	±3	±2	±2	±2	±2	±2	
Cementability (Type C film only), Min. peel strength in g/in of width	170	300	750	800	2000	2000	3000	—	Use DuPont adhesive #68040 on Alclne #1200 aluminum sheet (0.019 in thickness). Peel Test at 180° angle at peel rate 12 in/min.
Melt Temperature, Melting Endotherm Peak, °C	260–280								ASTM D-3418 (DTA).
Density, g/cm³, 23°C	2.13–2.17								ASTM D-1505.

Table 7
Property Value, Type L

Property	Film Gauge										Method
	500	1000	1500	2000	3000	4500	6000	7500	9000	12500	
Tensile Strength, psi, 25°C	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	ASTM D-882 for ≤10 mil thickness. ASTM D-638 for >10 mil thickness. 2 in/min testing speed.
Elongation, %, Min.	250	250	250	250	250	250	250	250	250	250	Same as above method.
Shrinkage, %, Max. at 200°C											Average of five measurements on room temperature samples before and after each test. Each specimen, 4 in x 4 in freely suspended in an oven controlled to 200°C ±1°C. Exposure time 0.5 hr.
MD	±2	±2	±2	±2	±4	±4	±4	±4	±5	±5	
TD	±2	±2	±2	±2	±4	±4	±4	±4	±5	±5	
Melt Temperature, Melting Endotherm Peak, °C	260-280										ASTM D-3418 (DTA).
Density, g/cm³, 23°C	2.13-2.17										ASTM D-1505.

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High Performance Films

Teflon® FEP

fluorocarbon film

Techniques for Fabricating Teflon® FEP

Introduction

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

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

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

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

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

Heat Sealing Principles

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

General

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

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

by localizing the heat applied to the film to as small an area as is practical. The use of hot bar or impulse sealing equipment necessitates bringing the entire thickness of film to the melting point of the polymer in order to accomplish a fusion temperature at the film interfaces. With relatively thin films, heat transfer time is sufficiently short to allow this method, although thinning out of the film adjacent to the seal occurs to a greater extent as film thickness increases. In continuous band sealing, this is accomplished by heating only the center portion of the band and by cooling the seal under pressure. Hot air sealing reduces thinning out by allowing the force of the air flow to act as the pressure medium and metal plates or guides to keep the majority of the film below the distortion temperature. Heat seals made with Type L Teflon® FEP and Type LP Teflon® PFA tend to be more durable.

Because molten Teflon® FEP fluorocarbon film has a tendency to stick to the jaws of a heat sealer, it is desirable to use a release agent in the sealing operation. Kapton® polyimide film may also be used as a release slip sheet.

Hot Bar Heat Sealing

The use of hot bar sealing equipment having a minimum temperature capability of 288°C (550°F) and a fast recovery rate will give a wide seal area and be limited to a straight seal. Because it is difficult to localize or isolate the film seal area, a degree of puckering takes place in thinner films. Thinning out will occur adjacent to the fusion area due to the jaw pressure when the film is in a fusion state. Because the equipment does not usually allow temperature cycling during the seal cycle, the film is taken from the jaws while in a molten state when film distortion is at a maximum.

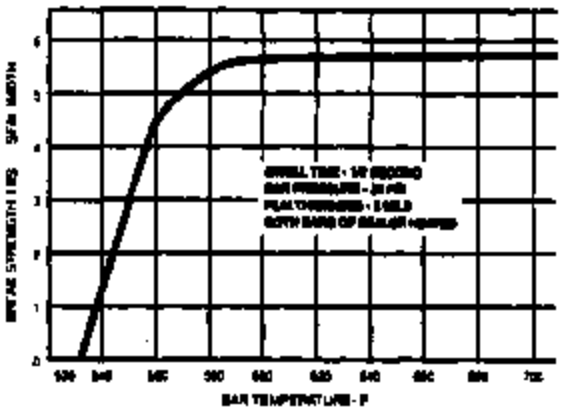
The following graphs illustrate the time/temperature/pressure relationships encountered in hot bar sealing. These general relationships hold true for other heat sealing methods as well.

Temperature

Figure 1 illustrates the effect of bar temperature upon the seal strength of 5-mil Teflon® FEP film at constant bar pressure and dwell time. Above a specific bar temperature (310°C [590°F] with this equipment) there is no significant change in the bond strength of the heat seal.

Figure 1. Effect of Bar Temperature Upon Seal Strength of Teflon® FEP Film

Pressure



In **Figure 2**, data are plotted for bar pressures of 30 psi and 60 psi with 2-mil film and a constant dwell time of ¼ sec. Pressure appears to have no significant effect upon the bond strength of the fusion heat seals. However, certain qualifications should be made. First, in thicker gauge film (5-mil and greater), pressure does affect the minimum temperature at which a fusion heat seal can be made. Higher pressures tend to yield a fusion heat seal at a slightly lower bar temperature, probably due to the fact that higher pressures can improve the rate of heat transfer from the heated bar to the film. At high pressures, however, cut through and thinning out occur. Teflon® FEP film possesses a relatively high melt viscosity, which is not nearly as much a problem as with lower melt viscosity thermoplastics.

Figure 2. Effect of Pressure Upon Seal Strength of Teflon® FEP Film

Time

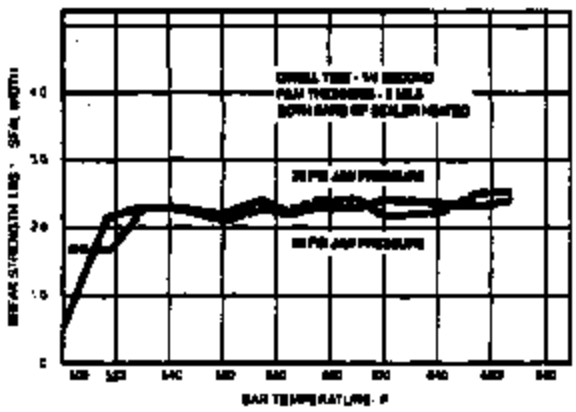
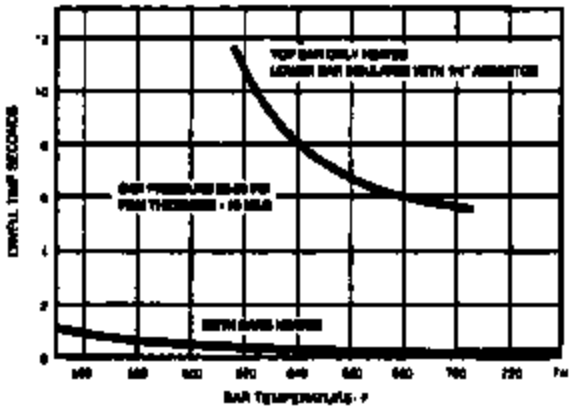


Figure 3 illustrates the considerable effect heating both bars vs. one bar of the sealer has upon the temperature-time relationship for obtaining a fusion heat seal. For example, at 338°C (640°F), it requires only 0.2 sec with two bars heated to obtain a fusion heat seal with 10-mil film, while with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

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



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

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

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

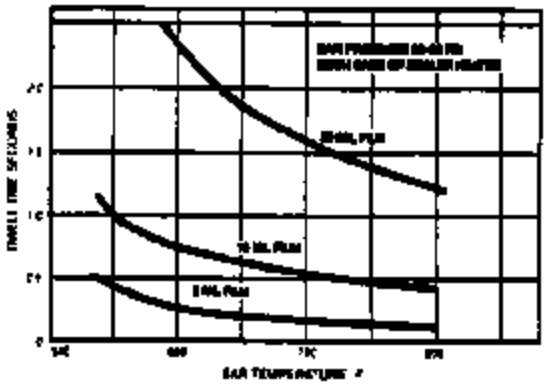
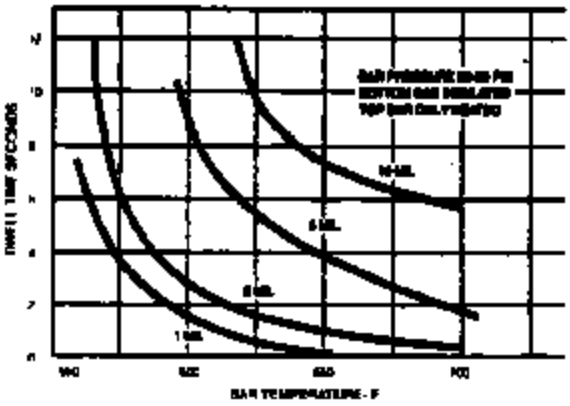


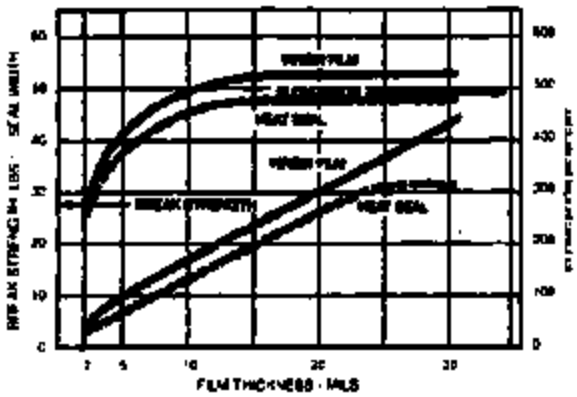
Figure 5. Temperature-Time Relationship for Obtaining Fusion Heat Seal with Teflon® FEP Film



Effect of Gauge on Heat Seals

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

Figure 6. Heat Seal Strength and Elongation Obtainable with Teflon® FEP Film Compared to Virgin Film



Impulse Heat Sealing

Vertrod Corp.* impulse heat sealing equipment has been used for Teflon® FEP fluorocarbon film. The heat sealing is effected by a pulse of electrical current, which is passed through Nichrome** ribbons located in either top and/or bottom jaws. These ribbons transfer heat at a very high temperature for a short period of time. By varying the voltage and time of impulse with a jaw pressure of 10–25 psi, ½–20 mil Teflon® FEP film may be sealed. The heavier gauges will usually require equipment modification.

The seal area will be the width of the Nichrome ribbons and, as with the hot bar sealer, will be limited to a straight seal. Thinning out at the edge of the seal will occur due to the thickness of the Nichrome ribbons and the molten state of the entire thickness of film when at the seal temperature. Because the Nichrome ribbons supply heat for only a short period of time, by allowing the seal to remain in the jaws for several seconds after the impulse, the seal will be cooled below its maximum distortion temperature before being removed. Some puckering will generally occur with thinner films because the seal area is not entirely isolated from the remainder of the film.

Shaped Seal

Curved or irregular sealing configurations that are not possible with hot bar or impulse sealing equipment may be made by using a heated metal shape such as a ring. However, special sealers for irregular shapes are commercially available. The metal shape must be capable of a minimum of 288°C (550°F) and preferably capable of higher temperatures to allow a reasonably short seal cycle (considering the heat transfer time of the film and any slip sheet that may be used).

Care should be taken to ensure that the metal shape is not warped at the elevated sealing temperatures. Machining at these temperatures usually corrects this and allows for an even pressure and heating distribution.

In order to localize heat to the seal area only, cooled metal or nonmetal shapes may be placed in contact with the film area not being sealed. An insulation barrier should be placed between the heated and cooled shapes.

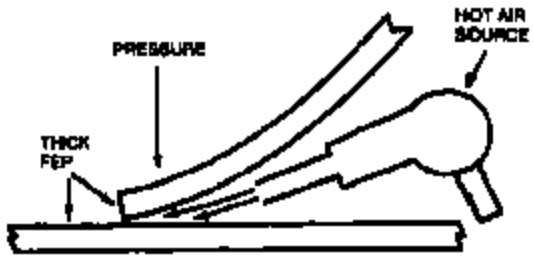
Sufficient contact time to allow the film interfaces to reach fusion temperature will depend upon the film thicknesses to be sealed and the temperature of the sealing mechanism. Heated metal shapes may be used on either one or both sides, both sides giving a faster heat transfer time and thus a shorter cycle.

A high-frequency generator may be used to heat, by induction techniques, a complex metal shape that cannot be heated by the use of conventional resistance type heater elements.

Hot Air Sealing

A hot air source may be used as a heat supply to seal Teflon® FEP film. For relatively thick films (greater than 20 mil), a hot air stream may be directed at the interfaces of the film to be sealed while applying minimal pressure to provide intimate contact of those surfaces. This method provides heat only to the surfaces to be sealed and keeps the major portion of the film below distortion temperature.

Illustration A. Hot Air Sealing of Thick Films



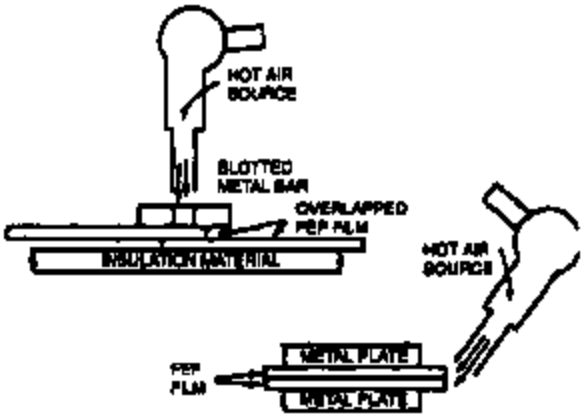
For thinner films where heat transfer time is sufficiently short, hot air may be applied to the outer surface of the film heating through the outer film layer to the interfaces and giving a fusion seal. If such a method is used, a metal guide should be

*Vertrod Corp., Brooklyn, NY

**Registered trademark of Driver Harris Company, Harrison, NJ

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

Illustration B. Hot Air Sealing of Thin Films



Thermoplastic Welding

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

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

Safety

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

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

Materials and Equipment

Welding Rods should be extruded virgin Teflon® FEP plastic, normally round, solid, and free of voids with a minimum diameter of 3/32 in and a maximum of 1/16 in.

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

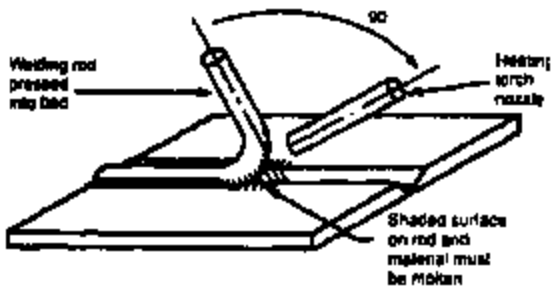
Inert Gas Supply and Pressure Regulator to provide 5–6 psig pressure at the tip of the welding tool.

Preparation

- Cleaning cannot be overemphasized. All surfaces, including welding rods and adjacent plastic for about 1 in beyond the joint, should be cleaned immediately prior to welding with a suitable solvent. **Do not use soap or detergents.**
- Bevelling of thermoplastic edges is essential to obtain a satisfactory weld. Mechanically guided power tools should be used for straighter edges. Use these bevel angle guidelines for Teflon® FEP sheet:
  - Butt Joints (single or double) 60°
  - Corners 60°
  - Fillets 45°
  - Laps Not required
- The joint must be kept in alignment during welding by mechanical clamping or tack welding with a maximum root gap of 1/32 in.

Welding

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



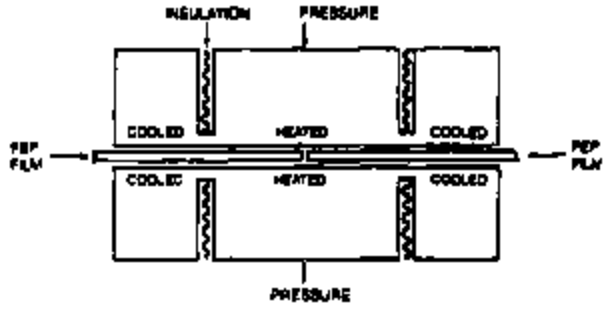
5) Continue welding at a steady and uniform rate of about ½–2 in/min.

6) Temperature, welding speed, rod pressure, and gas flow may be adjusted to vary from the indicated values as more skill and proficiency is achieved through experience.

Transparent Butt Seal

It has been demonstrated that an optically clear butt seal is possible by profile heating and cooling techniques (see Illustration C). By selectively heating and cooling a continuous metal surface in contact with the butt ends of Teflon® FEP fluorocarbon film, the film will flow and fuse to itself to give an optically clear seal. Heating the center portion of the metal where it is in contact with the butt ends and keeping the majority of the film on either side of the heated area cool restricts the thinning out and distortion of the film.

Illustration C. Transparent Butt Seal



Other Methods of Sealing

Induction Sealing

FEP film can be heat sealed by induction heating of metal or metal oxides at the bond interface.

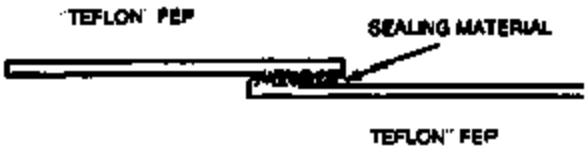
With induction heat sealing, metal or metal oxide is introduced at the bond interface. Heat is developed by energizing the magnetically excitable material with high-frequency induction generating equipment. The magnetic field passes through the films and generates heat at the bond interface. This eliminates the need for heat transfer through the thickness of the film.

Variables affecting the sealing rate are the type of metal used, its mass, and distance from the induction heating coil. Magnetic ferrous materials are best because of their intense hysteresis loss. Nonmagnetic metals like aluminum, copper, tantalum, and nickel have been induction heated, but higher power input and longer dwell time is required.

Blends or electromagnetic energy absorbing materials and a thermoplastic of the same composition as the materials to be bonded are commercially available in tape form or injection molded shapes.

The tape or shape is placed between the sections to be joined (see Figure 7) and magnetically excited. Coil designs provide the intense magnetic field needed. The actual weld is Teflon® FEP. If a low metal content is used, you can still obtain a true melt bond between the two FEP surfaces. This is extremely important for chemical applications.

Figure 7. Lap Weld Specimen



Heat Sealing Parameters

	Induction	Impulse
Max. Film Thickness	0.500 in or more	0.020 in
Sealing Cycle	3 sec—60-mil	6 sec—20-mil
Appearance	No distortion	Some distortion and thinning*
Pressure	3–4 psi	20–40 psi

*Vertrod two-step impulse system gives smooth seal.

Ultrasonic Sealing

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

Heat Bonding

Teflon® FEP Fluorocarbon Film to Various Substrates

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

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

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

Surface Treatment of Metals

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

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

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

Teflon® FEP Fluorocarbon Dispersion Priming of Metals

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

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

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

Table 1
Typical Platen Press Conditions

Substrate	Interface Temperature, °C (°F)	Pressure, psi	Dwell Time, min	Substrate Surface Preparation and Treatment
Aluminum	282 (540) 293 (560)	100 100	5 5	None, if Type C film is used Parker Bonderite 700 series*
Copper	282 (540)	100	3–5	Various treatments
Steel	293–304 (560–580)	100–300	5	Sandblast and degrease, phosphatized*
Stainless steel	360 (680) 293 (560)	300 300	5 5	None Dispersion primer of Teflon®—see paragraph above
Teflon® TFE	343 (650)	100	3–5	None
Nickel	282 (540)	100	5	None, if Type C film is used
Nickel Ceramics Nichrome	293 (560)	300	5	Dispersion primer of Teflon®
Nomex® nylon paper	282 (540)	100	5	Use Type C film Pre-dry Nomex® (at 121°C [250°F], 30 min)
Glass	296 (565)	10	10	Silane coupling agent**
Kapton® polyimide film	282 (540)	100	5	None, if Type C film is used

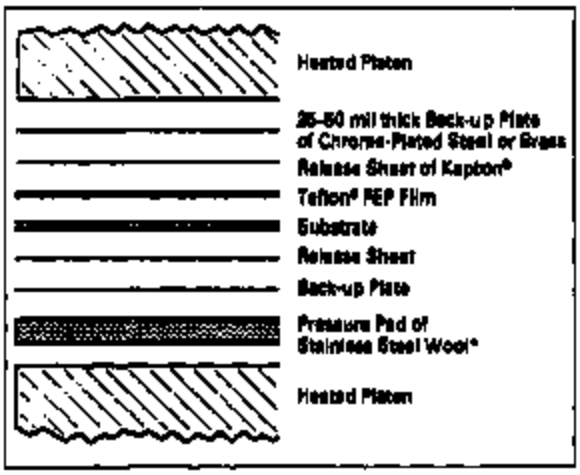
*Treating and phosphating chemicals are available from Oxy Metal Industries, 322 Main St., Morenca, MI 49066.
**Silane coupling agents are available from Union Carbide Corporation and Dow Corning.

Platen Press Laminating

Hot platen press laminating is the most common technique for bonding Teflon® FEP fluorocarbon film to other materials. There are a few fundamental considerations that contribute to good results with this technique. These are:

- Good platen temperature control and distribution (±5.5°C [±10°F] across the laminating area).
- Even pressure distribution across the laminating area. Use a pressure pad (see **Figure 8**).
- Compensating pressure control. (The selected laminating pressure should be maintained regardless of expansion or contraction of the materials being laminated.)
- Use the minimum temperature, time, and pressure combination that produce desired results.
- Cool laminate to at least 204°C (400°F) before releasing pressure. This may be done by quickly transferring laminate to a cold press or quenching it in cold water.

Figure 8. Platen Press Laminating



*Available from the International Steel Wool Corp.

Teflon® FEP Fluorocarbon Film as an Adhesive

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

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

Adhesive Laminating

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

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

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

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

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

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

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

Process Limitations

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

End-use Conditions

- Maximum continuous use temperature.
- Maximum intermittent temperature.
- Degree of flexibility or formability needed.
- Bond strength needed (peel or shear).
- Type of atmosphere (chemical, humidity, outdoor).

Metallizing

Teflon® FEP fluorocarbon film makes an excellent substrate for vacuum metallization—by either thermal evaporation or magnetron sputtering. Key properties are:

- Negligible moisture content
- Absence of additives and oligomers to outgas under vacuum and processing temperatures
- Inert to chemical reaction while in the metallizer
- Uniform film web thickness
- Good dimensional stability (low shrinkage)
- Resistance to degradation at metallizer temperature and pressure

As in the case for laminating, the film surface may have to be treated (Type C or sodium etched) to improve surface energy and enhance adhesion of the deposited metal particles. Untreated, general-purpose FEP film may be vacuum metallized for some applications depending upon the specific metal and deposition process used. Copper, aluminum, silver, gold, and some metallic oxides have been applied to Teflon® FEP film through vacuum metallization.

Thermoforming of Teflon® FEP Fluorocarbon Film

Introduction

Teflon® FEP fluorocarbon film is a true thermoplastic material that is readily formable in either vacuum or pressure-forming equipment. Because it is available in thicknesses of ½–190 mil, Teflon® FEP film can be used in a wide variety of applications from surfacing to completely self-supported structures. Its formability combined with its release properties, chemical inertness, and high service temperature make Teflon® FEP film ideal for use in various antistick and corrosion-resistant surfacing applications.

Cementable film (treated or etched) may be adversely affected by thermoforming due to large area increases (stretched) and prolonged heat.

Vacuum Forming

Straight vacuum forming is adequate for most applications using ½-, 1-, 2-, and 5-mil films. It can also be used for thicker films where the mold is not too intricate. Modified vacuum forming techniques such as drape forming, use of a heated plug assist, and snapback forming are applicable. The heating time depends upon the distance of the film from the heaters and the complexity of the shape to be formed. As shown in Table 2, using a heater located 4 in above the film, a 10-sec heating time is optimum for forming 5-mil film in a 7 in × 12 in × 2 in female mold.

A radiant heater having a watt density of at least 3.5 kW/ft² is required to heat the film to the temperature where it can be formed. Most commercial equipment is supplied with heating elements of 1.7–2.5 kW/ft².

Molds for vacuum forming 10- and 20-mil Teflon® FEP film should be heated to 93–149°C (200–300°F) in order to keep the film from cooling before it has been completely formed. In some cases, heated molds are helpful for forming thinner films also.

Table 2
Optimum Conditions for Vacuum Forming

Film Gauge, mil	Heat Density, kW/ft²	Time, sec	Remarks
1	1.9	32	Only with rested heater
1	3.7	8	
2	3.7	10	
5	3.7	12	
10	3.7	20	Thick portion at point of initial contact with mold

Note: The mold used for this first set of data is a vertical cylinder 1½ in high and 3 in diameter. It represents a 200% area increase.

Film Gauge, mil	Heat Density, kW/ft²	Time, sec	Remarks
2	3.7	8	
5	3.7	10	
10	3.7	—	Heated in formed piece throughout time range. Heated mold necessary.
20	3.7	—	

Note: This mold is a pan-shaped cavity 7 in × 12 in × 2 in. It represents an area increase of 80%.

Pressure Forming

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

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

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

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

Table 3
Optimum Conditions for Pressure Forming

Film Gauge, mil	Temp., °C (°F)	Heat Time, sec	Dwell Time, sec	Pressure, psi	Remarks
1	246 (475)	10	8	60	
2	252 (485)	10	6	60	
5	254 (490)	10	6	60	
10	254 (490)	10	7	60	Holes
20	254 (490)	10	6	100	

Note: The mold for the first set of data is a group of nine 3-in square pouches, 1 in deep. It represents an area increase of about 130% in each pouch. This mold has no heating.

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

Note: The need for a heated mold is proved by the use of a disk shaped mold 4½ in diameter and 1 in deep heated with strip heater. Area increase is 87%.

Summary of Important Points

Thermoformable?

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

Problems?

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

What does it take?

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

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

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

What does the FEP film do?

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

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

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

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

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

Deep Draws

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

Detailed Draws
Very good detail in the formed part is possible with Teflon® FEP fluorocarbon film. To do so, the FEP film must be pulled tight against the mold while still hot (crystal clear).

Shrinkage
If the formed shape is stripped from the mold while hot, upon cooling some of the residual shrinkage will be removed. Thus, it will have less chance of fitting the mold again than if it was completely cooled while on the mold.

Webbing
Webbing can take place as the film is formed. It is related to mold design and caused by excess material not having a place to go; so it folds over on itself. This is most common with male molds in deep draws.

By placing a ring around the mold or small shapes at the points of webbing to take up the excess film, this foldover can generally be kept from occurring in the formed shape.

Mold Materials
Metals, Teflon® TFE, and glass are the most frequently used mold materials. Plaster, wood, and lower temperature plastics may be used for several formed parts, if they are masked from the heating cycle, but may char under continued use.

Notes on Thermoforming
As in a molding operation, after cooling to room temperature, there will be shrinkage of the formed piece. The amount of the shrinkage will depend upon its temperature at the time of forming. A shrinkage allowance must be built into the mold. In the case of Tefloo® FEP film, the allowance will be 6–8% depending on expected temperatures of the film.

There will also be variable stresses in the piece due to the elongation of the film during the forming operation. These are not usually apparent until an unrestrained piece is exposed to an elevated temperature, at which time stress relieving may distort the piece. This elongation stress can vary in amount in different sections of a formed piece and can also vary with different films used on the same mold. The film temperature/yield stress relationship will also have an effect. They can be "normalized" by using pressure-forming techniques at a temperature above that to which the restrained piece will be exposed.

Excessive thinning of film, at times to the point of rupture, can be experienced when forming in molds with a high ratio of depth to width of draw. A radius on the edges of the mold will help the film accommodate itself to the draw by making it easier to "flow" over a corner. Thickness of original film, its temperature, and rate of draw are also important.

An insulator such as TFE, glass, or wood (vs. a conductor such as metal) may offer some advantages in surface appearance. Many times a metal will give a finish with optical distortion in it, while TFE or wood will give less distortion to the part.

Mold Design
If the formed part has straight sides, try to design the mold so the formed part may be easily removed.

Forming into a female mold may offer advantages in removal vs. the tight fit of a formed shape over a male mold without tapered sides.

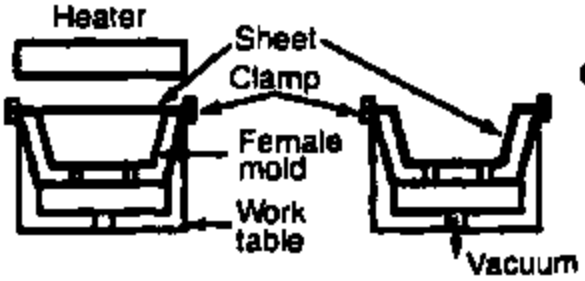
Vacuum Holes
Vacuum holes should be as small as practical: 1/32 in maximum, 1/64 in preferable.

Mold design may allow vacuum to be drawn through slits, a preferable method for gaining detail.

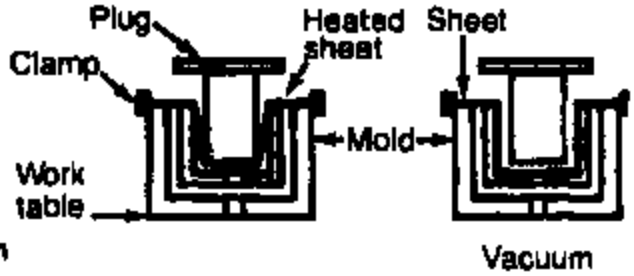
Vacuum holes should be located at strategic spots to pull the film in all crevices. Not every low spot or crevice must have a vacuum hole, but a sufficient number should be located to prevent any bridging of the film between high areas of the mold.

Most Commonly Used Forming Techniques

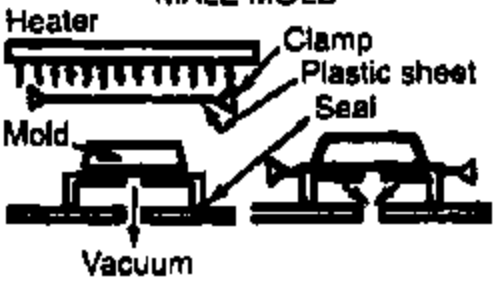
STRAIGHT VACUUM FORMING
FEMALE MOLD



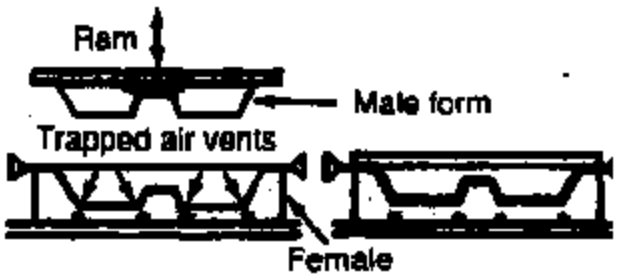
VACUUM FORMING WITH
PLUG ASSIST



DRAPE VACUUM FORMING
MALE MOLD

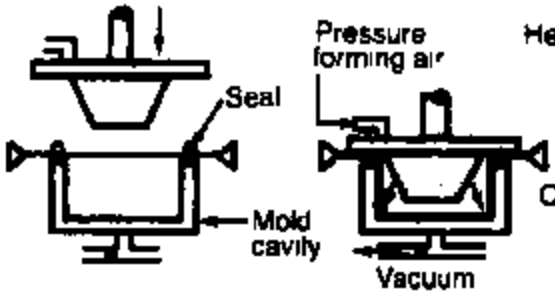


MATCHED MOLD FORMING

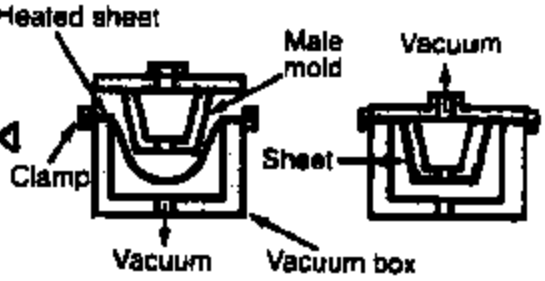


Less Frequently Used Techniques

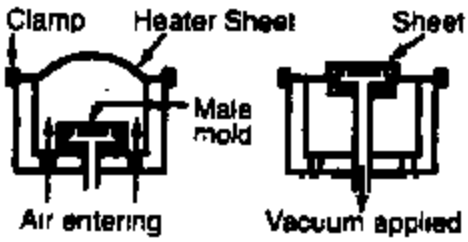
PRESSURE FORMING w PLUG ASSIST
FEMALE MOLD



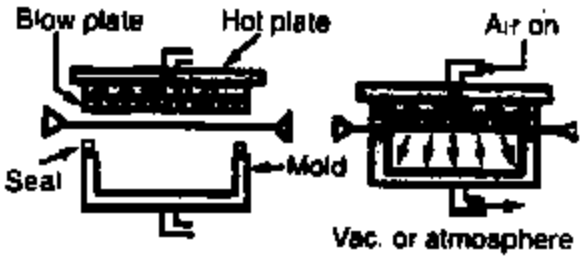
VACUUM SNAP-BACK FORMING



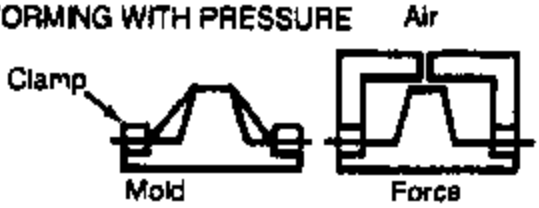
AIR-SLIP FORMING



PRESSURE FORMING - FEMALE MOLD



BLOWBACK FORMING WITH PRESSURE



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DuPont Films

DuPont Films

High Performance Films

Teflon® PFA

fluorocarbon film

Description

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

Chemical Compatibility

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

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

Electrical Reliability

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

Wide Thermal Range

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

Mechanical Toughness

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

Long Time Weatherability*

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

Reliability

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

*Type C film not recommended for outdoor use.

The convenience of Teflon® fluorocarbon in easy-to-use film facilitates the design and fabrication of this low friction thermoplastic for all sorts of high-performance jobs. It is transparent and can be *heat sealed, thermoformed, welded,* and *heat bonded.* Superior antistick properties make it an ideal release film for many applications. A *cementable* type with an invisible surface treatment is available for bonding to one or both sides with adhesives. This versatility is augmented by the superior properties of a true melt-processible fluorocarbon and by the wide choice of product dimensions available from DuPont.

Table 1
Types and Gauges of DuPont Teflon® PFA Film

Gauge	50	100	200	500	750LP	1000	2400	3000	5000	8000	12500
Thickness											
mil	½	1	2	5	7.5	10	20	30	50	80	125
in	0.0005	0.001	0.002	0.005	0.0075	0.010	0.020	0.030	0.050	0.080	0.125
µm	12.5	25	50	125	187	250	500	750	1250	2000	3175
Approximate Area Factor											
ft²/lb	180	90	45	18	13.5	9	4.5	3	1.8	1	0.7
in²/lb	25,000	12,500	6,450	2,580	1,935	1,290	645	430	215	138	98
m²/kg	36	18	9	4	3	2	1	0.6	0.3	0.2	0.14
Type LP—General-Purpose	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available
Type CLP—One Side Cementable	—	Available	Available	Available	—	—	—	—	—	—	—

Films are available in the following widths: 50–500 gauge, ½ in to 60 in available; 750–12500 gauge, ½ in to 48 in available. See current price list for widths by specific gauge and type.

Table 2
Summary of Properties of Teflon® PFA Film

	Property	Test Method	Typical Value*	
			SI Units	English Units
Mechanical	Tensile Strength at Break	ASTM D-882	21 N/mm²	3000 psi
	Elongation at Break	ASTM D-882	300%	
	Yield Point	ASTM D-882	12 MPa	1700 psi
	Elastic Modulus	ASTM D-882	480 MPa	70,000 psi
	Impact Resistance	DuPont pneumatic impact tester	6.2×10^4	14 in-lb/mil
	Folding Endurance (MIT)	ASTM D-2176	100,000 cycles	
	Tear Strength—Initial (Graves)	ASTM D-1004	4.90 N	500 g
	Tear Strength—Propagating (Elmendorf)	ASTM D-1922	0.74 N	75 g
Thermal	Melt Point	ASTM D-3418 (DTA)	302–310°C	575–590°F
	Thermal Conductivity	Cenco-Fitch	0.195 W/(m·K)	1.35 Btu-in/(h-ft²-°F)
	Specific Heat	—	1172 J/(kg·K)	0.28 Btu/(lb·°F)
	Dimensional Stability	30 min at 150°C (302°F)	MD = 1% shrinkage TD = 1% shrinkage	
	Oxygen Index	ASTM D-2863	95%	
Electrical	Dielectric Strength, short-time, in air at 23°C (73°F), 6.35 mm (¼ in) diameter electrode, 0.79 mm (1/32 in) radius, 60 Hz, 500 V/s rate of rise: 0.025 mm (1 mil) film	ASTM D-149 Method A	260 kV/mm	6500 V/mil
	Dielectric Constant, 25°C (77°F), 100 Hz to 1 MHz	ASTM D-150	2.0	
	Dissipation Factor, 25°C (77°F), 100 Hz to 1 MHz	ASTM D-150	0.0002–0.0007	
	Volume Resistivity, –40 to 240°C (–40 to 464°F)	ASTM D-257	$>1 \times 10^{17}$ ohm-cm	
Chemical	Moisture Absorption	—	<0.02%	
	Permeability, Gas:	ASTM D-1434	cm³/(m²-24 h-atm)**	
	Carbon Dioxide		14×10^3	
	Nitrogen		2.0×10^3	
	Oxygen		6.7×10^3	
	Permeability, Vapors:	ASTM E-96	g/(m²-d)	g/(100 in²-24 h)
	Water		2	0.13
	Teflon® is chemically inert and solvent resistant to virtually all chemicals, except molten alkali metals, gaseous fluorine, and certain complex halogenated compounds, such as chlorine trifluoride at elevated temperatures and pressures.			
Misc.	Density	ASTM D-1505	2150 kg/m³	134 lb/ft³
	Coefficient of Friction Kinetic (Film-to-Steel)	ASTM D-1894	0.1–0.3	
	Refractive Index	ASTM D-542	1.350	
	Solar Transmission	ASTM E-424	96%	

*For 0.050-mm (2-mil) film at 25°C (77°F), unless otherwise specified

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

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DUPONT

TI-NHTSA 018376

DuPont Films

Summary of Properties

DuPont High Performance Films

Kapton® polyimide film

TI-NHTSA 018377

Table of Contents

General Information

Kapton® polyimide film possesses a unique combination of properties which 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].

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	0.27	0.35	0.55	ASTM D-1922-89
Tear Strength—Initial (Graves), N	7.2	16.0	28.0	46.6	ASTM D-1004-90
Folding Endurance (MIT), 10³ cycles	285	55	8	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)	0.83	0.03	0.03	0.03	IPC TM 650 Method 2.2.4A
Limiting Oxygen Index, %	37	43	46	48	ASTM D-2863-87

Table 4
Physical Properties of Kapton® Type FN Film*

Property	Typical Value for Film Type** 120FN616	150FN019	200FN020
Ultimate Tensile Strength, MPa (psi)			
23°C (73°F)	207 (30,000)	165 (23,800)	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)	51 (8,000)	48 (7,000)	55 (8,000)
200°C (392°F)	42 (6,000)	43 (6,000)	35 (5,000)
Stress at 5% Elongation, MPa (psi)			
23°C (73°F)	79 (11,500)	66 (9,600)	76 (11,000)
200°C (392°F)	53 (8,000)	41 (6,000)	46 (7,000)
Ultimate Elongation, %			
23°C (73°F)	75	70	65
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·m (ft-lb)	78 (0.58)	68.6 (0.51)	156.8 (1.16)
Tear Strength—Propagating (Elmendorf), N	0.28 (0.02)	0.47 (0.03)	0.67 (0.05)
Tear Strength—Initial (Graves), N	11.2 (2.5)	11.2 (2.5)	11.2 (2.5)
Polymer Type	BPDA	PMDA	PMDA
FEP, wt %	20	13	27
Density, g/cc or g/mL	1.53	1.67	1.57

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

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

Mechanical Properties

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

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

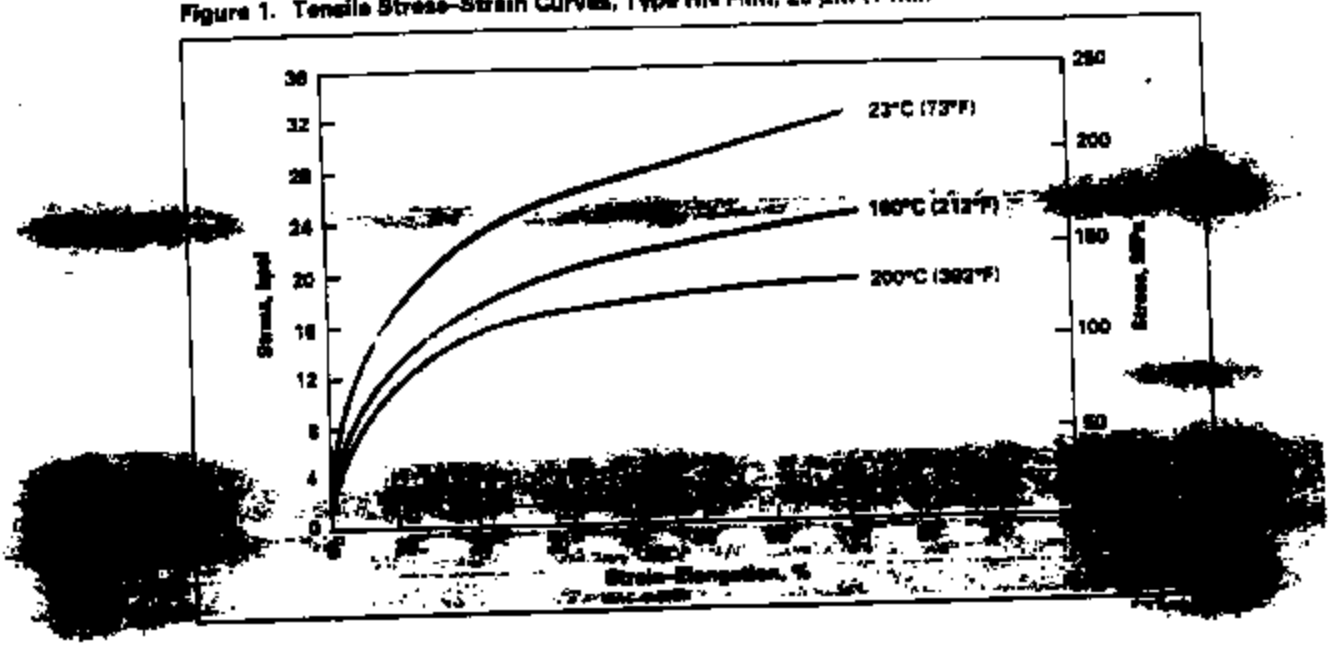
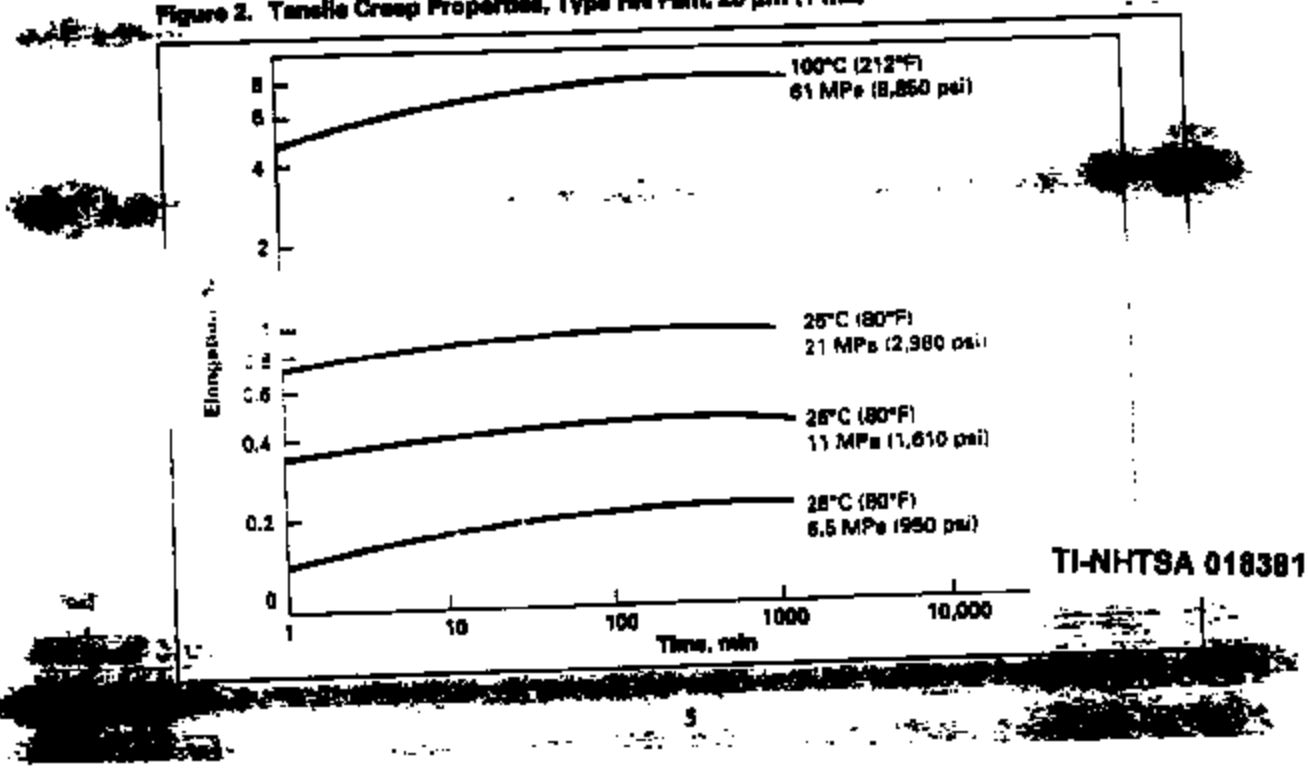


Figure 2. Tensile Creep Properties, Type HN Film, 25 μm (1 mil)



Hydrolytic Stability

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

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

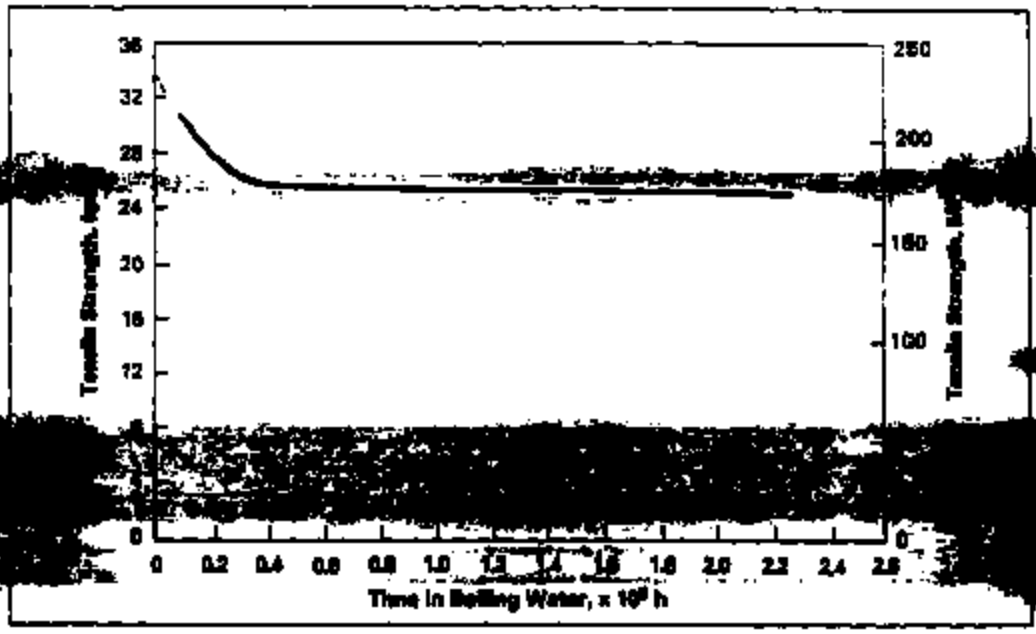
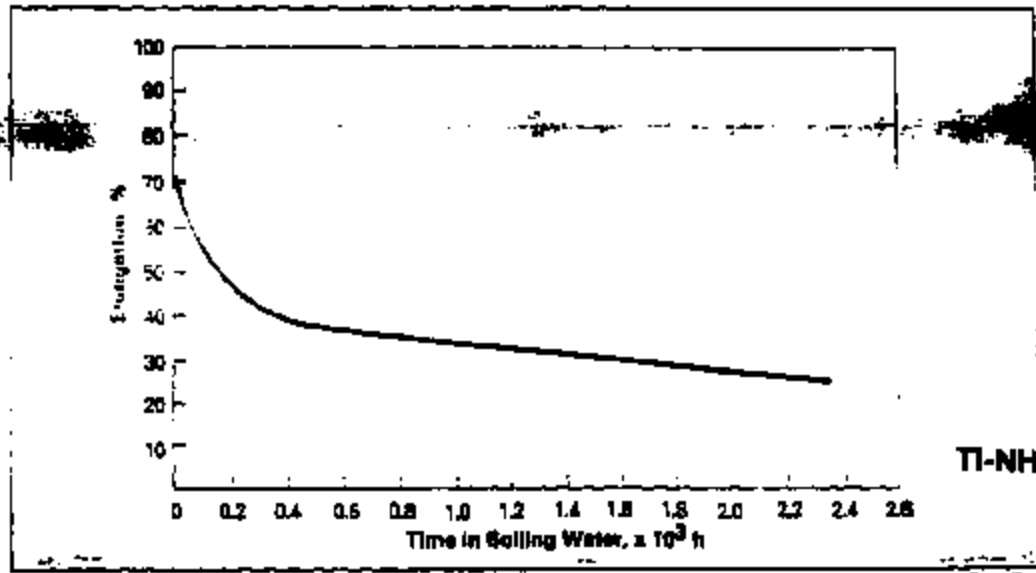


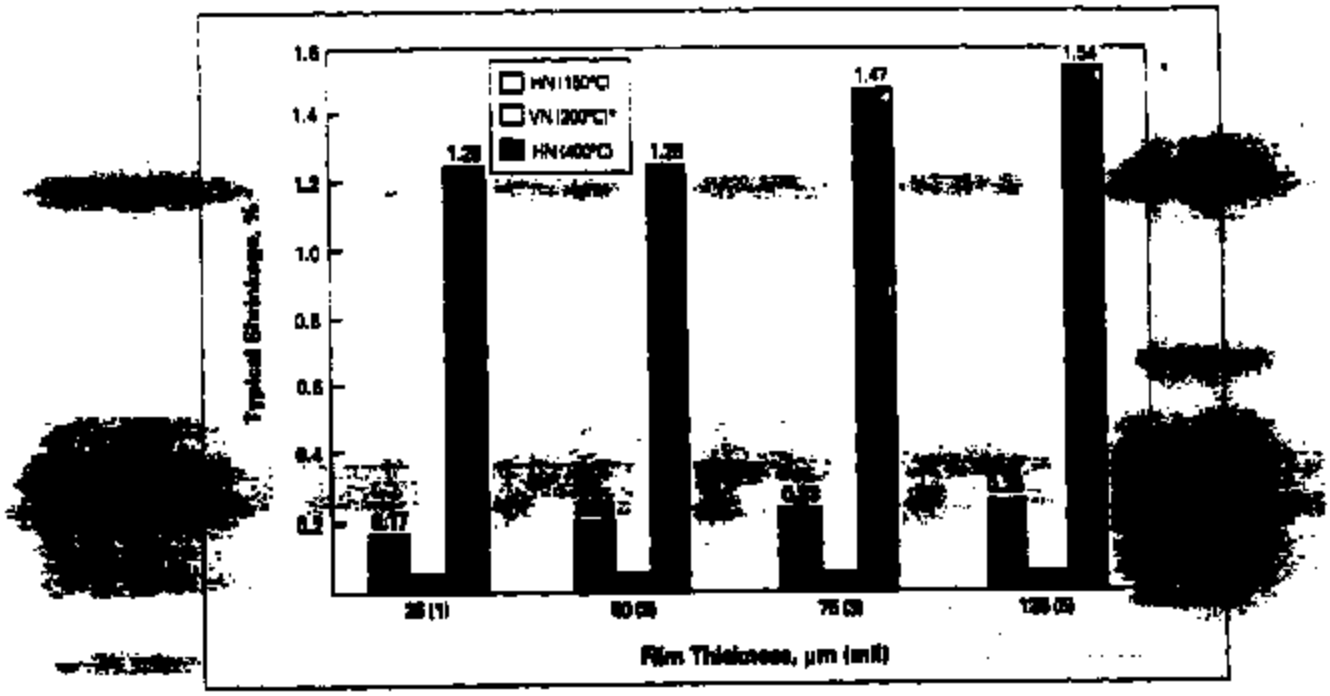
Figure 4. Ultimate Elongation After Exposure to 100°C (212°F) Water, Type HN Film, 25 µm (1 mil)



Dimensional Stability

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

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



*Type VN shrinkage is 0.09% for all thicknesses.

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

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

Thermal Aging

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

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

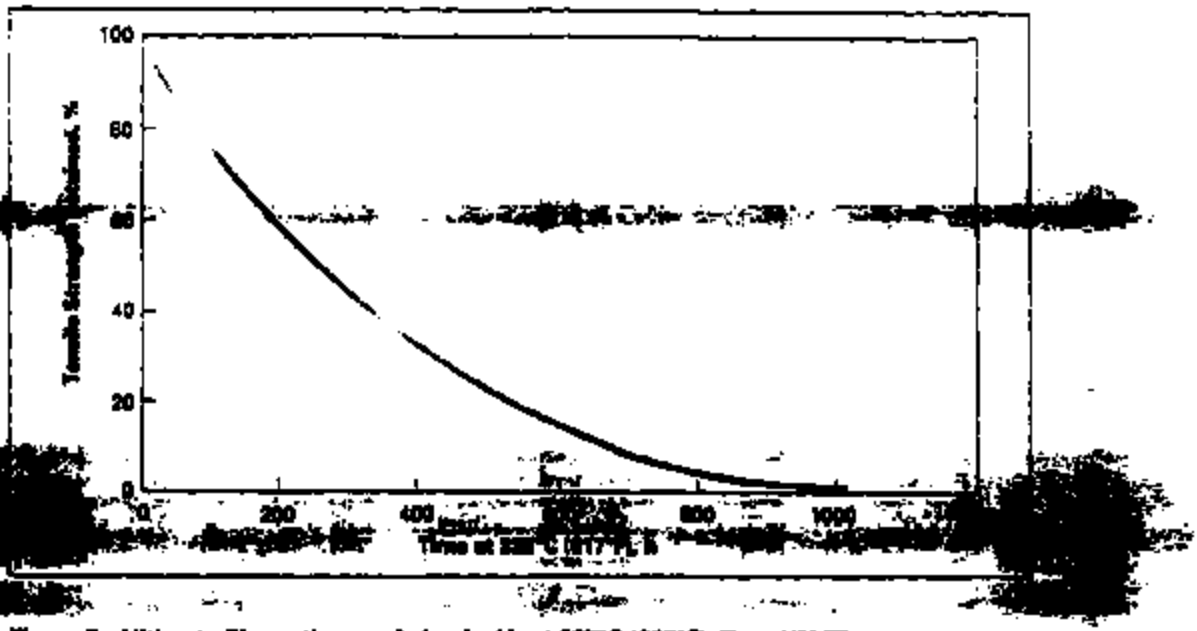


Figure 7. Ultimate Elongation vs. Aging in Air at 325°C (617°F), Type HN Film, 25 µm (1 mil)

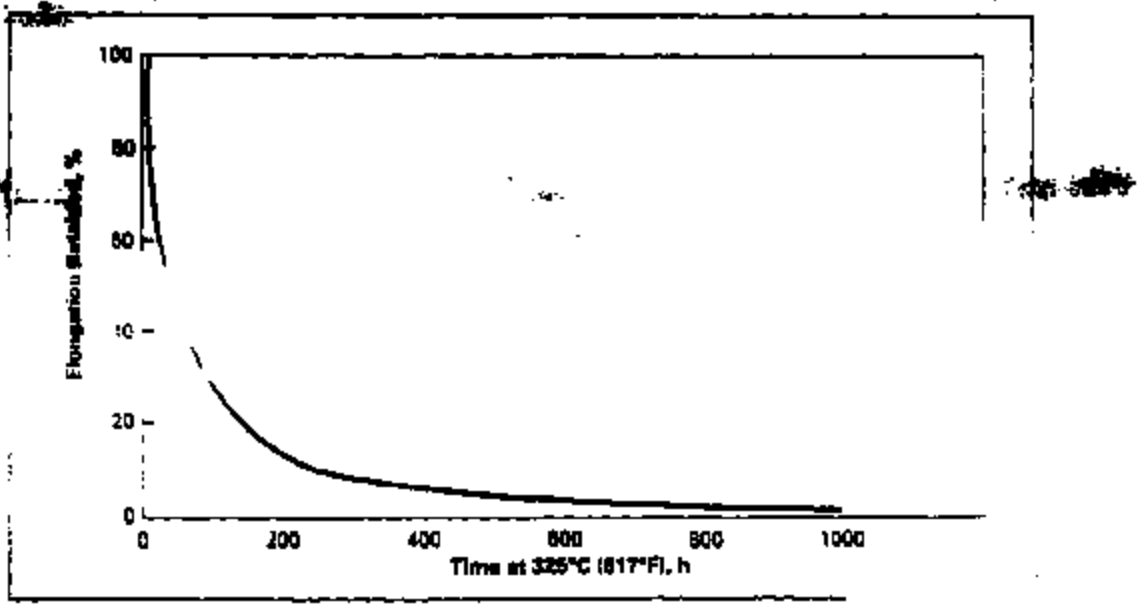
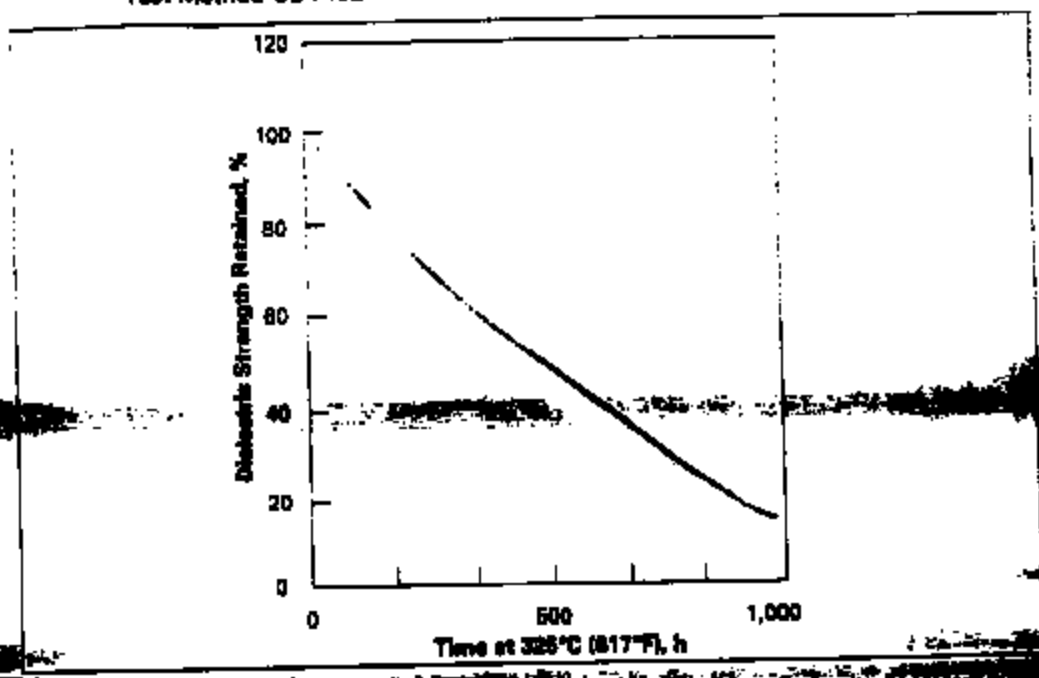


Figure 8. Retained Dielectric Strength at 325°C (617°F) for 25 µm (1 mil) Film, Test Method UL-746B



The life of Kapton® polyimide film at high temperature is significantly extended in a non-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 analysis 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)*

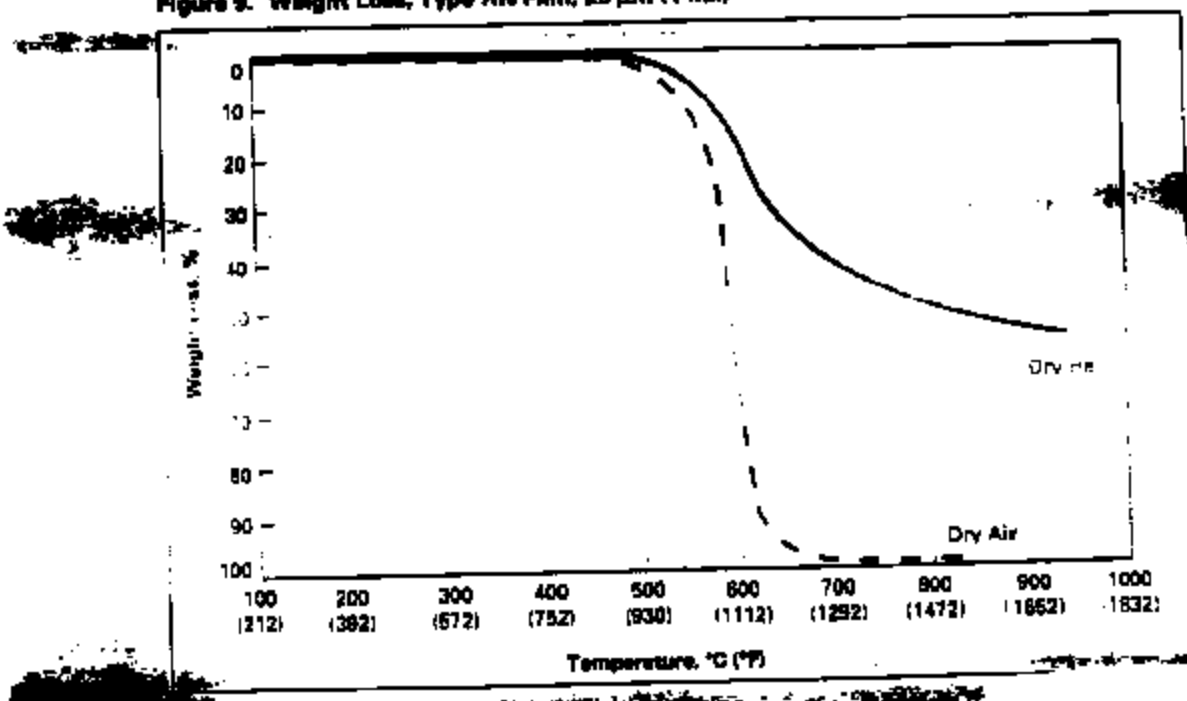
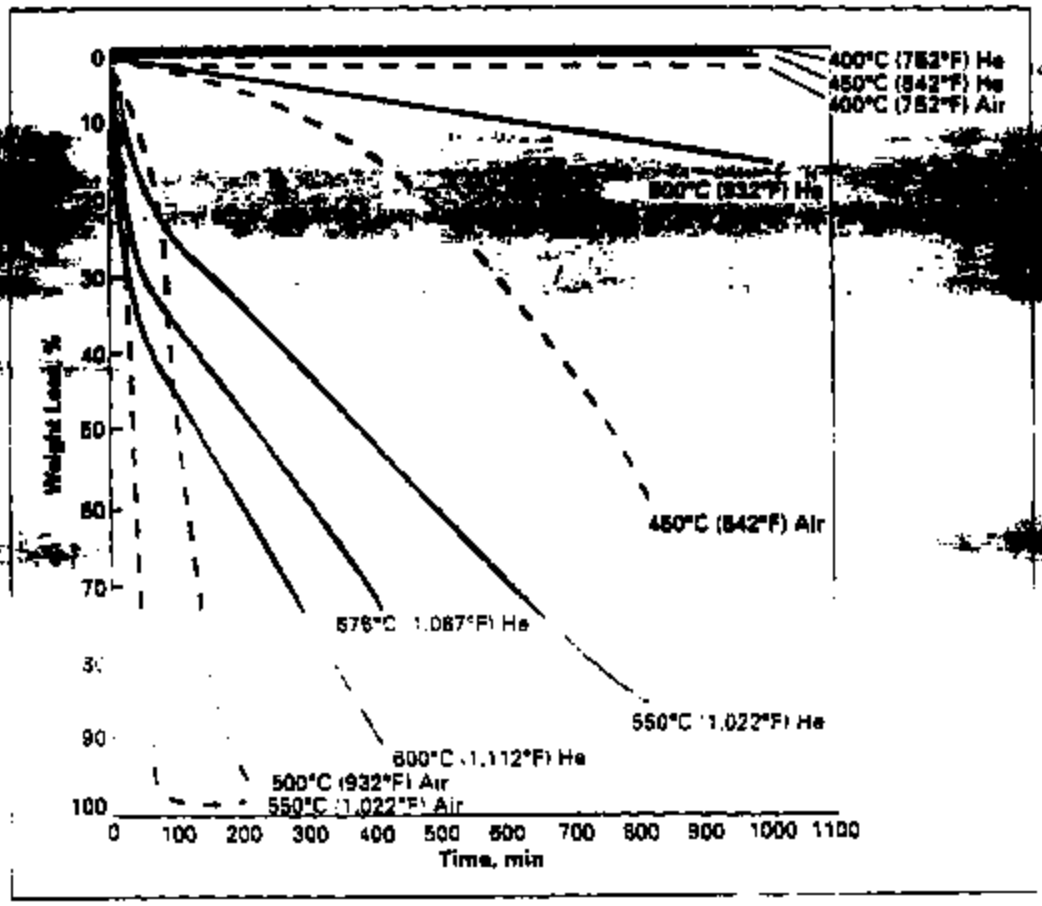


Table 6
Time Required for Reduction in Ultimate Elongation from 70% to 1%
Type HN Film, 25 µm (1 mil)

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
[illegible]	[illegible]

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



Electrical Properties

The most common electrical properties of Kapton® polyimide film of various gauges are shows 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® Types 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-149-81[1]
25 µm (1 mil)	303	(7,700)	1/4" electrodes	
50 µm (2 mil)	240	(6,100)	500 V/sec rise	
75 µm (3 mil)	205	(5,200)		
125 µm (5 mil)	164	(4,160)		
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)	0.0029			
125 µm (5 mil)	0.0026			
Volume Resistivity	[illegible]		[illegible]	[illegible]
25 µm (1 mil)	1.8 × 10[illegible]			
50 µm (2 mil)	1.5 × 10[illegible]			
75 µm (3 mil)	1.4 × 10[illegible]			
125 µm (5 mil)	1.5 × 10[illegible]			

Table 8
Typical Electrical Properties of Kapton® Type FN Film

Property	120FN615	160FN019	200FN029
Dielectric Strength, V/µm (V/mil)	272 (6,900)	197 (5,000)	197 (5,000)
Dielectric Constant	3.1	2.7	3.0
Dissipation Factor	0.0018	0.0013	0.0013
Volume Resistivity, Ω-cm			
at 23°C (73°F)	1.4 × 10[illegible]	2.3 × 10[illegible]	1.9 × 10[illegible]
at [illegible]°C (392°F)	4.4 × 10[illegible]	3.6 × 10[illegible]	3.[illegible] × 10[illegible]

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	329	8500	3.0	0.0015
20	315	8000	3.3	0.0017
50	303	7700	3.8	0.0030
80	280	7100	4.7*	0.0027*
100	248	6300	3.6	0.0025

*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 absorption possible regardless of the driving force.

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

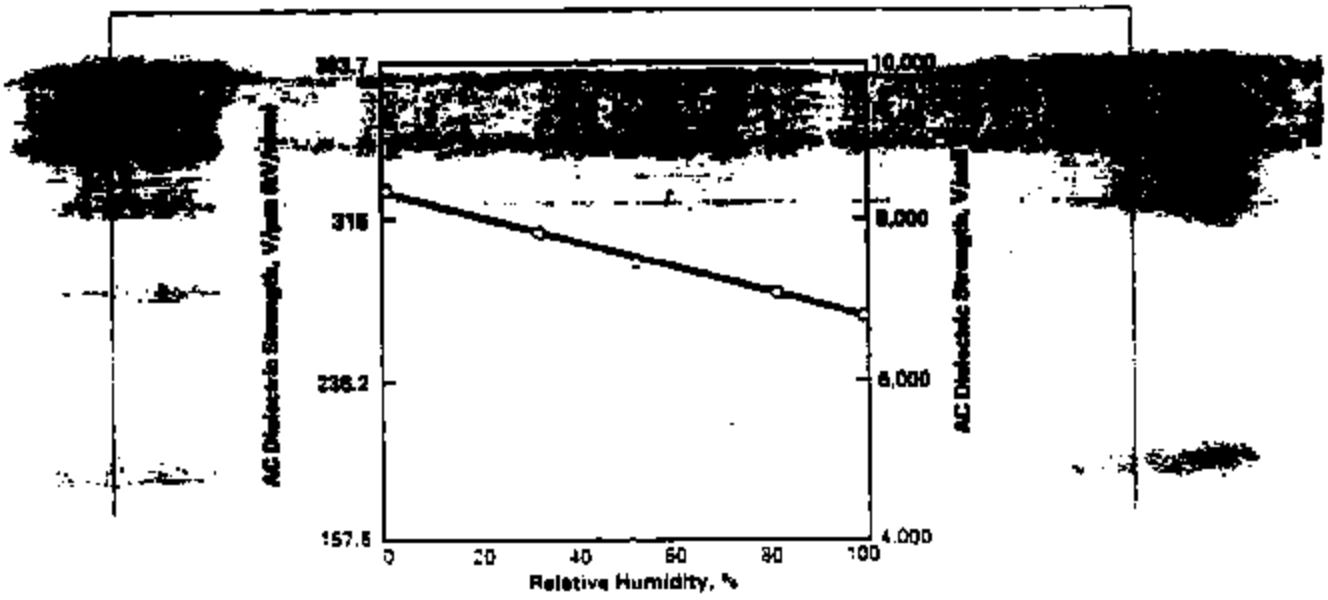


Figure 12. Dissipation Factor vs. Relative Humidity, Type HN Film, 25 µm (1 mil)

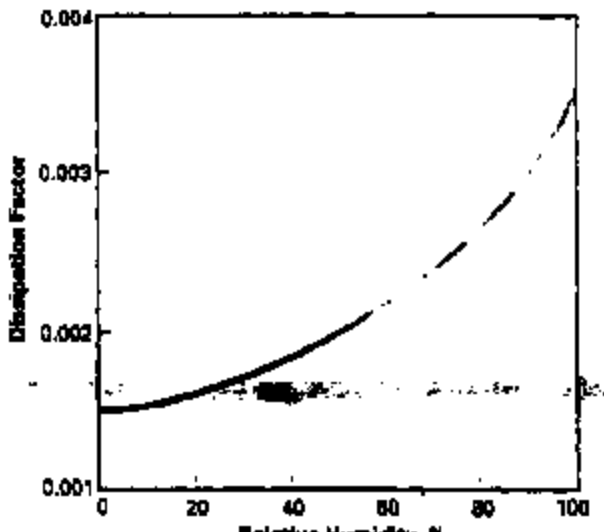
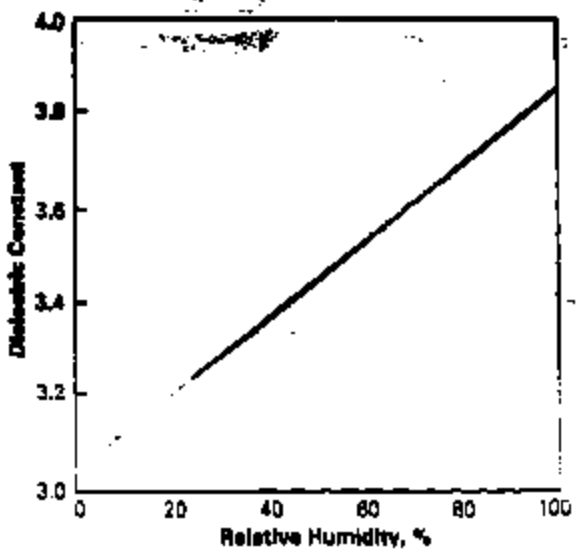


Figure 13. Dielectric Constant vs. Relative Humidity, Type HN Film, 25 µm (1 mil)



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)

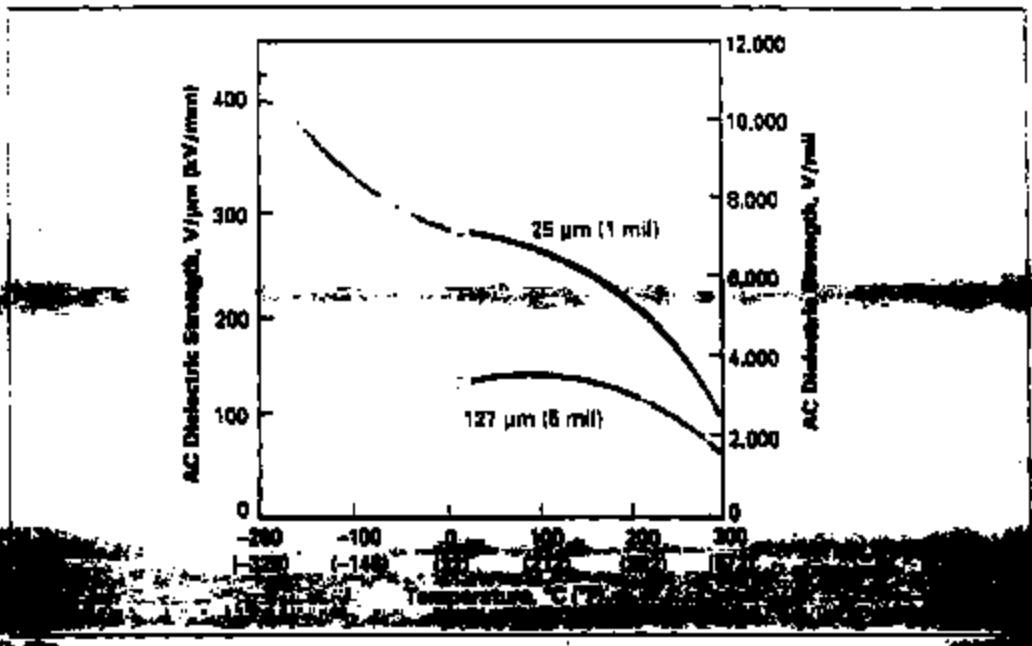


Figure 15. Dielectric Constant vs. Temperature, Type HN Film, 25 µm (1 mil)

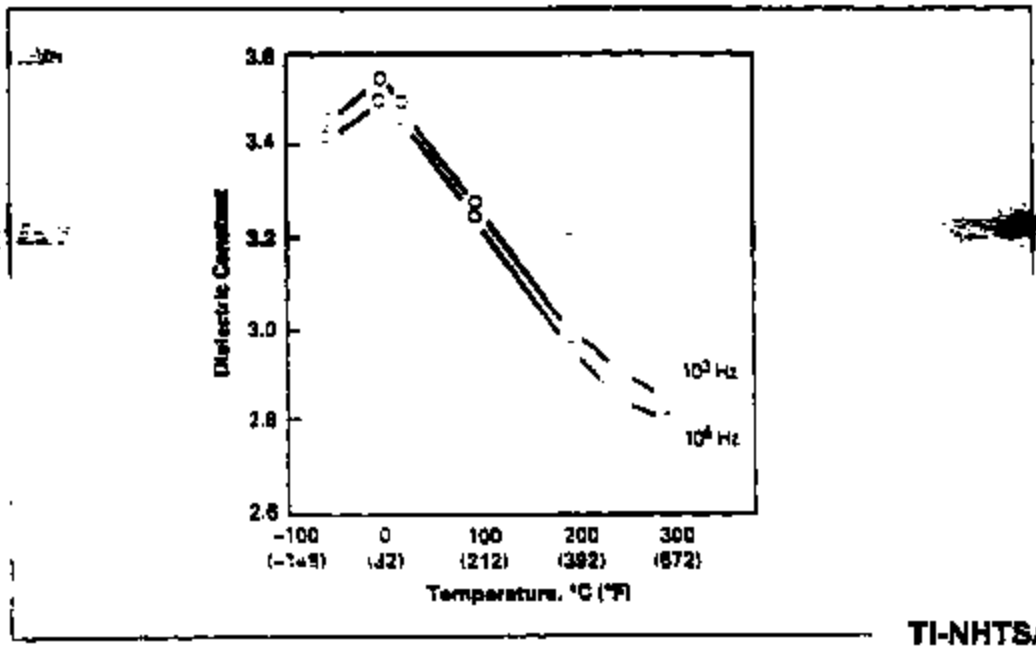


Figure 16. Dissipation Factor vs. Temperature, Type HN Film, 25 µm (1 mil)

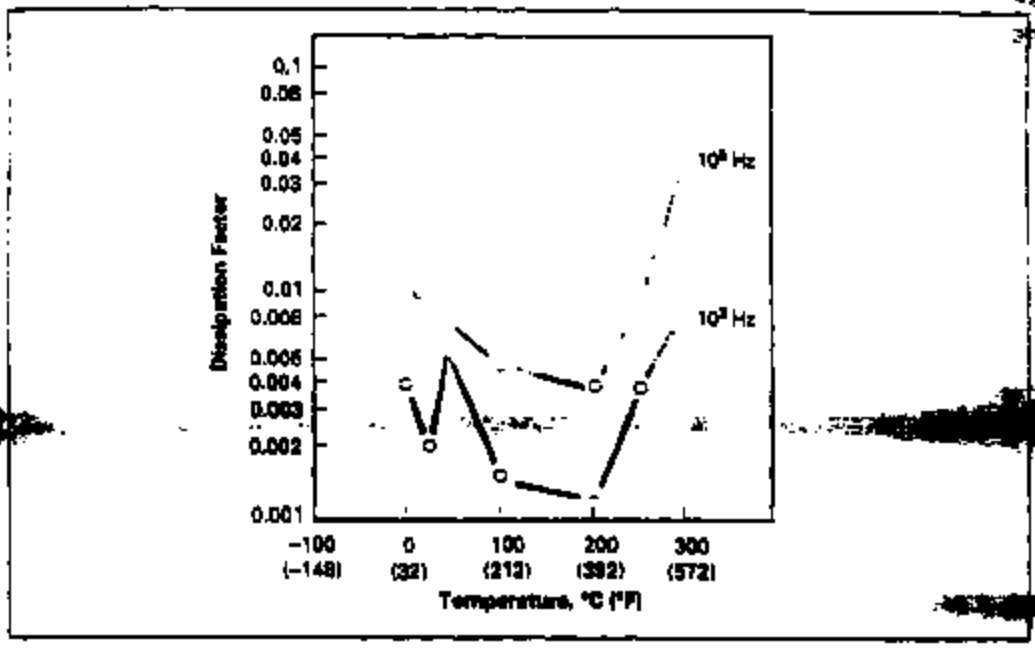
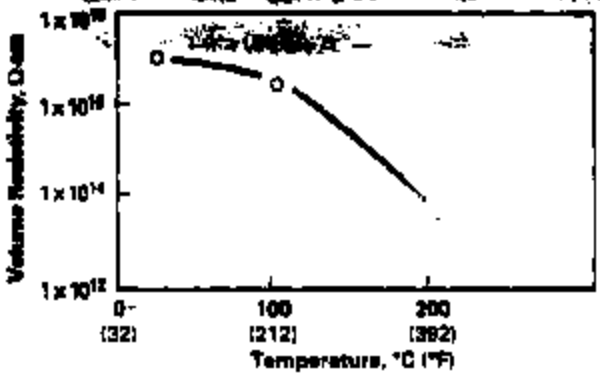


Figure 17. Volume Resistivity vs. Temperature, Type HN Film, 25 µm (1 mil)



Effect of Frequency

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

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

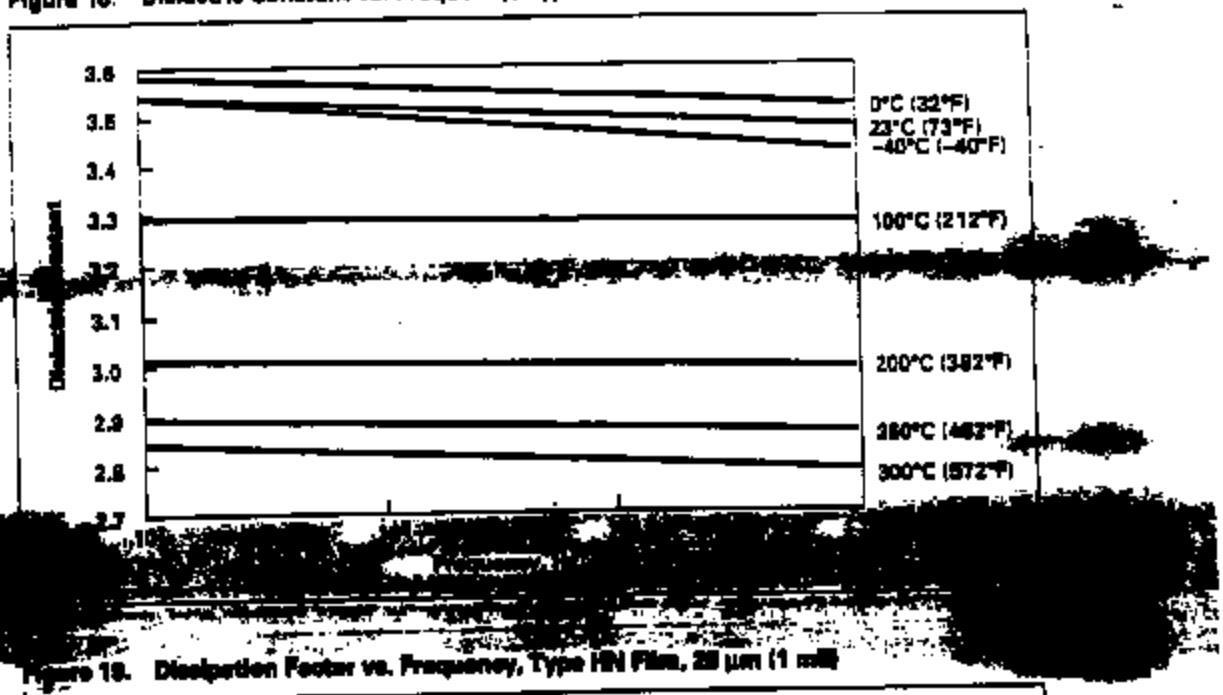


Figure 19. Dissipation Factor vs. Frequency, Type HN Film, 25 µm (1 mil)

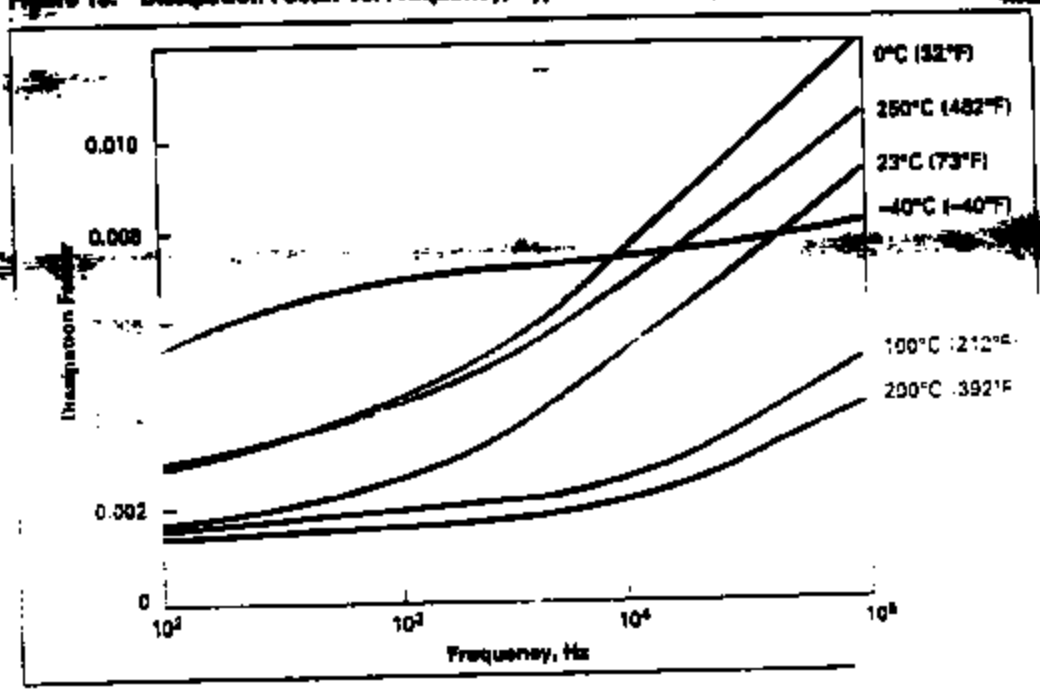


Figure 20. Dielectric Constant vs. Frequency, Type HN Film, 125 µm (5 mil)*

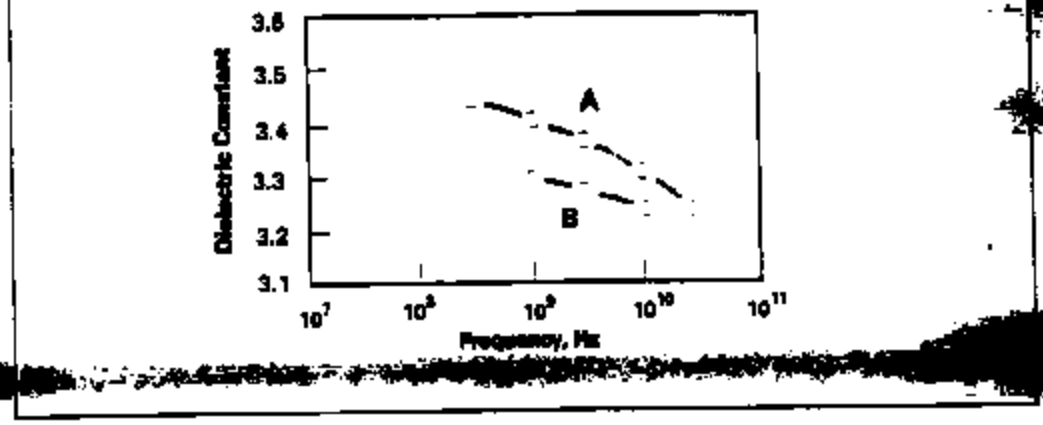
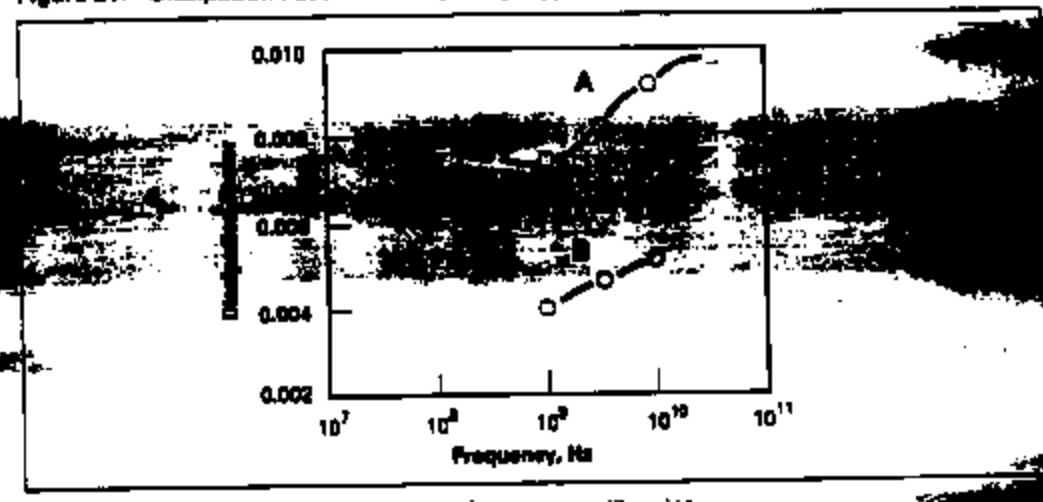


Figure 21. Dissipation Factor vs. Frequency, Type HN Film, 125 µm (5 mil)*



*Technical Report AFML-TR-72-39—Curve A is 500H Kapton® as received and measured at 23°C (73°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 hours. Performance of 500HN is believed to be equivalent to 500H.

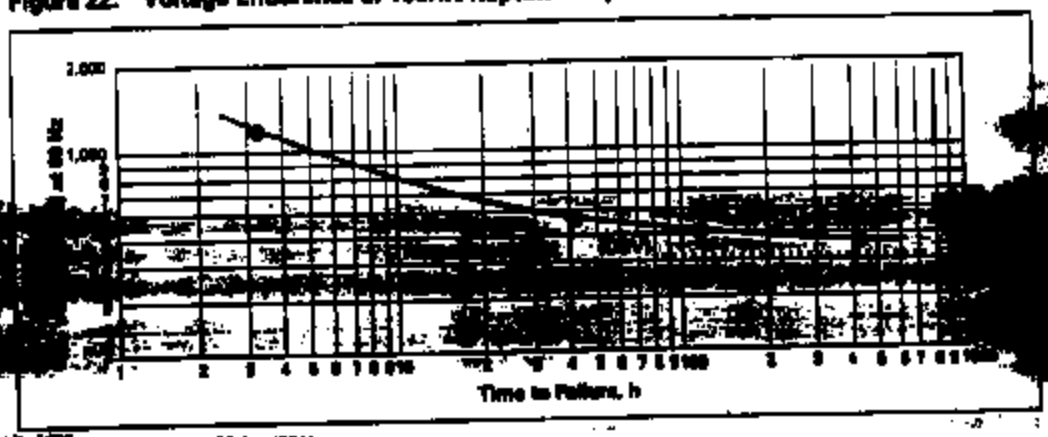
Corona Life

Like all organic materials, Kapton® is attacked by a corona discharge, and when exposed continuously to it will ultimately fail dielectrically. At moderate levels of corona exposure, devices insulated with Kapton® have survived up to 3,000 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) = 428 V

Chemical Properties

Typical chemical properties of Kapton[a] Types HN and FN films are given in Tables 10 and 11.

The chemical properties of Type VN film [illegible] similar to those of Type HN.

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

Property	Typical Value: Tensile Retained, %	Typical Value: Elongation Retained, %	Test Condition	Test Method
Chemical Resistance			10 min at 23°C	IPC TM-650 Method 2.3.2B
Isopropyl Alcohol	96	94		
Toluene	99	91		
Methyl Ethyl Ketone	[illegible]	90		
Methylene Chloride/ Trichloroethylene (1:1)	[illegible]	[illegible]		
2 N Hydrochloric Acid	[illegible]	[illegible]		
2 N Sodium Hydroxide	82	84		
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 [illegible]	22 ppm/% [illegible]		23°C (73°F), 20-80% RH	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Carbon Dioxide	[illegible]	[illegible]		
Oxygen	[illegible]	[illegible]		
Hydrogen	[illegible]	[illegible]		
Nitrogen	[illegible]	[illegible]		
Helium	[illegible]	415		ASTM E-96-92
Vapor	g/(m²·24 h)	g/(100 in²·24 h)		
Water	54	3.5		

Table 11
Chemical Properties of Kapton[a] Type FN Films

Property	120FN616	150FN019	[illegible]
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	[illegible]	[illegible]
g/(100 in²·24 h)	1.13	[illegible]	[illegible]

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Radiation Resistance

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

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

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

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

Tensile Modulus, MPa (psi x 10³)	3172 (460)	3278 (475)	3378 (490)	3278 (475)	2903 (421)
Volume Resistivity Ω-cm x 10¹⁶ at 200°C (392°F)	4.8	6.8	5.2	1.7	1.6
Dielectric Constant 1 kHz at 23°C (73°F)	3.46	3.84	3.69	3.71	3.80
Dissipation Factor 1 kHz at 23°C (73°F)	0.0020	0.0029	0.0024	0.0027	0.0028
Dielectric Strength V/μm (kV/mm)					

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

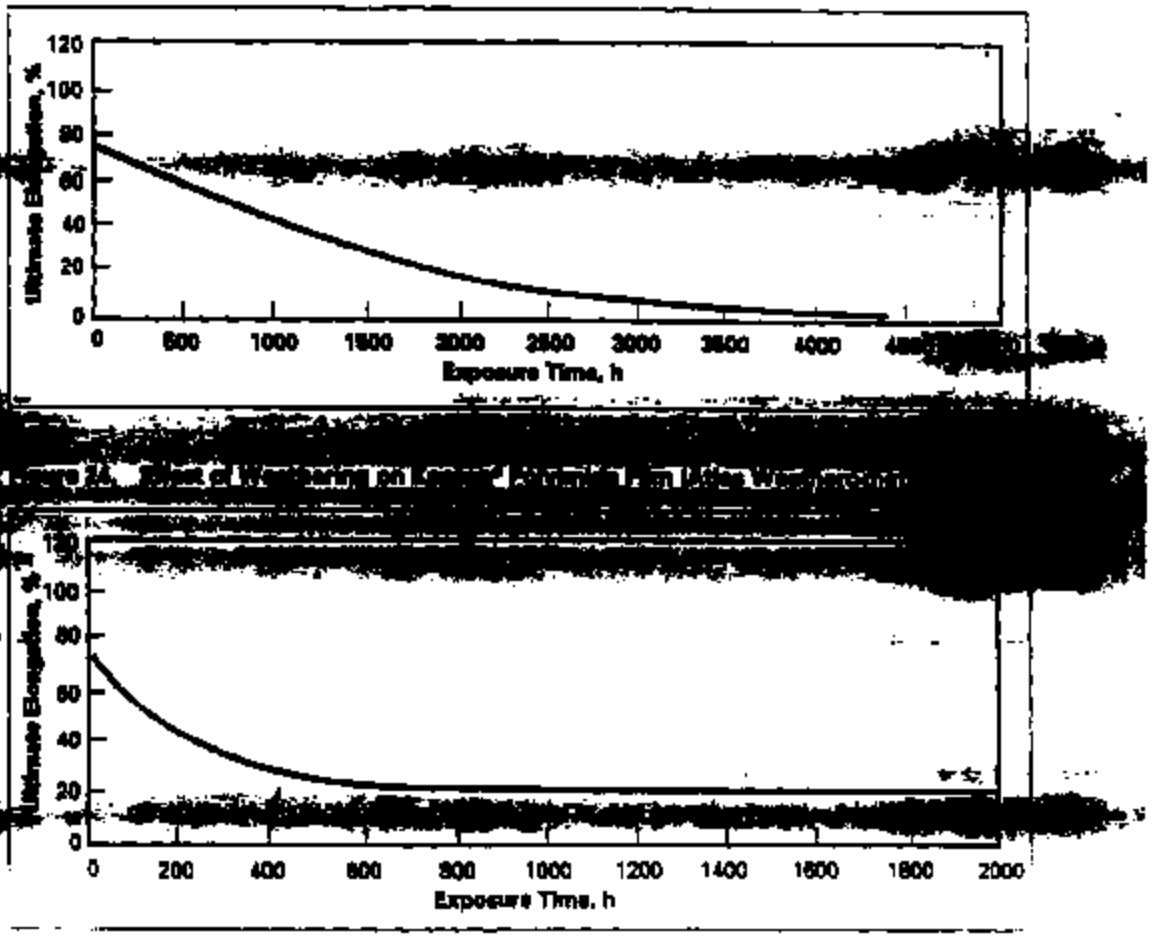
	5 x 10⁷ Gy	10⁸ Gy
5 x 10¹⁵ neutrons/cm² Flux at 175°C (347°F)	Film Darkened	Film Darkened and Tough

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

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

*Vacuum environment, 5 x 10^{-6} mm Hg at 50°C (122°F). UV intensity equal to space sunlight to 2800Å.

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



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
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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	18	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	9.2	45

Nomenclature/Construction, Type FN

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

Table 16
Type FN Film Constructions

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

Safety and Handling

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

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

Kapton® film can be used safely at elevated temperatures with proper ventilation. At elevated temperatures, Kapton® can release small amounts of *N,N*-dimethylacetamide residual solvent. Adequate ventilation in accordance with OSHA (29 CFR 1910.1000) will provide safe handling and use.

For additional information, users should refer to the following bulletins: Kapton® Polyimide Film—Safe Handling, E-72084 and Kapton® Polyimide Film—Products of Decomposition, H-16512.

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DuPont High Performance Films

Information Bulletin

DuPont Films

High Performance Films

Teflon® FEP

fluorocarbon film

Teflon® as Film

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

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

Teflon® Is Unique Among Plastics

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

Teflon® FEP Film Is Offered

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

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

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

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

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

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

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

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

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

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

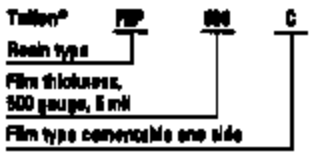
For additional information, call (800) 237-4357.

Types and Gauges

Table 1
Types and Gauges of DuPont Teflon® FEP Fluorocarbon Film

Gauge	50	100	200	300	500	750	1000	1500	2000	3000	4000	6000	12500	19000
Thickness, mil	0.5	1	2	3	5	7.5	10	15	20	30	60	90	125	190
Thickness, µm	12.5	25	50	75	125	190	250	375	500	750	1500	2300	3125	4750
Approximate area factor, ft²/lb	180	90	45	30	18	12	9	6.0	4.5	3	1.5	1	0.72	0.47
Approximate area factor, m²/kg	36	18	9	6	4	2.5	2	1.2	1	0.6	0.3	0.2	0.14	0.09
Availability														
Type A—FEP, general-purpose	X	X	X	X	X	X	X	—	X	—	—	—	—	—
Type C—FEP, one side cementable	X	X	X	X	X	—	—	—	—	—	—	—	—	—
Type C-35—FEP, both sides cementable	X	X	X	—	X	—	—	—	—	—	—	—	—	—
Type L—FEP, high stress crack resistance in extreme environments	—	—	—	—	X	—	X	X	X	X	X	X	X	X

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



Mechanical and Thermal Properties

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

Tensile Properties

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

Figure 1. Tensile Stress vs. Elongation of Teflon® FEP Film

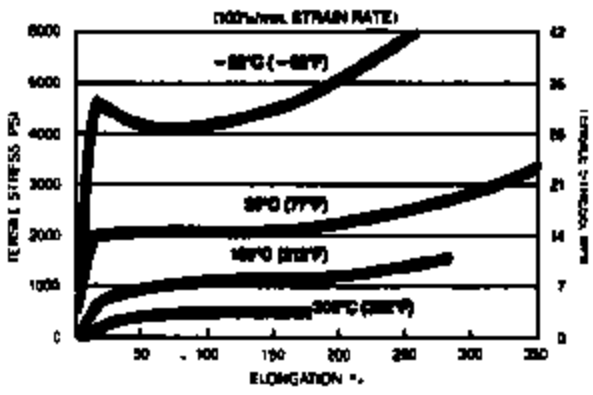
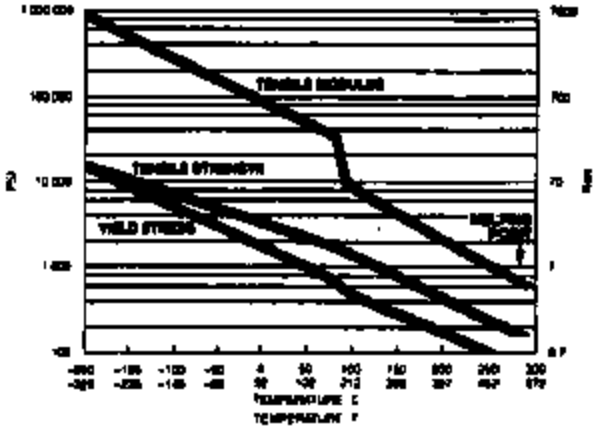


Figure 2. Tensile Properties of Teflon® FEP Film vs. Temperature



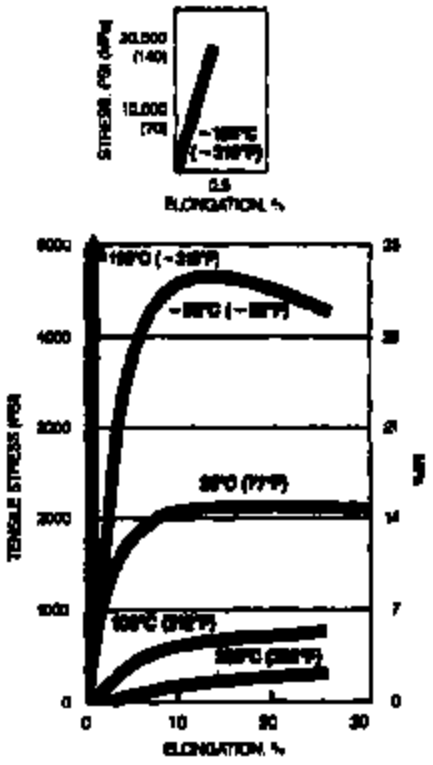
Dimensional Stability

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

Hygroscopic Expansion

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

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



Residual Shrinkage

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

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

Thermal Expansion

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

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

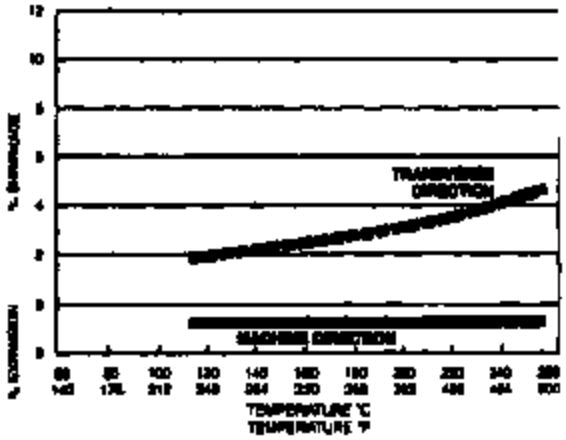


Table 2
Typical Mechanical Properties of Teflon® FEP Film*

Property	ASTM Method	SI Units	English Units
Tensile strength (at break)	D-882-81	21 MPa	3000 psi
Elongation at break	D-882-81	300%	300%
Elastic modulus	D-882-81	480 MPa	70 000 psi
Yield point	D-882-81	12 MPa	1700 psi
Stress to produce 5% strain	D-882-81	12 MPa	1700 psi
Folding endurance (MIT)	D-2176-69	10,000 cycles	10,000 cycles
Initial tear strength (Brevet)	D-1004-66	5.3 N	1.2 lbf
Propagating tear strength (Elmendorf)	D-1922-67	2.5 N	250 g
Bursting strength**	D-774-97 (Mullen)	76 kPa	11 psi
Density	D-1505-85	2160 kg/m³	134 lb/ft³
Coefficient of friction kinetic (film to steel)	D-1894-61	0.5	0.3

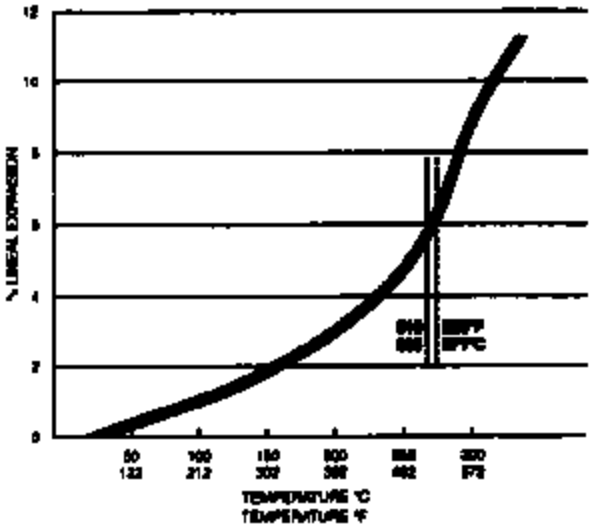
*200 gauge unless otherwise noted
**100 gauge film

Table 3
Typical Thermal Properties of Teflon® FEP Film*

Property		ASTM Method	SI Units	English Units
Melt point		D-3418 (DTA)	260–280°C	500–535°F
Maximum continuous service temperature			205°C	400°F
Zero strength** temperature		---	285°C	480°F
Specific heat			1172 J/kg·K	0.28 Btu/lb·°F
Coefficient of thermal conductivity			0.186 W/m·K	1.35 $\frac{Btu \cdot in}{h \cdot ft^2 \cdot °F}$
Coefficient of linear thermal expansion		D-696-79	$9.4 \times 10^{-5} \frac{mm}{mm \cdot °C}$	$5.4 \times 10^{-5} \frac{in}{in \cdot °F}$
Flammability classification		ANSI/UL-94	VTM-0	VTM-0
Oxygen index		D-2863-77	95%	95%
Dimensional stability	MD	30 min at 150°C (302°F)	0.7% expansion	0.7% expansion
	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

Figure 5. Thermal Expansion of Teflon® PEP Film



Electrical Properties

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

Table 4
Typical Electrical Properties of Teflon® PEP Fluorocarbon Film 25 µm (1 mil) Thickness

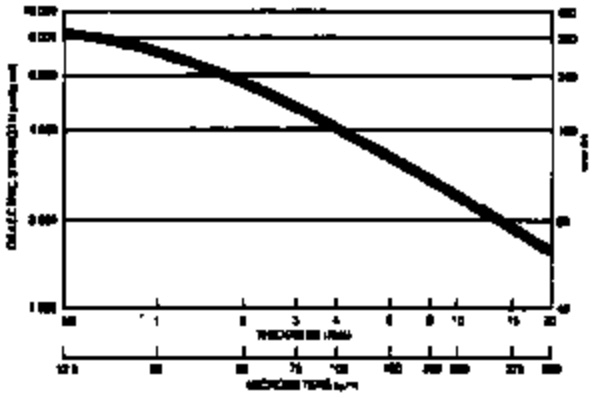
Property	ASTM Method	SI Units	English Units
Dielectric strength	D-149A-81 (6.4 mm (0.25 in) electrode in air, 60 Hz)	280 kV/mm	6500 V/mil
Dielectric constant	D-150-81 (1 kHz)	2.0	2.0
Dissipation factor	D-150-81 (1 kHz)	0.0002	0.0002
Volume resistivity	D-257-78	1×10^{18} ohm-m	1×10^{16} ohm-cm
Surface resistivity	D-257-78	1×10^{16} ohm (per square)	1×10^{16} ohm (per square)
Surface arc resistance	D-495-78	>185 s*	>185 s*

*Samples melted in arc did not track.

Dielectric Strength

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

Figure 6. Dielectric Strength vs. Film Thickness of Teflon® FEP



Dielectric Constant

For Teflon® fluorocarbon film, dielectric constant is independent of film thickness. There is no difference between Type A and Type C films.

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

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

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

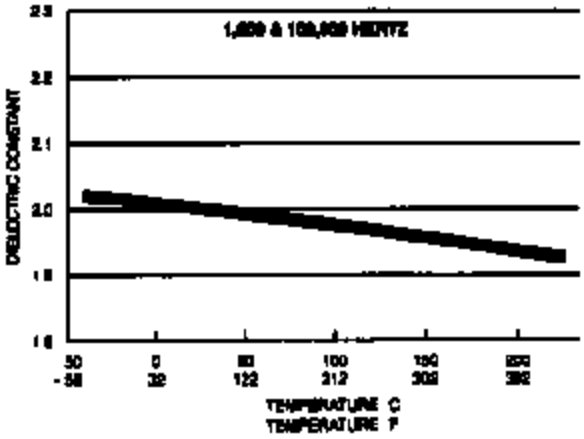
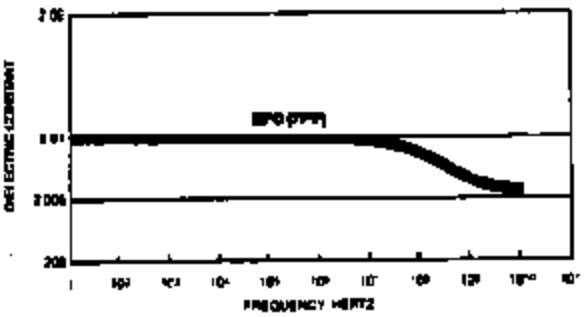


Figure 8. Dielectric Constant vs. Frequency



Dissipation Factor

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

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

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

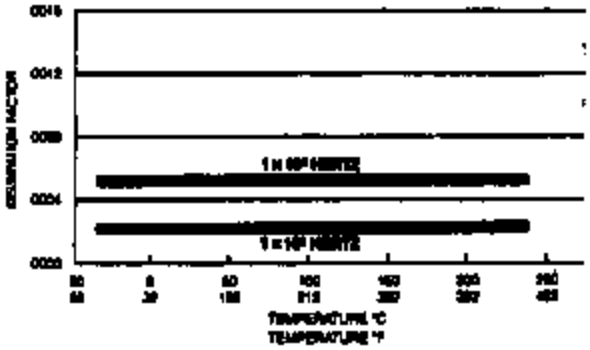
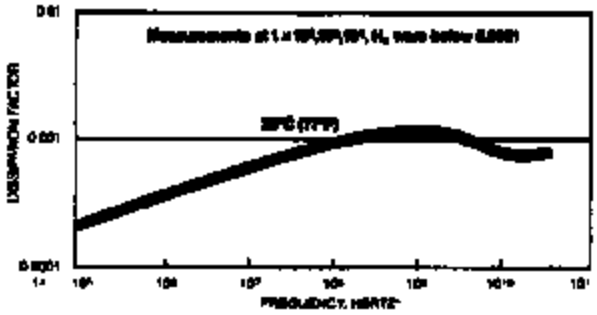


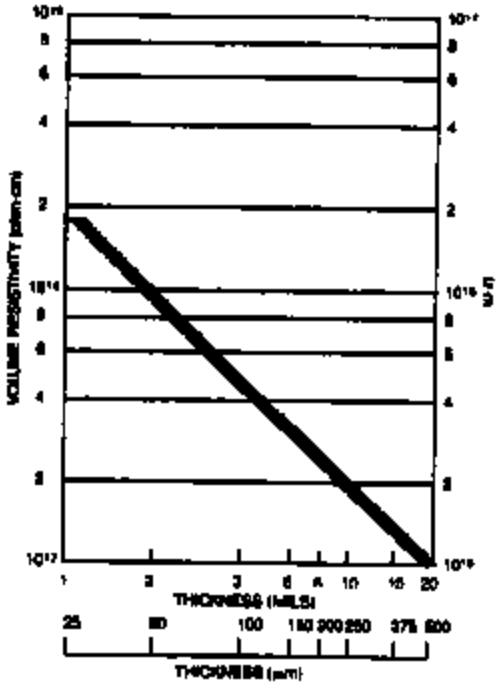
Figure 10. Dissipation Factor vs. Frequency of Teflon® FEP Film



Volume Resistivity

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

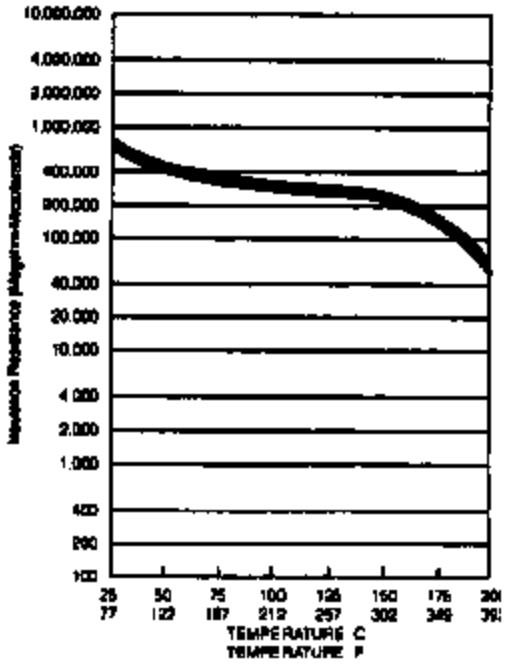
Figure 11. Volume Resistivity vs. Thickness (at 175°C (347°F))



Insulation Resistance

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

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



Chemical Properties

Teflon® 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, Teflon® 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 Teflon® FEP film has been found to be nonreactive.

Table 6
Typical Chemicals with Which Teflon® 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	Furans	Perfluoroxylene	Vinyl methacrylate
Cetane	Gasoline	Phenol	Water
Chlorine	Hexachlorethane	Phosphoric acid	Xylene
Chloroform	Hexane	Phosphorus pentachloride	Zinc chloride
Chlorosulfonic acid	Hydrazine		
Chromic acid	Hydrochloric acid		
Cyclohexane			

*Based on experiments conducted up to the boiling points of the liquids listed. Teflon® 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 Teflon® FEP film.

**Some halogenated solvents may cause moderate swelling.

Physical Properties

Absorption

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

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

Permeability

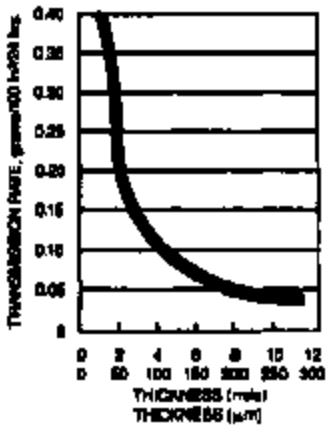
Many gases and vapors permeate Teflon® films at a much lower rate than for other thermoplastics (see **Figure 13**). In general, permeation increases with temperature, pressure, and surface contact area and decreases with increased film thickness. **Table 6** lists rates at which various gases are transmitted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

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

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

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

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



Notes: Values are averages only and not for specification purposes. To convert the permeation values for 100 in^2 to those for 1 m^2, multiply by 15.5.

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

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

Optical Properties

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

Other optical properties of Teflon® films of interest are:

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

Figure 14. Transmission Spectrum for Teflon® FEP Film

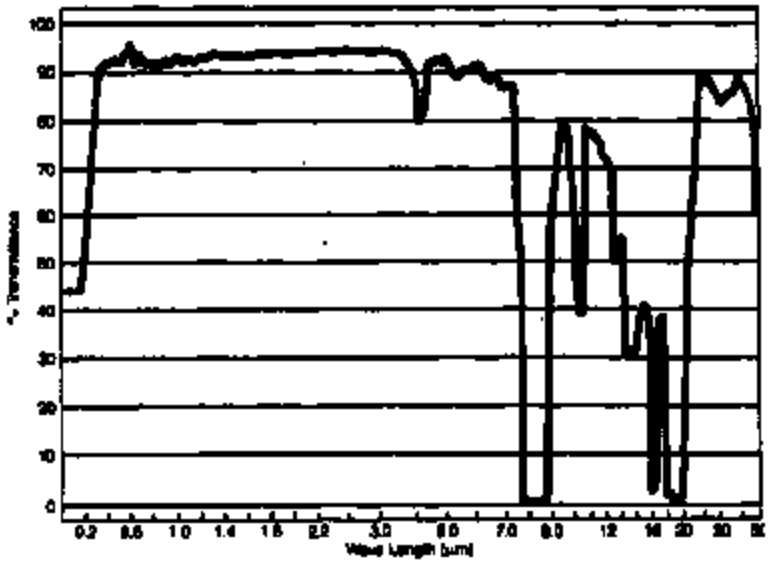


Figure 15. Transmittance at Normal Incidence of Solar Radiation through Teflon® FEP Films for Various Thicknesses

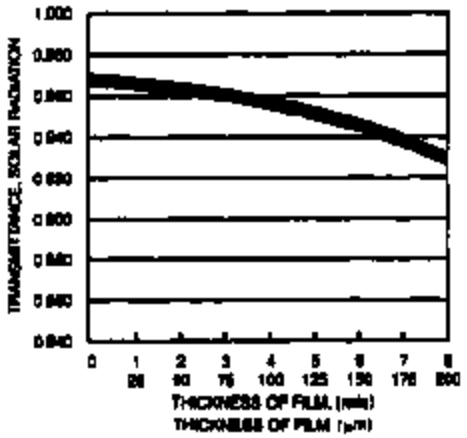
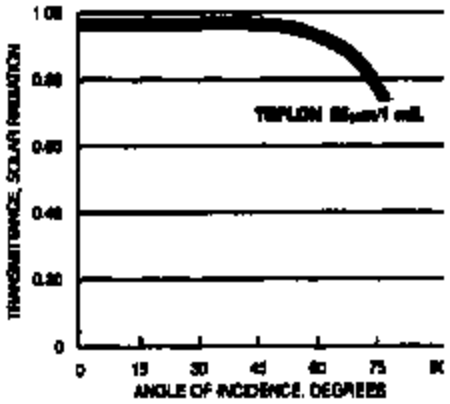


Figure 16. Transmittance of Solar Radiation through 25 μm (1 mil) Teflon® FEP Film for Various Angles of Incidence



Miscellaneous Properties

Cryogenic Service

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

FDA Compliance

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

USDA Acceptance

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

Mildew (Fungus) Resistance

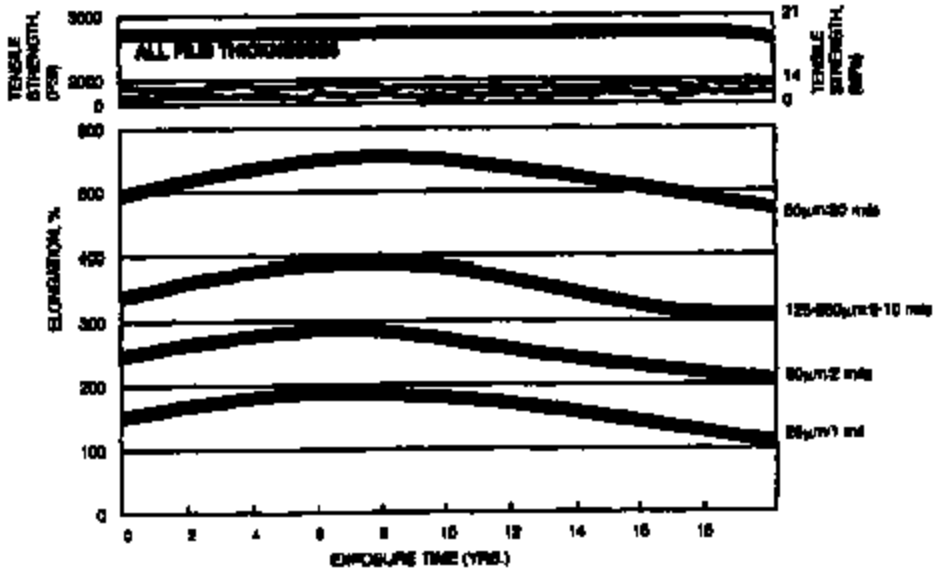
Teflon® FEP has been shown to be completely resistant to mildew growth by testing both in humidity chamber exposure inoculated with a mixed spore suspension and a soil burial test for three months.

Weatherability

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

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

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



Safety and Handling

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

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

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

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

Other related literature available from DuPont:

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

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DuPont Films

Information Bulletin

DuPont Films

High Performance Films

Teflon® FEP

fluorocarbon film

Teflon® as Film

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

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

Teflon® Is Unique Among Plastics

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

Teflon® FEP Film Is Offered

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

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

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

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

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

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

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

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

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

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

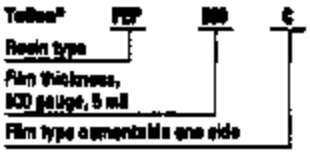
For additional information, call (800) 237-4357.

Types and Gauges

Table 1
Types and Gauges of DuPont Teflon® FEP Fluorocarbon Film

Gauge	50	100	200	300	500	750	1000	1500	2000	3000	4000	6000	12500	19000
Thickness, mil	0.5	1	2	3	5	7.5	10	15	20	30	60	90	125	190
Thickness, µm	12.5	25	50	75	125	190	250	375	500	750	1500	2300	3125	4750
Approximate area factor, ft²/lb	180	90	45	30	18	12	9	6.0	4.5	3	1.5	1	0.72	0.47
Approximate area factor, m²/kg	38	18	9	6	4	2.5	2	1.2	1	0.6	0.3	0.2	0.14	0.09
Availability														
Type A—FEP, general-purpose	X	X	X	X	X	X	X	—	X	—	—	—	—	—
Type C—FEP, one side cementable	X	X	X	X	X	—	—	—	—	—	—	—	—	—
Type C-2S—FEP, both sides cementable	X	X	X	—	X	—	—	—	—	—	—	—	—	—
Type L—FEP, high stress crack resistance in extreme environments	—	—	—	—	X	—	X	X	X	X	X	X	X	X

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



Mechanical and Thermal Properties

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

Tensile Properties

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

Figure 1. Tensile Stress vs. Elongation of Teflon® FEP Film

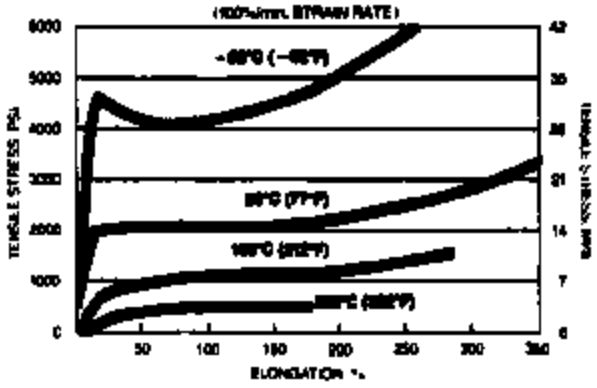
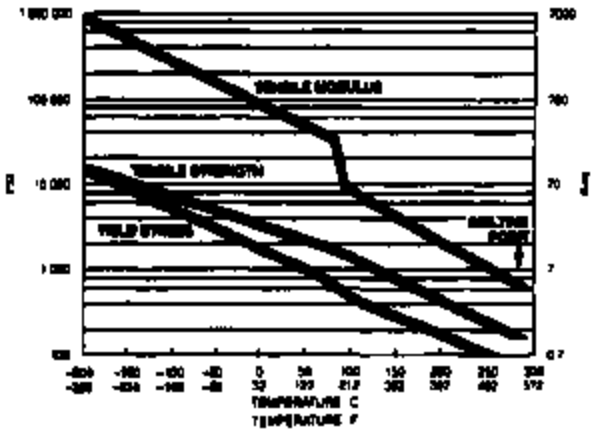


Figure 2. Tensile Properties of Teflon® FEP Film vs. Temperature



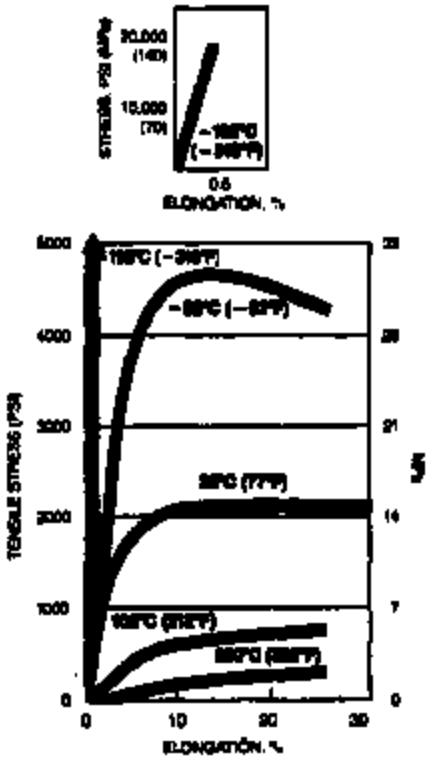
Dimensional Stability

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

Hygroscopic Expansion

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

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



Residual Shrinkage

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

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

Thermal Expansion

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

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

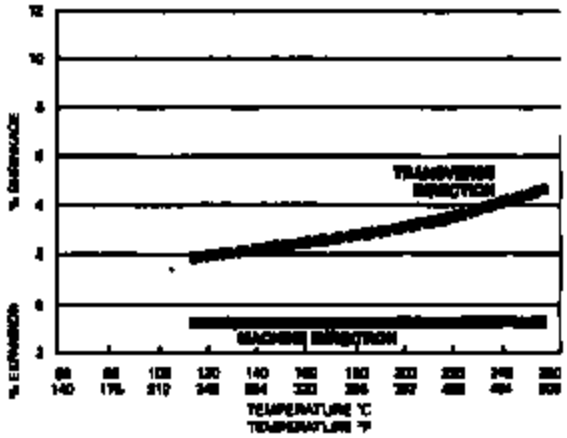


Table 2
Typical Mechanical Properties of Teflon® FEP Film*

Property	ASTM Method	SI Units	English Units
Tensile strength (at break)	D-882-81	31 MPa	3000 psi
Elongation at break	D-882-81	300%	300%
Elastic modulus	D-882-81	480 MPa	70 000 psi
Yield point	D-882-81	12 MPa	1700 psi
Stress to produce 5% strain	D-882-81	12 MPa	1700 psi
Folding endurance (MIT)	D-2176-69	10,000 cycles	10,000 cycles
Initial tear strength (Graves)	D-1004-66	8.3 N	1.2 lbf
Propagating tear strength (Elmendorf)	D-1922-67	2.5 N	250 g
Bursting strength**	D-774-97 (Mullen)	76 kPa	11 psi
Density	D-1505-68	2150 kg/m³	(34 lb/ft³
Coefficient of friction kinetic (film to steel)	D-1894-61	0.3	0.3

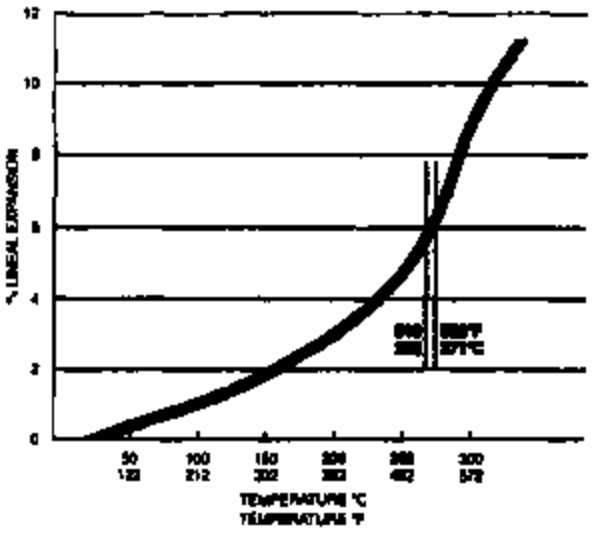
*200 gauge unless otherwise noted
**100 gauge film

Table 3
Typical Thermal Properties of Teflon® FEP Film*

Property	ASTM Method	SI Units	English Units
Melt point	D-3418 (DTA)	260-280°C	500-535°F
Maximum continuous service temperature		205°C	400°F
Zero strength** temperature	***	285°C	480°F
Specific heat		1172 J/kg·K	0.28 Btu/lb·°F
Coefficient of thermal conductivity		0.196 W/m·K	1.36 $\frac{Btu \cdot in}{h \cdot ft^2 \cdot °F}$
Coefficient of linear thermal expansion	D-696-79	$8.4 \times 10^{-5} \frac{cm}{cm \cdot °C}$	$5.4 \times 10^{-5} \frac{in}{in \cdot °F}$
Flammability classification		ANSI/UL-94	VTM-0
Oxygen index	D-2863-77	95%	95%
Dimensional stability MD	30 min at 150°C (302°F)	0.7% expansion	0.7% expansion
Dimensional stability TD	30 min at 150°C (302°F)	2.2% 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 8 sec

Figure 5. Thermal Expansion of Teflon® FEP Film



Electrical Properties

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

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

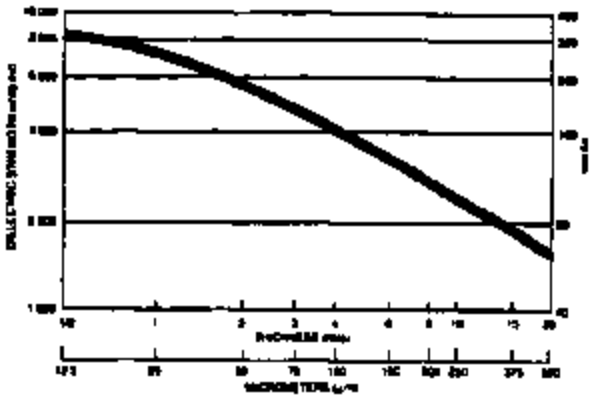
Property	ASTM Method	SI Units	English Units
Dielectric strength	D-149A-81 [0.4 mm (0.25 in) electrode in air, 60 Hz]	280 kV/mm	6500 V/mil
Dielectric constant	D-150-81 (1 kHz)	2.0	2.0
Dissipation factor	D-150-81 (1 kHz)	0.0002	0.0002
Volume resistivity	D-257-78	1×10^{16} ohm-m	1×10^{18} ohm-cm
Surface resistivity	D-257-78	1×10^{16} ohm (per square)	1×10^{16} ohm (per square)
Surface arc resistance	D-495-73	>185 s*	>185 s*

*Samples melted in arc did not track.

Dielectric Strength

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

Figure 6. Dielectric Strength vs. Film Thickness of Teflon® FEP



Dielectric Constant

For Teflon® fluorocarbon film, dielectric constant is independent of film thickness. There is no difference between Type A and Type C films.

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

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

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

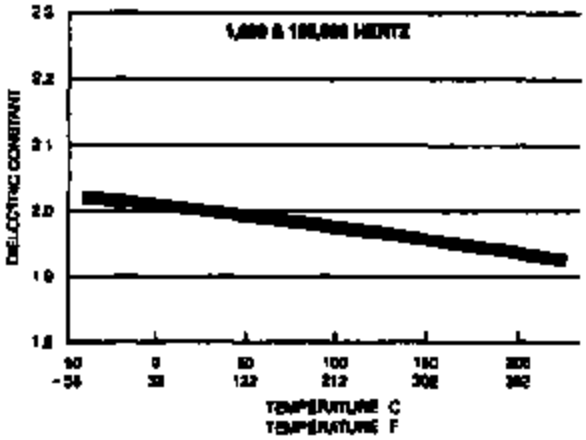
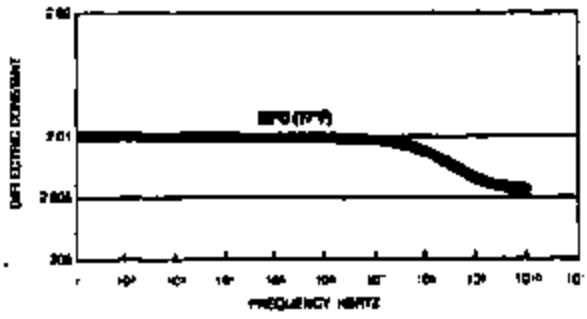


Figure 8. Dielectric Constant vs. Frequency



Dissipation Factor

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

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

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

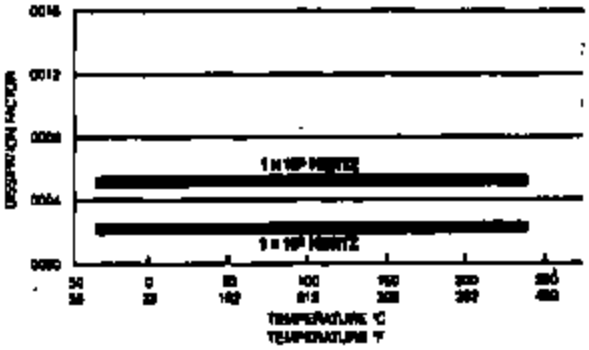
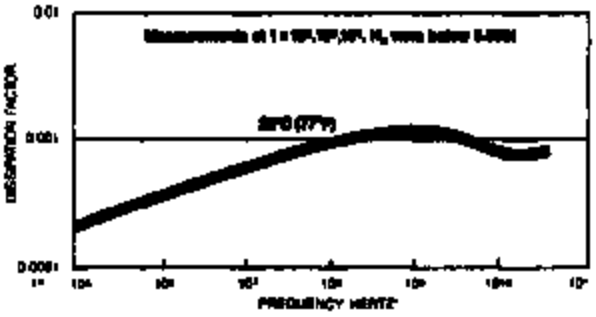


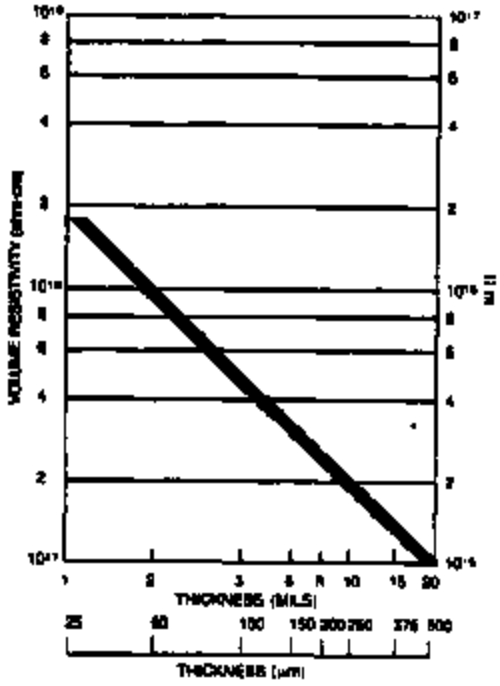
Figure 10. Dissipation Factor vs. Frequency of Teflon® FEP Film



Volume Resistivity

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

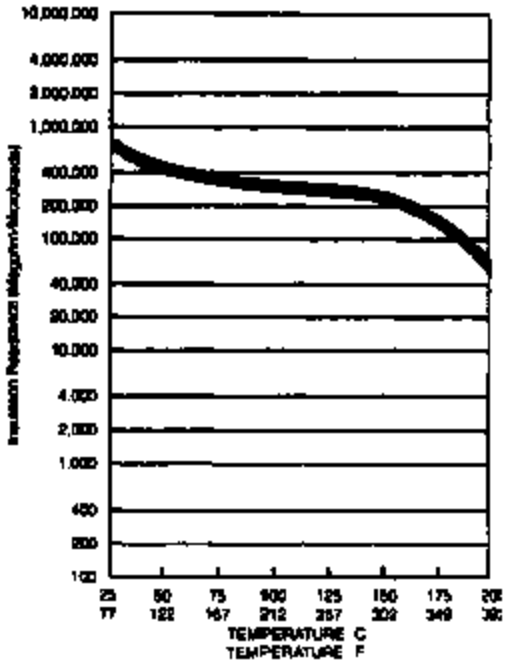
Figure 11. Volume Resistivity vs. Thickness (at 175°C [347°F])



Insulation Resistance

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

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



Chemical Properties

Teflon® 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, Teflon® 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 Teflon® FEP film has been found to be nonreactive.

Table 5
Typical Chemicals with Which Teflon® 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	Trichloroacetic acid
Butyl acetate	Fluoronitrobenzene	Ozone	Trichlorethylene
Butyl methacrylate	Formaldehyde	Perchlorethylene	Tricresyl phosphate
Calcium chloride	Formic acid	Pentachloro-benzamide	Triethanolamine
Carbon disulfide	Furane	Perfluoroxylene	Vinyl methacrylate
Cetane	Gasoline	Phenol	Water
Chlorine	Hexachlorethane	Phosphoric acid	Xylene
Chloroform	Hexane	Phosphorus pentachloride	Zinc chloride
Chlorosulfonic acid	Hydrazine		
Chromic acid	Hydrochloric acid		
Cyclohexene			

*Based on experiments conducted up to the boiling points of the liquids listed. Teflon® 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 Teflon® FEP film.

**Some halogenated solvents may cause moderate swelling.

Physical Properties

Absorption

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

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

Permeability

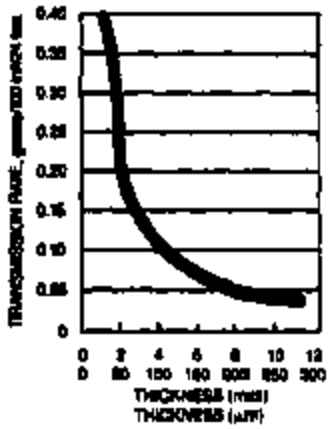
Many gases and vapors permeate Teflon® films at a much lower rate than for other thermoplastics (see **Figure 13**). In general, permeation increases with temperature, pressure, and surface contact area and decreases with increased film thickness. **Table 6** lists rates at which various gases are transmitted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

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

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

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

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



Notes: Values are averages only and not for specification purposes. To convert the permeation values for 100 in^2 to those for 1 m^2, multiply by 15.5.

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

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

Optical Properties

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

Other optical properties of Teflon® films of interest are:

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

Figure 14. Transmission Spectrum for Teflon® FEP Film

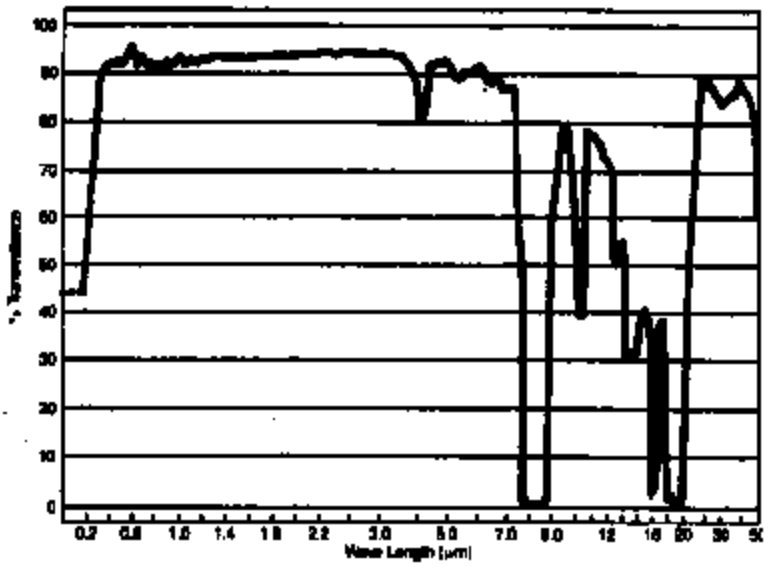


Figure 15. Transmittance at Normal Incidence of Solar Radiation through Teflon® FEP Films for Various Thicknesses

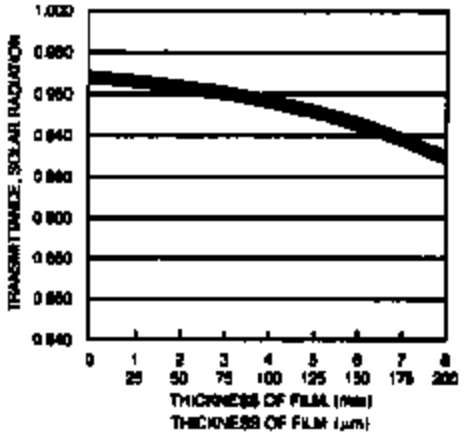
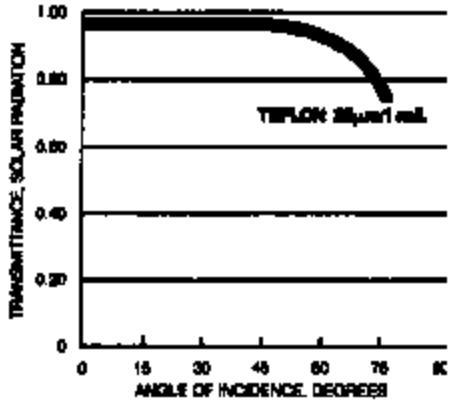


Figure 16. Transmittance of Solar Radiation through 25 μm (1 mil) Teflon® FEP Film for Various Angles of Incidence



Miscellaneous Properties

Cryogenic Service

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

FDA Compliance

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

USDA Acceptance

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

Mildew (Fungus) Resistance

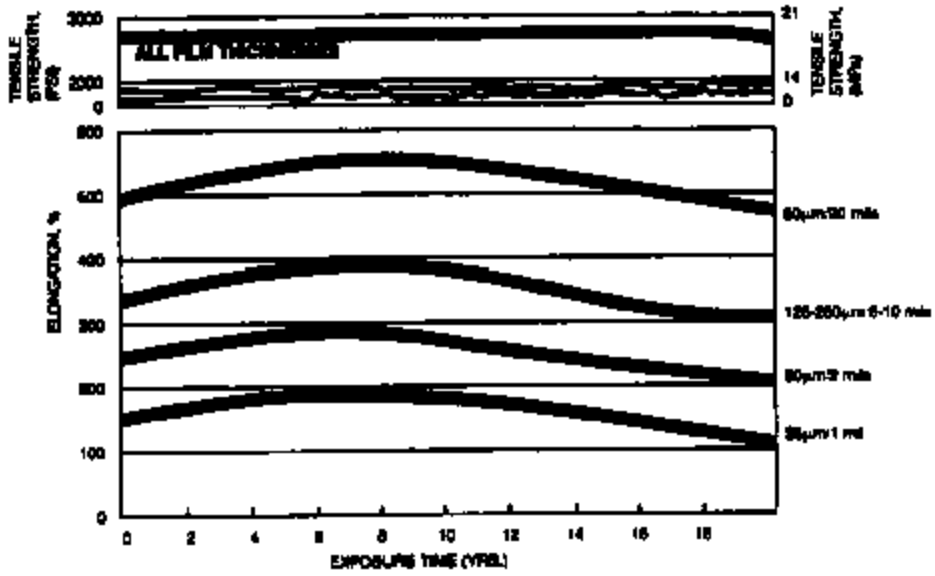
Teflon® FEP has been shown to be completely resistant to mildew growth by testing both in humidity chamber exposure inoculated with a mixed spore suspension and a soil burial test for three months.

Weatherability

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

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

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



Safety and Handling

Unheated Teflon® fluorocarbon is essentially inert. Animal tests indicate that Teflon® is nonirritating and nonsensitizing to the skin. Dust generated by cutting, grinding, or machining the unheated film should be avoided, as with any other nuisance dusts that are regulated by OSHA at 15 mg/m³ in air (29 CFR 1910.1000).

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

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

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

Other related literature available from DuPont:

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

United States
DuPont High Performance Films
P.O. Box 89
Route 23 South and DuPont Road
Circleville, OH 43113
Ordering Information:
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Product Information:
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Fax: 800-879-4481

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DuPont Canada, Inc.
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Mississauga, Ontario, Canada
L5M 2H3
Inquiries: 905-821-5603
Customer Service: 800-263-2742
Fax: 905-821-5230

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Barueri, Sao Paulo
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Meguro-ku, Tokyo 153
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Fax: 81-3-5434-6193

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#07-01 World Trade Centre
Singapore 099253
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Fax: 65-279-3456

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East Wing
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Fax: 852-2721-4117

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Fax: 91-22-6438297

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#726, Yeoksam-dong, Kangnam-ku
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82-2-222-5398
Fax: 82-2-222-5476

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Taiwan, ROC
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Fax: 866-3-4620676

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DuPont Films

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CIRCLEVILLE, OH. 43113 1"
DROP OFF #40 ATTN: STEVE WUNSCH

DuPont Films

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P.O. BOX 69
CIRCLEVILLE, OH 43113

DONNA BUTTERFIELD
CUSTOMER SERVICE REPRESENTATIVE
KAPTON/TEFLON FILMS
PHONE: (800) 967-5607
(614) 474-0684
FAX: (800) 879-4451

TO: JULIE POMBO
DARLENE SANVILLE
KEN ANDREWS

AS YOU'RE PROBABLY ALL AWARE BY NOW, WE HAVE CHANGED THE TYPE OF CORES WE'RE USING TO TRY TO PREVENT THE PROBLEM OF THE PLASTIC CORES BEING OUT OF ROUND. YOU WILL CONTINUE TO RECEIVE THE PLASTIC CORES UNTIL THE FILM ALREADY SLIT ON PLASTIC AT THE WAREHOUSE HAS BEEN SHIPPED.

BECAUSE THE NEW CORES ARE SO EXPENSIVE WE WOULD LIKE TO HAVE YOU SEND THE USED CORES BACK TO US SO THEY CAN BE REUSED. YOUR OPERATORS MAY USE THE CARTONS THE FILM WAS ORIGINALLY SHIPPED IN FOR RETURNING THE CORES. WE DO ASK THAT THEY KEEP THE DIFFERENT SIZES SEPARATE. I AM ENCLOSING ADDRESS LABELS MARKED WITH THE CORE SIZE AND I HAVE MARKED YOUR PART NUMBER ON THE BACK OF THE LABELS.

IF YOU HAVE ANY QUESTIONS, PLEASE FEEL FREE TO CALL ME. THANK YOU.

Donna

DUPONT

TI-NHTSA 018423

SCRATCHES

LISA M. 3RD SHIFT

ROUTE TO: _____

TEXAS INSTRUMENTS

ATTLEBORO, MASSACHUSETTS 02703

REPORT OF DISCREPANT IN-PROCESS MATERIAL

No. 037477

DWG NO. & NAME	SPC NOTIFIED	REV.	DESCRIPTION	DATE	Mfg. Supervision Reviewed
27223-4	☐		103567	1-6-99	Tom Deangelo

SOURCE	DEPT	PROD. CODE	QUANTITY
RAYTON STRIP	PSM	47	1 ROLL

ITEM	ATTRIBUTE/REQUIREMENT	ACTUAL	DISP	AC	RE	DEFT
	MATERIAL SHOULD BE FREE OF DEFECTS	SCRATCHES ON MATERIAL ??		0	1	ROLL

MAT'L/PROD. CONTROL

☐ CHECK INVENTORY AT LOCATIONS
☐ PART/MATERIAL IN SHORT SUPPLY

PRIORITY ☐ 1 ☐ 2 ☐ 3

COMMENTS:

PRINTED | SIGNATURE | DATE

MRB ENGINEERING DISPOSITION

MRB SIGNATURE / DATE

- ☐ RETURN TO SUPPLIER
- ☐ REWORK AT TI
- ☐ SORT AT TI
- ☐ SCRAP
- ☒ REVISE (I.A.)

COMMENTS: Notification letter to be sent to Supplier. No Engineering Form.

NOTE — IF DISP. OTHER THAN RTS - MRB CORRECTIVE ACTION MUST BE COMPLETED

REWORK PROCEDURE: (MFG./ENG.)

ESTIMATED TIME: _____

REVISED CONTRACT: NO. / BY / ACTUAL MFG. HOURS / GOOD FOR REWORK

INSPECTION AFTER REWORK	DISP	AC	RE	DEFT	INSPECTOR	DATE	ORIG. DWG. (Attach any revised Dwg.)

MRB CORRECTIVE ACTION

TI
- ☐ — CHANGE DRAWING/SPEC (COPY MUST BE ATTACHED)
- ☐ — USE ENCLOSED SAMPLES AS ACCEPTABLE VISUAL STANDARDS
- ☐ — OTHER (EXPLAIN)

SUPPLIER
- ☐ — PROVIDE CORRECTIVE ACTION WITH FORMAL RESPONSE
- ☐ — SUBMIT INSPECTION DATA WITH FUTURE SHIPMENTS
- ☐ — CONDUCT CAPABILITY STUDY AND SUBMIT TO ENGINEERING
- ☒ — OTHER (EXPLAIN)

COMMENTS: Provide Formal Response to Notification.

RECEIVING INSPECTION

IR SEQUENCE NO.	DISP. CODE	AREA	LOCATION	ACTION TAKEN TO PREVENT RECURRENCE

REJECT VALIDATION		SUPPLIER NOTIFIED	
INITIAL	DATE	INITIAL	DATE

PROCUREMENT ASSURANCE

DO NOT WRITE BELOW THIS LINE

- ☐ FOR INFO ONLY - SUPPLIER
- ☐ EXTERNAL C.A.R.
- ☐ FOR INFO ONLY - INTERNAL
- ☐ INTERNAL C.A.R.

Before shutdown, I had spoken to Tom, Andy and Doug about how TSL could help you achieve your goals in 98, especially in regards to new products. In other words, we would like to be more proactive and less reactive than in the past. In response, Tom had asked for a memo that he could forward to his staff since nothing had immediately came to mind. Rather than detailing what we do in a memo we have added a Capabilities section to our Web Site at http://www-mcd.mc.ti.com/tsl/ in the hopes that this might be useful.

At the end of this memo is a list of the major projects that have already been identified as of being of use to the ABU. If there are any other tasks that would be of use, we would be happy to add them. We well know that it is difficult to identify problems before they occur. In fact, Tom, Doug and Steve have already noted that the most valuable contribution that the Surface Lab (for instance) provides is responsive, accurate problem solving services. The purpose of this memo is to see if we can be more aware of the needs of the ABU and to make sure that we are focusing our efforts on those items that are most important. We plan on updating you quarterly with our progress and to see if there are other projects that we should be considering.

TSL MAJOR PROJECTS IMPACTING ABU

LAB	PROJECT
All	Achieve AZLA Accreditation
Enviro	Implement Spectrum Analyzer Kit (CCIS)
Enviro	Computerized monitoring of humidity and thermal chambers
Enviro	Create detailed equipment usage instructions for major equipment
Enviro	Create detailed T'Stat and CB instructions for Mil/Customer acceptance tests
Enviro	Implementation of PM system
Spec Proj	Develop method to distinguish between good and bad lots of PPS for Kapton PS replacement
Spec Proj	Create system to document for customers the hermiticity and gas composition of T'stats
Surface	Determine feasibility and cost of implementing APT ASIC fuse FA capabilities; then implement
Mat	Provide failure analysis and technical consulting on resolution of PS failures
Gage Lab	Reduce overdue gage percentage to 6.5%
Gage Lab	Evaluate, select and start implementation of new Gage Control system.

If you want, we could come over for a meeting; alternatively, phone or E-mail response would be fine.

Thanks and Regards,

Al

32450 / DuPont

DRAWINGS AVAILABLE UPON REQUEST

ROUTE TO_____

TEXAS INSTRUMENTS

ATTLEBORO, MASSACHUSETTS 02703

REPORT OF DISCREPANT IN-PROCESS MATERIAL

No. 032450

DWG NO. & NAME	SPC CHANGE	REV.	INSPECTOR	DATE	Mfg. Supervision Reviewt
TE# 27225-4 KAPTON	☐		2236	1-14-98	
SOURCE	DEVICE		PROD. CODE	QUANTITY PARTIAL ROLL	

ITEM	ATTRIBUTE/REQUIREMENT	ACTUAL	#INSP	AC	RE	#DEF
1	KAPTON SHOULD BE HANDLED LOCALLY THROUGH RAPID-A/E AT NCSE 2	KAPTON JAMMING AT RAPID-AIR CAUSING TOO MANY BAD PARTS				

MAT'L/PROD. CONTROL

☐ CHECK INVENTORY AT (LOCATION) _____
☐ PARTS/MATERIAL IN SHORT SUPPLY

PRIORITY ☐ 1 ☐ 2 ☐ 3

COMMENTS:

PLANNER: | SIGNATURE | DATE

MRB ENGINEERING DISPOSITION

- ☐ RETURN TO SUPPLIER
- ☐ REWORK AT TI
- ☐ SORT AT TI
- ☒ SCRAP
- ☐ DEVIATE (U A I)

COMMENTS: SCRAP PARTIAL ROLL RETURN TO SUPPLIER

NOTE — IF DISP. OTHER THAN RTS - MRB CORRECTIVE ACTION MUST BE COMPLETED

MRB SIGNATURES	DATE
PURCHASING	
MFG ENG	1-26-98
QRA ENG	1-26-98
M/E MGR	
D/E MGR	
QRA MGR	

SR 1/4

REWORK PROCEDURE: (MFG./ENG.)

ESTIMATED TIME_____

REWORK COMPLETE ON | BY | ACTUAL STD. HOURS | GOOD FOR REMARKS

INSPECTION AFTER REWORK	#INSP	AC	RE	#DEF	INSPECTOR	DATE	QRA ENG. (Signature required if RE)

MRB CORRECTIVE ACTION

TI
- ☐ — CHANGE DRAWING/SPEC (CSN/ECN MUST BE ATTACHED)
- ☐ — USE ENCLOSED SAMPLES AS ACCEPTABLE VISUAL STANDARDS
- ☐ — OTHER (EXPLAIN)

SUPPLIER
- ☐ — PROVIDE CORRECTIVE ACTION WITH FORMAL RESPONSE
- ☐ — SUBMIT INSPECTION DATA WITH FUTURE SHIPMENTS
- ☐ — CONDUCT CAPABILITY STUDY AND SUBMIT TO ENGINEERING
- ☐ — OTHER (EXPLAIN)

COMMENTS: ISSUE SUPPLIER ALERT

RECEIVING INSPECTION

M RECEIVER NO.	DISP. CODE	AREA	LOCATION	ACTION TAKEN TO PREVENT RECURRENCE:

REJECT VALIDATION — INITIAL | DATE

SUPPLIER NOTIFIED — INITIAL | DATE

PROCUREMENT ASSURANCE

DO NOT WRITE BELOW THIS LINE

- ☐ FOR INFO ONLY - SUPPLIER
- ☐ EXTERNAL C.A.R.
- ☐ FOR INFO ONLY - INTERNAL
- ☐ INTERNAL C.A.R.
- ☐

SIGNATURE | DATE

FORM 5979

TI-NHTSA 018431

TEXAS
INSTRUMENTS

Ron Souza
34 Forest Street
P.O. Box 2964
Mail Stop 11-09
Attleboro, MA 02703-0964

(508) 236-3868

February 27, 1998

Ms. Donna Butterfield
E.I. DupontDe Nemours & Co.
US Route 23
Circleville, OH 43113-0000
Tel: 800-967-5607 X1
Fax: 614-474-0699

Dear Ms. Butterfield,

Enclosed is Supplier Alert 032450 on TI part number 27225-4, one of the items we purchase from your company. Please bring it to the attention of the appropriate person(s). This Alert's purpose is to inform Dupont of a concern that the PSM group at TI has with this particular issue. This is not a request for formal corrective action, however the return of the form with the questions addressed would provide our team with the understanding that Dupont is aware of the concern and is acknowledging the conditions.

Dupont's prompt response to the Supplier Alert within 10 days would be appreciated.

Sincerely,
Ron Souza
Ron Souza

ROUTE TO_____

TEXAS INSTRUMENTS

ATTLEBORO, MASSACHUSETTS 02703

REPORT OF DISCREPANT IN-PROCESS MATERIAL

No. 032450

DWG NO. & NAME / SOURCE	SPC CERTIFIED	REV.	INSPECTOR	DATE	Mfg. Supervision Review:
TI# 27225-4 KAPTON /	☐		72#31	1-14-98	
	DEVICE		PROD. CODE	QUANTITY PARTIAL ROLL	

ITEM	ATTRIBUTE/REQUIREMENT	ACTUAL	#INSP	AC	RE	#DEF
1	KAPTON SHOULD BE BONDING EVENLY THROUGH RAPID-AIR AT A/C # 2	KAPTAN JAMMING AT RAPID-AIR CAUSING STOPS + BAD PARTS				

MATL/PROD. CONTROL

☐ CHECK INVENTORY AT (LOCATION) _____
☐ PARTS/MATERIAL IN SHORT SUPPLY

PRIORITY ☐ 1 ☐ 3 ☐ 6

COMMENTS:

PLANNER: | SIGNATURE | DATE

MRB ENGINEERING DISPOSITION

☐ RETURN TO SUPPLIER
☐ REWORK AT TI
☐ SORT AT TI
☒ SCRAP
☐ DEVIATE (U A I)

COMMENTS:
SCRAP PARTIAL ROLL
RETURN TO SUPPLIER

NOTE — IF DISP. OTHER THAN RTS - MRB CORRECTIVE ACTION MUST BE COMPLETED

MRB SIGNATURES	DATE
PURCHASING	1-26-98
MFG ENG	1-26-98
QRA ENG	
ME MGR	
DE MGR	
QRA MGR	

REWORK PROCEDURE: (MFG./ENG.)

ESTIMATED TIME_____

REWORK COMPLETE
ON
BY
ACTUAL STD. HOURS
GOOD PCS. REMAINING

INSPECTION AFTER REWORK	#INSP	AC	RE	#DEF	INSPECTOR	DATE	QRA EXIS. (Signature required if rej.)

MRB CORRECTIVE ACTION

TI
— CHANGE DRAWING/SPEC (ORIGECH MUST BE ATTACHED) ☐
— USE ENCLOSED SAMPLES AS ACCEPTABLE VISUAL STANDARDS ☐
— OTHER (EXPLAIN) ☐

SUPPLIER
— PROVIDE CORRECTIVE ACTION WITH FORMAL RESPONSE ☐
— SUBMIT INSPECTION DATA WITH FUTURE SHIPMENTS ☐
— CONDUCT CAPABILITY STUDY AND SUBMIT TO ENGINEERING ☐
— OTHER (EXPLAIN) ☐

COMMENTS:
ISSUE SUPPLIER ALERT

RECEIVING INSPECTION

RI SEQUENCE NO.	DISP. CODE:	AREA	LOCATION	ACTION TAKEN TO PREVENT RECURRENCE:

REJECT VALIDATION — INITIAL _____ DATE _____

SUPPLIER NOTIFIED — INITIAL _____ DATE _____

PROCUREMENT ASSURANCE

DO NOT WRITE BELOW THIS LINE

☐ FOR INFO ONLY - SUPPLIER ☐
☐ EXTERNAL C.A.R. ☐
☐ FOR INFO ONLY - INTERNAL ☐
☐ INTERNAL C.A.R. ☐
☐ ☐

SIGNATURE _____ DATE _____

FORM 5975

REVIEW

3/11/98

RDIM#032450

Submitted Supplier Alert
to
E.I. Dupont

TEXAS INSTRUMENTS INCORPORATED, AUTOMOTIVE SENSORS & CONTROLS	
TITLE: PROCESSING AND FLOW OF INPROCESS MATERIAL REJECTIONS	DOC. NO. QAS 231

SUPPLIER ALERT
Please respond within 10 days

Address Response To:

Ron Souza Mail Stop: 11-09
Texas Instruments, Inc.
P.O. Box 2964
34 Forest Street
Attleboro, MA 02703-0964

Tel: 508-236-3988
Fax:: 508-236-3827
E-mail:

DATE PREPARED: 2/27/98

SUPPLIER: EI Dupont

PART NAME: Select one

PART NUMBER: 27225-4

LOT No. N/A

DRAWING REV: AA

RDIM No. 032450 attached
attached

QUANTITY: 1 REEL
QUANTITY:

This notice is being issued by the PRM Material Review Board to inform you that parts inspected on the date shown above were found to contain unacceptable dimensions and/or conditions outlined below. Even though no formal rejection has been issued, it is expected that you will review your processes or system(s) in order to identify areas that will improve the acceptability of your product.

SPECIFICATION: No deformities per note 1.

OBSERVED CONDITION: There appears to be a curvature of the roll along one edge which apparently causes some jamming in our automated assembly machinery. Data included for your information

---

SUPPLIER RESPONSE: Please reply to the following inquiries and reply to above addressee.

1) Do you recognize this as a discrepancy you may have seen before? ☐ Yes, ☐ No

2) Do you currently have a process control mechanism in place to prevent this discrepancy from occurring? ☐ Yes, ☐ No

3) If you answered Yes to question (2), why do you think it occurred again? If you answered No to question 2, what actions, if any, would you anticipate on taking to prevent recurrence?

Authorized Signature: _____ Date: _____

Please respond within 10 days.

TEXAS
INSTRUMENTS

Ron Souza
34 Forest Street
P.O. Box 2064
Mail Stop 11-09
Attleboro, MA 02703-0964

(508) 236-3959

February 27, 1998

Ms. Donna Butterfield
E.I. DupontDe Nemours & Co.
US Route 23
Circleville, OH 43113-0000
Tel: 800-967-5607 X1
Fax: 614-474-0699

Dear Ms. Butterfield,

Enclosed is Supplier Alert 032450 on TI part number 27225-4, one of the items we purchase from your company. Please bring it to the attention of the appropriate person(s). This Alert's purpose is to inform Dupont of a concern that the PSM group at TI has with this particular issue. This is not a request for formal corrective action, however the return of the form with the questions addressed would provide our team with the understanding that Dupont is aware of the concern and is acknowledging the conditions.

Dupont's prompt response to the Supplier Alert within 10 days would be appreciated.

Sincerely,
Ron Souza
Ron Souza

Receiving Inspection CC: 146 ---- WORK ORDER

- INDICATE TYPE OF SERVICE REQUIRED: O First Article Inspection O Dimensional Analysis

(Each submission must have samples and two full size drawings attached.)

- MAIL REQUEST TO: Receiving Inspection MS 11-11 → Review Schedule on: http://www-gqs.mc.ti.com/gqs/

PART NUMBER: 27325-4	REV: AA	SUPPLIER: E.I. DUPONT	
MATERIAL: KAPTON	TOOL ID: N/A	NO. of Cavities: N/A	
BUSINESS UNIT: PSM	PRODUCT CODE: 047	COST CENTER: 0149	
DATE SUBMITTED: 1/30/98	DATE REQUIRED: 2/3/98	MANAGER'S APPROVAL IF FAI IS URGENT N/A	
REQUESTED BY: RON SOUZA		TELEPHONE: 3988	MAIL STATION: 11-09

ENGINEERING INSTRUCTIONS:

Measure the flatness of the surface on the outer diameter of the rolled tape. The drawing does not specify any specific dimension, however the curvature observed tends to present itself as a difficulty to the production machinery. We need to understand the amount of deviation from pure flatness we are observing in order to discuss the issue with the Supplier.

TOOL APPROVAL REPORT

27225-4

Part number 27225-4	Rev AA	Product Code: 047		Cost Center 149	
Supplier E. I. Dupont	Requested by:	Ron Souza	236-3686	Req Date	02/03/98
	Prepared by:	Kim Dorsey	236-3671	Completion Date:	02/17/98

maximum deviation at extreme outside of rail	.0048		dial indicator
	.0075		fixmass indicator
	.0091		optical comparator
	all dimensions are in inches		

ROUTE TO_____

TEXAS INSTRUMENTS
ATTLEBORO, MASSACHUSETTS 02703

REPORT OF DISCREPANT IN-PROCESS MATERIAL

No. 032450

DWG NO. & NAME	SPC	REV.	INSPECTOR	DATE	Mfg. Supervision Review:
TI# 27225-4 KAPTON			[illegible]	2-16-98	
SOURCE	DEVICE		PROD. CODE	QUANTITY 1 ROLL	

ITEM	ATTRIBUTE/REQUIREMENT	ACTUAL	#INSP	AC	RE	#DEF
1	KAPTON SHOULD BE BONDING EVENLY THROUGH RAPID-AIR AT AIC# 8	KAPTON JAMMING AT RAPID-AIR CAUSING SDFS & BAD PARTS				

MAT'L/PROD. CONTROL

☐ CHECK INVENTORY AT (LOCATION) _____
☐ PART/MATERIAL IN SHORT SUPPLY

PRIORITY ☐ 1 ☐ 2 ☐ 3

COMMENTS:

PLANNER: | SIGNATURE | DATE

MRB ENGINEERING DISPOSITION

☐ RETURN TO SUPPLIER
☐ REWORK AT TI
☐ SORT AT TI
☒ SCRAP
☐ DEVIATE (U.A.I)

COMMENTS:
SCRAP PARTIAL ROLL
RETURN TO SUPPLIER

NOTE — IF DISP. OTHER THAN RTS - MRB CORRECTIVE ACTION MUST BE COMPLETED

MRB SIGNATURES	DATE
PURCHASING	2-26-98
MFG ENG	2-26-98
QRA MGR	
ME MGR	
DIE MGR	
QRA MGR	

5 1/8

REWORK PROCEDURE: (MFG./ENG.)

ESTIMATED TIME _____

REWORK COMPLETE ON
BY
ACTUAL STD. HOURS
GOOD PCS. REMARKS

INSPECTION AFTER REWORK	#INSP	AC	RE	#DEF	INSPECTOR	DATE	QRA ENG. (Signature required if ref.)

MRB CORRECTIVE ACTION

TI
— CHANGE DRAWING/SPEC (DSWEIN MUST BE ATTACHED) ☐
— USE ENCLOSED SAMPLES AS ACCEPTABLE VISUAL STANDARDS ☐
— OTHER (EXPLAIN) ☐

SUPPLIER
— PROVIDE CORRECTIVE ACTION WITH FORMAL RESPONSE ☐
— SUBMIT INSPECTION DATA WITH FUTURE SHIPMENTS ☐
— CONDUCT CAPABILITY STUDY AND SUBMIT TO ENGINEERING ☐
— OTHER (EXPLAIN) ☐

COMMENTS:
ISSUE SUPPLIER ALERT

RECEIVING INSPECTION

M RECEIVING NO.	DISP. CODE:	AREA	LOCATION	ACTION TAKEN TO PREVENT RECURRENCE

REJECT VALIDATION — INITIAL _____ DATE _____

SUPPLIER NOTIFIED — INITIAL _____ DATE _____

PROCUREMENT ASSURANCE

DO NOT WRITE BELOW THIS LINE

☐ FOR INFO ONLY - SUPPLIER ☐
☐ EXTERNAL C.A.R. ☐
☐ FOR INFO ONLY - INTERNAL ☐
☐ INTERNAL C.A.R. ☐
☐ ☐

SIGNATURE _____ DATE _____

FORM 8887A

TI-NHTSA 018439

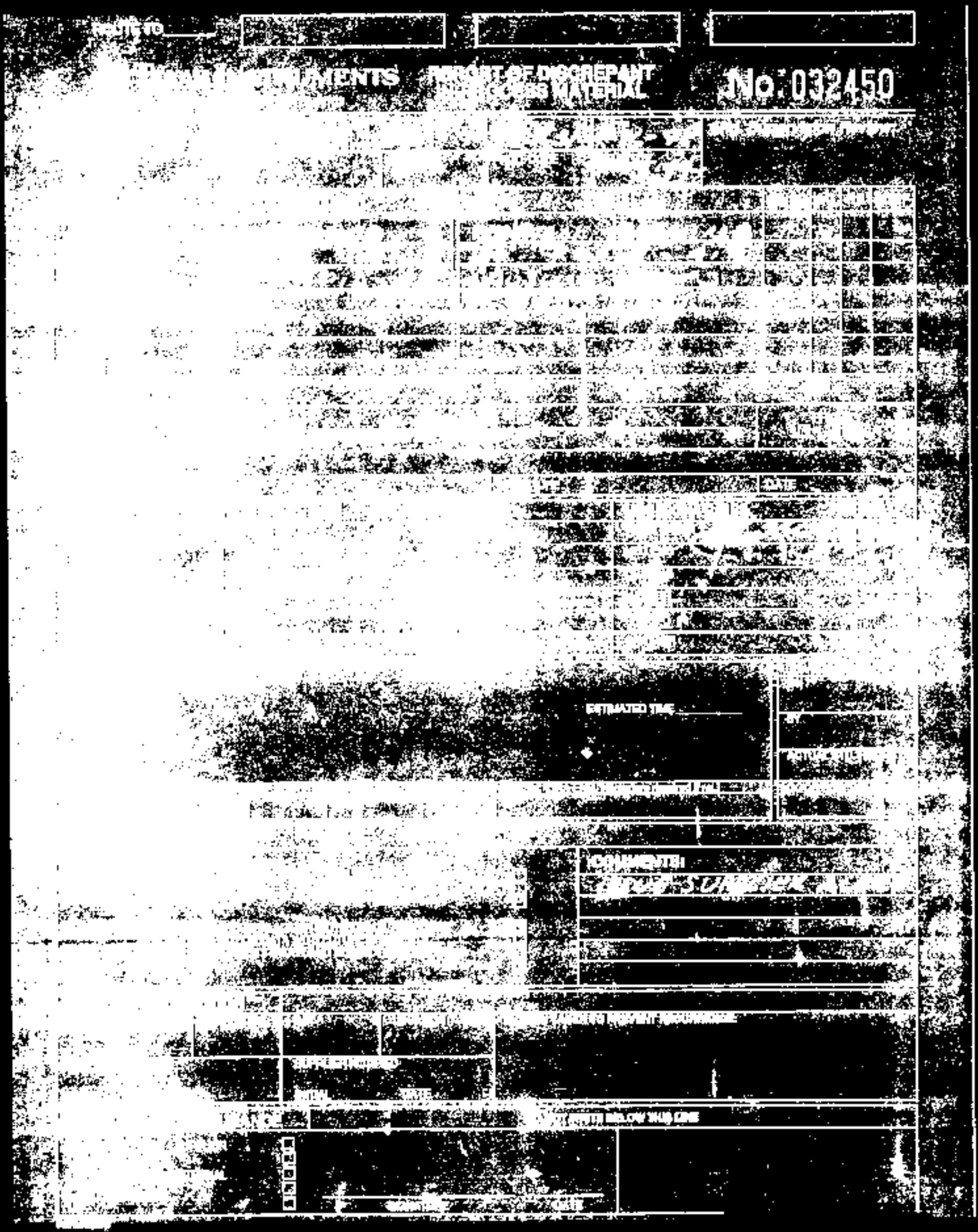
ROUTE TO_____

TEXAS INSTRUMENTS REPORT OF DISCREPANT PROCESS MATERIAL

No. 032450

Mfg. Supervision Review:

TI-NHTSA 018440


No: 032450

ROUTE TO_____

TEXAS INSTRUMENTS

ATTLEBORO, MASSACHUSETTS 02703

REPORT OF DISCREPANT IN-PROCESS MATERIAL

No. 032450

PART NO. & NAME	SPC CERTIFIED	REV.	INSPECTOR	DATE	Mfg. Supervision Review:
TI 2725-4 KAPTON	☐		723631	9-16-98	
SOURCE	DEVICE		PROD. CODE	QUANTITY	

ITEM	ATTRIBUTE/REQUIREMENT	ACTUAL	#INSP	AC	RE	#DEF
1	KAPTON SHOULD	KAPTON THINNING				
	BE PRESENT EVENLY	AT RIGHT AIR				
	THROUGH RAIL AIR	CAUSING STUBS				
	AT AREA 2.	+ BAD PARTS				

MAT'L/PROD. CONTROL

☐ CHECK INVENTORY AT (LOCATION) _____
☐ PART/MATERIAL IN SHORT SUPPLY

PRIORITY ☐ 1 ☐ 2 ☐ 3

COMMENTS:

PLANNER: | SIGNATURE | DATE

MRB ENGINEERING DISPOSITION

☐ RETURN TO SUPPLIER
☐ REWORK AT TI
☐ SORT AT TI
☐ SCRAP
☐ DEVIATE (U A)

COMMENTS:

NOTE — IF DISP. OTHER THAN RTS - MRB CORRECTIVE ACTION MUST BE COMPLETED

MRB SIGNATURES	DATE
PURCHASING	
MFG ENG	
QRA ENG	
MFG MGR	
DIE MGR	
QRA MGR	

REWORK PROCEDURE: (MFG./ENG.)

ESTIMATED TIME _____

REWORK COMPLETE ON / BY / ACTUAL STD. HOURS / GOOD PCS. REMAINING

INSPECTION AFTER REWORK	#INSP	AC	RE	#DEF	INSPECTOR	DATE	QRA ENG. (Signature required if rej.)

MRB CORRECTIVE ACTION

TI
— CHANGE DRAWING/SPEC (DEVIATION MUST BE ATTACHED) ☐
— USE ENCLOSED SAMPLES AS ACCEPTABLE VISUAL STANDARDS ☐
— OTHER (EXPLAIN) ☐

SUPPLIER
— PROVIDE CORRECTIVE ACTION WITH FORMAL RESPONSE ☐
— SUBMIT INSPECTION DATA WITH FUTURE SHIPMENTS ☐
— CONDUCT CAPABILITY STUDY AND SUBMIT TO ENGINEERING ☐
— OTHER (EXPLAIN) ☐

COMMENTS:

RECEIVING INSPECTION

RI SEQUENCE NO.	DISP. CODE	AREA	LOCATION	ACTION TAKEN TO PREVENT RECURRENCE:

REJECT VALIDATION — INITIAL / DATE

SUPPLIER NOTIFIED — INITIAL / DATE

PROCUREMENT ASSURANCE

DO NOT WRITE BELOW This Line

☐ FOR INFO ONLY - SUPPLIER ☐
☐ EXTERNAL C.A.R. ☐
☐ FOR INFO ONLY - INTERNAL ☐
☐ INTERNAL C.A.R. ☐
☐ ☐

SIGNATURE _____ DATE _____

FORM 6224

TI-NHTSA 018442

32479 / DuPont

ROUTE TO_____

TEXAS INSTRUMENTS
ATTLEBORO, MASSACHUSETTS 02703

REPORT OF DISCREPANT IN-PROCESS MATERIAL

No. 032479

DWG NO. & NAME	☐ SPC OBTAINED	REV.	INSPECTOR	DATE	Mfg. Supervision Review
TI# 27225-4 KAPTON			723631	3-11-98	
SOURCE: DUPONT	DEVICE		PROD. CODE	QUANTITY: 1 REEL	

ITEM	ATTRIBUTE/REQUIREMENT	ACTUAL	#INSP	AC	RE	#DEF
1	INNER PLASTIC	INSERT OF KAPTON				
	INSERT OF KAPTON	MEASURES 6" + on				
	ROLL SHOULD MEASURE	HALF of ROLL				
	6" IN DIA. TO FIT	will NOT FIT				
	THE MACHINE PAYOFF	on Payoff REEL				
	REEL					

MAT'L/PROD. CONTROL

☐ CHECK INVENTORY AT (LOCATION) _____
☐ PARTS/MATERIAL IN SHORT SUPPLY

PRIORITY ☐ 1 ☐ 2 ☐ 3

COMMENTS:

PLANNER | SIGNATURE | DATE

MRB ENGINEERING DISPOSITION

☐ RETURN TO SUPPLIER
☐ REWORK AT TI
☐ SORT AT TI
☑ SCRAP
☐ DEVIATE (U.A.)

COMMENTS:

NOTE — IF DISP. OTHER THAN RTS - MRB CORRECTIVE ACTION MUST BE COMPLETED

MRB SIGNATURES	DATE
PURCHASING	
MFG ENG	3/26/98
QRA ENG	Ron Lenzi 4-9
MFG MGR	
DIE MGR	
QRA MGR	

R 3/12

REWORK PROCEDURE: (MFG./ENG.)

ESTIMATED TIME _____

REWORK COMPLETE ON | BY | ACTUAL STD. HOURS | GOOD PCS REMAINING

INSPECTION AFTER REWORK	#INSP	AC	RE	#DEF	INSPECTOR	DATE	QRA ENG. (Signature required if rel.)

MRB CORRECTIVE ACTION

TI
- ☐ — CHANGE DRAWING/SPEC (CHANGE MUST BE ATTACHED)
- ☐ — USE ENCLOSED SAMPLES AS ACCEPTABLE VISUAL STANDARDS
- ☐ — OTHER (EXPLAIN)

SUPPLIER
- ☐ — PROVIDE CORRECTIVE ACTION WITH FORMAL RESPONSE
- ☐ — SUBMIT INSPECTION DATA WITH FUTURE SHIPMENTS
- ☐ — CONDUCT CAPABILITY STUDY AND SUBMIT TO ENGINEERING
- ☐ — OTHER (EXPLAIN)

COMMENTS:
Issue Supplier Alert

RECEIVING INSPECTION

TI SEQUENCE NO. | DISP. CODE: | AREA | LOCATION | ACTION TAKEN TO PREVENT RECURRENCE:

REJECT VALIDATION: INITIAL _____ DATE _____

SUPPLIER NOTIFIED: INITIAL _____ DATE _____

PROCUREMENT ASSURANCE

DO NOT WRITE BELOW THIS LINE

- ☐ FOR INFO ONLY - SUPPLIER
- ☐ EXTERNAL C.A.R.
- ☐ FOR INFO ONLY - INTERNAL
- ☐ INTERNAL C.A.R.
- ☐

SIGNATURE _____ DATE _____

FORM 8007I

TI-NHTSA 018444

In REVIEW

3/23/98

RDIM # 032479
Part # 27225-4

E.I. Dupont

What is status of RDIM?

Jon reviewing drawing note 3 on allowance of ¼" allowable variance

Roy

To be signed off

4/13/98

RDIM # 032479
Part # 27225-4

E.I. Dupont

Core is slightly oval

37482/DuPont

ROUTE TO_____

TEXAS INSTRUMENTS
ATTLEBORO, MASSACHUSETTS 02703

REPORT OF DISCREPANT IN-PROCESS MATERIAL

No. 037482

DWG NO. & NAME: Kapton 27225-4	☐ SPC CONTROL	REV.	WORK ORDER: 2094	DATE: 2-20-99	Mfg. Supervision Review: Tom Wood
SOURCE: Dupont	DEPT: P36	PROD. CODE: 045	QUANTITY: Reel		

ITEM	ATTRIBUTE/REQUIREMENT	ACTUAL	#INSP	AC	RE	REJ
	Kapton should be free from scraches	Kapton has large scraches along the top and bottom	all			ok

MAT'L/PROD. CONTROL

☐ CHECK INVENTORY AT (LOCATION) Receiving Screen
☐ PARTS/MATERIAL IN SHORT SUPPLY Qty

PRIORITY ☐ 1 ☐ 2 ☐ 3

COMMENTS:

PLANNER: | SIGNATURE: | DATE:

MRB ENGINEERING DISPOSITION

☐ RETURN TO SUPPLIER
☐ REWORK AT TI
☐ SORT AT TI
☐ SCRAP
☒ DEVIATE (U A R)

COMMENTS:

NOTE — IF DISP. OTHER THAN RTS OR CORRECTIVE ACTION MUST BE COMPLETED

MRB SIGNATURES	DATE
PURCHASING	
MFG ENG	
QRA ENG	1/20/99
MAT MGR	1/20/99
DE MGR	
QRA MGR	

REWORK PROCEDURE (MFG./ENG.)

ESTIMATED TIME _____

REWORK COMPLETE	
ON	
BY	
ACTUAL STD. HOURS	
GOOD PCS. REMAINING	

INSPECTION AFTER REWORK	#INSP	NO	RE	ACC	INSPECTOR	DATE	QRA ENG. (Signature required if rej.)

MRB CORRECTIVE ACTION

TI
— CHANGE DRAWING/SPEC (CHANGE NOTICE TO BE ATTACHED) ☐
— USE ENCLOSED SAMPLES AS ACCEPTABLE VISUAL STANDARDS ☒
— OTHER (EXPLAIN) ☐

SUPPLIER
— PROVIDE CORRECTIVE ACTION WITH FORMAL RESPONSE ☐
— SUBMIT INSPECTION DATA WITH FUTURE SHIPMENTS ☐
— CONDUCT CAPABILITY STUDY AND SUBMIT TO ENGINEERING ☐
— OTHER (EXPLAIN) ☐

COMMENTS:
Cosmetic Marks Only.
Ok to use

RECEIVING INSPECTION

W REC'D/RCE NO.	DISP. CODE:	AREA	LOCATION	ACTION TAKEN TO PREVENT RECURRENCE:

REJECT VALIDATION — INITIAL / DATE

SUPPLIER NOTIFIED — INITIAL / DATE

PROCUREMENT ASSURANCE

DO NOT WRITE BELOW THIS LINE

☐ FOR INFO ONLY - SUPPLIER ☐
☐ EXTERNAL C.A.R. ☐
☐ FOR INFO ONLY - INTERNAL ☐

TI-NHTSA 016448

ROUTE TO_____

TEXAS INSTRUMENTS

ATTLEBORO, MASSACHUSETTS 02703

REPORT OF DISCREPANT IN-PROCESS MATERIAL

No. 017504

DWG NO. & NAME: 74775-1 Kapton Z 9999	☐ SPC CONTROL	REV.	INSPECTOR: 751571	DATE: 7/6/94	Mfg. Supervision Review: CC Richard
SOURCE: DUPONT	DEVICE: 65E		PROD. CODE: 047	QUANTITY: 15	

ITEM	ATTRIBUTE/REQUIREMENT	ACTUAL	MNSP	AC	RE	SOSP
	Kapton should Not have any scratchs.	Kapton has scratchs.	1.5	0	15	

MAT'L/PROD. CONTROL

☐ CHECK INVENTORY AT (LOCATION) _____
☐ PART/MATERIAL IN SHORT SUPPLY

PRIORITY ☐ 1 ☐ 2 ☐ 3

COMMENTS:

PLANNER: | SIGNATURE | DATE

MRB ENGINEERING DISPOSITION

☐ RETURN TO SUPPLIER
☐ REWORK AT TI
☐ SORT AT TI
☐ SCRAP
☑ DEVIATE AS IS

COMMENTS:

Operator Please Monitor Scratches As Reel Is Run To Make Sure That They Do Not Become More Severe.

NOTE — IF DISP. OTHER THAN RTS - MRB CORRECTIVE ACTION MUST BE COMPLETED

MRB SIGNATURES	DATE
PURCHASING	
MFG ENG	R. Scott 7/10/94
QRA ENG	Richard K. Dahl 7/10/94
DIE MGR	
QRA MGR	Pete Bogosh 7/10/94

REWORK PROCEDURE: (MFG/ENG.)

ESTIMATED TIME _____

REWORK COMPLETE	
ON	
BY	
ACTUAL RTD. HOURS	
GOOD FOR REWORKS	

INSPECTION AFTER REWORK	INSP	AC	RE	SOSP	INSPECTOR	DATE	QRA ENG. (Signature required if ref.)

MRB CORRECTIVE ACTION

TI
- — CHANGE DRAWING/SPEC (ORIGION MUST BE ATTACHED) ☐
- — USE ENCLOSED SAMPLES AS ACCEPTABLE VISUAL STANDARDS ☐
- — OTHER (EXPLAIN) ☐

SUPPLIER
- — PROVIDE CORRECTIVE ACTION WITH FORMAL RESPONSE ☐
- — SUBMIT INSPECTION DATA WITH FUTURE SHIPMENTS ☐
- — CONDUCT CAPABILITY STUDY AND SUBMIT TO ENGINEERING ☐
- — OTHER (EXPLAIN) ☐

COMMENTS:

RECEIVING INSPECTION

IR SEQUENCE NO.	DISP. CODE	AREA	LOCATION	ACTION TAKEN TO PREVENT RECURRENCE:

REJECT VALIDATION — INITIAL _____ DATE _____

SUPPLIER NOTIFIED — INITIAL _____ DATE _____

PROCUREMENT ASSURANCE

DO NOT WRITE BELOW THIS LINE

- ☐ FOR INFO ONLY - SUPPLIER ☐
- ☐ EXTERNAL C.A.R. ☐
- ☐ FOR INFO ONLY - INTERNAL ☐
- ☐ INTERNAL C.A.R. ☐
- ☐ ☐

SIGNATURE _____ DATE _____

FORM [illegible]

ROUTE TO_____

TEXAS INSTRUMENTS

ATTLEBORO, MASSACHUSETTS 02703

REPORT OF DISCREPANT IN-PROCESS MATERIAL

No. 017509

DWG NO. & NAME		REV.	INSPECTOR	DATE	Mfg. Supervision Review:
27225-4	E9898 Kapton		8012-0	5-2-94	
SOURCE	DEVICE		PROD. CODE	QUANTITY	
DuPont	6565		042	1 Reel	

ITEM	ATTRIBUTE/REQUIREMENT	ACTUAL	MINOR	MAJ	REJ	CRIT
	Should be free of any lines	lines on kapton				

MAT'L/PROD. CONTROL

☐ CHECK INVENTORY AT (LOCATION) _____
☐ PART/MATERIAL IN SHORT SUPPLY

PRIORITY ☐ 1 ☐ 2 ☐ 3

COMMENTS:

PLANNER: | SIGNATURE: | DATE:

MRB ENGINEERING DISPOSITION

☐ RETURN TO SUPPLIER
☐ REWORK AT TI
☐ SCRAP AT TI
☐ SCRAP
☒ DEVIATE (L.A.D.)

COMMENTS:

NOTE — IF DISP. OTHER THAN RTS - MRB CORRECTIVE ACTION MUST BE COMPLETED

MRB SIGNATURES		DATE
PURCHASING		
MFG ENG	[signature]	5/4/94
QRA ENG	[signature]	5/4/94
MFG MGR		
DIE MGR	[signature]	5/4/94
QRA MGR		

REWORK PROCEDURE: (MFG./ENG.)

ESTIMATED TIME _____

REWORK COMPLETE
OK
BY
ACTUAL MFG. HOURS
GOOD PCS. REMAINING

INSPECTION AFTER REWORK	SAMP	AQ	RE	SCRP	INSPECTOR	DATE	QRA ENG. (Signature required if rej.)

MRB CORRECTIVE ACTION

TI
- ☐ — CHANGE DRAWING/SPEC (DRAWING MUST BE ATTACHED)
- ☒ — USE ENCLOSED SAMPLES AS ACCEPTABLE VISUAL STANDARDS
- ☐ — OTHER (EXPLAIN)

SUPPLIER
- ☐ — PROVIDE CORRECTIVE ACTION WITH FORMAL RESPONSE
- ☐ — SUBMIT INSPECTION DATA WITH FUTURE SHIPMENTS
- ☐ — CONDUCT CAPABILITY STUDY AND SUBMIT TO ENGINEERING
- ☐ — OTHER (EXPLAIN)

COMMENTS:
Bob Duffy will cut a sample area from reel to make new acceptance visual standard.

RECEIVING INSPECTION

M RECEIVER NO.	DISP. CODE:	AREA	LOCATION	ACTION TAKEN TO PREVENT RECURRENCE:

REJECT VALIDATION — INITIAL _____ DATE _____

SUPPLIER NOTIFIED — INITIAL _____ DATE _____

PROCUREMENT ASSURANCE

DO NOT WRITE BELOW THIS LINE

- ☐ FOR INFO ONLY - SUPPLIER
- ☐ EXTERNAL C.A.R.
- ☐ FOR INFO ONLY - INTERNAL
- ☐ INTERNAL C.A.R.
- ☐

SIGNATURE _____ DATE _____

FORM 8308

TI-NHTSA 018451

ROUTE TO: _____

TEXAS INSTRUMENTS
ATTLEBORO, MASSACHUSETTS 02703

REPORT OF DISCREPANT IN-PROCESS MATERIAL

No. 017506

37225-4

PRD NO. & NAME	SPD certified	REV.	INSPECTOR	DATE	Mfg. Supervision Review:
LBS NO SWITCH			75190	7-13-94	
SOURCE: T.I. DUPONT	DEVICE: 047		PROD. CODE	QUANTITY: 9	

ITEM	ATTRIBUTE/REQUIREMENT	ACTUAL	MINOR	MAJ	MIN	DISP
	KARTON SHOULD NOT HAVE LINES ON IT.	LINES ON KARTON IN M.O. SWITCHES	9		9	
		KARTON MEASURES .00045 TO .00075 ON LASER PROFILOMETER 7/13/94				

MAT'L/PROD. CONTROL REFERENCE VENDOR STANDARD # PSM-037

☐ CHECK INVENTORY AT (LOCATION) _____
☐ PARTS/MATERIAL IN SHORT SUPPLY

PRIORITY ☐1 ☐2 ☐3

COMMENTS:

PLANNER: _____ SIGNATURE _____ DATE _____

MRB ENGINEERING DISPOSITION

- ☐ RETURN TO SUPPLIER
- ☐ REWORK AT TI
- ☐ SORT AT TI
- ☐ SCRAP TBD
- ☑ DEVIATE (U A I)

NOTE — IF DISP. OTHER THAN RTS - MRB CORRECTIVE ACTION MUST BE COMPLETED

COMMENTS:
Burn in Switches into 1 cycle for SOAK CYCLE TEST to Determine if Karton Will Crack or Fuse.

MRB SIGNATURES		DATE
PURCHASING		
MFG ENG	D. Sethi	8/10/94
QRA ENG	R.A.K. Pillai	7/26/94
DE LDR		
DE MGR	J. McCluskey	8/10/94
QRA MGR		

REWORK PROCEDURE: (MFG/ENG.) DEVICES PASS 1,000 K CYCLES/PDQ4

ESTIMATED TIME: _____

REWORK COMPLETE: ON _____ BY _____ ACTUAL STD. HOURS _____ GOOD FOR REMARKS

INSPECTION AFTER REWORK	MINOR	MAJ	MIN	DISP	INSPECTOR	DATE	QRA ENG. (Mandatory method 5 only)

MRB CORRECTIVE ACTION

TI
- ☐ — CHANGE DRAWING/SPEC (DRAWING MUST BE ATTACHED)
- ☐ — USE ENCLOSED SAMPLES AS ACCEPTABLE VISUAL STANDARDS
- ☐ — OTHER (EXPLAIN)

SUPPLIER
- ☐ — PROVIDE CORRECTIVE ACTION WITH FORMAL RESPONSE
- ☐ — SUBMIT INSPECTION DATA WITH FUTURE SHIPMENTS
- ☐ — CONDUCT CAPABILITY STUDY AND SUBMIT TO ENGINEERING
- ☐ — OTHER (EXPLAIN)

COMMENTS:
Disposition pending Above TBD Results

RECEIVING INSPECTION

SEQUENCE NO.	DEP. CODE	AREA	LOCATION	ACTION TAKEN TO PREVENT RECURRENCE

REJECT VALIDATION — INITIAL _____ DATE _____

SUPPLIER NOTIFIED — INITIAL _____ DATE _____

PROCUREMENT ASSURANCE

DO NOT WRITE BELOW THIS LINE

- ☐ FOR INFO ONLY - SUPPLIER
- ☐ EXTERNAL C.A.R.
- ☐ FOR INFO ONLY - INTERNAL
- ☐ INTERNAL C.A.R.

SIGNATURE _____ DATE _____

FORM 2167F

SUPPLIER ALERT

BOB DUFFY MS: 11-11
TEXAS INSTRUMENTS INC.
P.O. Box 2964
34 FOREST STREET
ATTLEBORO MA 02703-0964

TEL: 508-236-1453
FAX: 508-236-3768
E-MAIL: bduffy@klixon.mc.ti.com

DATE PREPARED: 6-May-96

SUPPLIER: EI Dupont

DRAWING REV:

PART NUMBER: 27225-4

PART NAME: Kapton Strip

QUANTITY: 1 Reel

This notice is being issued by the PSM Materials Review Board to inform you that parts inspected on the date shown above were found to contain unacceptable dimensions and/or conditions as outlined below. Even though no formal rejection has been issued, it is expected that you will review your process(es) or system(s) in order to identify areas that will improve the acceptability of your product.

SPECIFICATION: Workmanship

ACTUAL: The core of the reel is buckled.
We are unable to place core on the feeding mechanism of our Switch Assembly Machine

INSPECTION METHOD Visual

COMMENTS:

INSPECTED BY: Bob Duffy
VALIDATED BY:

ID NUMBER: DUPO-601

Reference R.D.I.D.M Number: 022682

ROUTE TO _____

TEXAS INSTRUMENTS
ATTLEBORO, MASSACHUSETTS

REPORT OF DISCREPANT IN-PROCESS MATERIAL

No. 022682

DWG NO. & NAME	☐ SPC CERTIFIED	REV.	INSPECTOR	DATE	Mfg. Supervision Review:
27225-4 KAPTON STRIP		W	4446	4/30/96	

SOURCE	DEVICE	PROD. CODE	QUANTITY
FT DURANT	4SR8	047	1 REEL

ITEM	ATTRIBUTE/REQUIREMENT	ACTUAL	#INSP	AC	RE	#DEF
	WORKMANSHIP	CODE BUCKLED - CONNOT FIT REEL INTO MACHINE	1	0	1	1

MATL/PROD. CONTROL — REWRITTEN AS SUPPLIER ALERT # DUP08601 - 6MAY96 - RKD

☐ CHECK INVENTORY AT (LOCATION) _____
☐ PART/MATERIAL IN SHORT SUPPLY

PRIORITY ☐ 1 ☐ 2 ☐ 3

COMMENTS:

PLANNER: | SIGNATURE | DATE

MRB ENGINEERING DISPOSITION

☐ RETURN TO SUPPLIER
☐ REWORK AT TI
☐ SORT AT TI
☐ SCRAP
☐ DEVIATE (U A I)

COMMENTS:

NOTE — IF DISP. OTHER THAN RTS - MRB CORRECTIVE ACTION MUST BE COMPLETED

MRB SIGNATURES	DATE
PURCHASING	
MFG ENG	
QRA ENG	Ronald K Duff 5/6/96
MS MGR	
DIE MGR	
QRA MGR	

REWORK PROCEDURE: (MFG./ENG.)

ESTIMATED TIME _____

REWORK COMPLETE ON _____ BY _____ ACTUAL STD. HOURS _____ GOOD POS. REMARKS _____

INSPECTION AFTER REWORK	#INSP	AC	RE	#DEF	INSPECTOR	DATE	QRA ENG. (Signature required if mfg.)

MRB CORRECTIVE ACTION

TI
- — CHANGE DRAWING/SPEC (CONCESSION MUST BE ATTACHED) ☐
- — USE ENCLOSED SAMPLES AS ACCEPTABLE VISUAL STANDARDS ☐
- — OTHER (EXPLAIN) ☐

SUPPLIER
- — PROVIDE CORRECTIVE ACTION WITH FORMAL RESPONSE ☐
- — SUBMIT INSPECTION DATA WITH FUTURE SHIPMENTS ☐
- — CONDUCT CAPABILITY STUDY AND SUBMIT TO ENGINEERING ☐
- — OTHER (EXPLAIN) ☐

COMMENTS:

RECEIVING INSPECTION

RESIDUANCE NO.	DISP. CODE	AREA	LOCATION	ACTION TAKEN TO PREVENT RECURRENCE:

REJECT VALIDATION — INITIAL _____ DATE _____

SUPPLIER NOTIFIED — INITIAL _____ DATE _____

PROCUREMENT ASSURANCE

DO NOT WRITE BELOW THIS LINE

- ☐ FOR INFO ONLY - SUPPLIER ☐
- ☐ EXTERNAL Q.A.R. ☐
- ☐ FOR INFO ONLY - INTERNAL ☐
- ☐ INTERNAL Q.A.R. ☐
- ☐ ☐

SIGNATURE _____ DATE _____

FORM 8679

TI-NHTSA 018454

M9509

TEST NO. 147337

TECHNICAL SERVICE LABS

LOG NO. 10744

TEST NO. 147337

[redacted]

REPORT OF RESULTS:

DATE RECEIVED _____ DATE OUT Complete 4-20-98 Cobb

TECHNICIAN	EK		
HOURS WORKED *	FTIR #2		
PROCEDURE USED	TSL-C-060	TSL-M-10 17	
	07-10711		

*PCC I.D.

MC=325	TM=431	CLKE=122	FACIL=514
PC=127	WIRE=432	CAN=954	FACIL=521
VERS=166	EPD=821	AD DEV=266	FACIL=531
AFCC=483	PEP=822	EMCD=877	STAFF=655
IMD=430	CSD=635		

DISTRIBUTION: White and Yellow - Lab Pink - Requestor

Kill, Beth

From: Kill, Beth
Sent: Tuesday, April 14, 1998 11:50 AM
To: Souza, Ron
Cc: Almeida, Andrea; Su, Rose; Silvarto, John
Subject: TSL # 147937, Compare old and new lots of Kapton

Objective:
Compare different lots of DuPont Kapton. The new material is much darker than material received in the past. Confirm that the new material is Kapton and that it has the same properties as the older material.

Results:
FT-IR spectroscopy confirms that both the old and new lots of Kapton strip have the same chemical composition. Both produced matches with polyimide, with match factors over 80%. Visual comparison of the IR spectra shows they are the same. I will forward the IR spectral data by internal mail.

I have forwarded the samples to the metallography lab for a tensile test and for thickness measurement. The remainder will go to the special projects lab for thimble characterization. Please call if you have any questions.

Regards,
Beth

Ext. 3069 MS 10-16 Fax 1670

TEXAS INSTRUMENTS INC.
METALLOGRAPHY LAB, MS 10-15
ATTLEBORO, MASS. 02703

#15 2" GAUGE LENGTH STRAIGHT PULL
W/O EXTENSOMETER

Test type: Tensile

Instron Corporation
Series IX Automated Materials Testing System 8.06
Test Date: 28 Apr 1998

Operator name: STEVE CUMB

Sample Identification: 147337
Interface Type: Data Systems Adapter
Machine Parameters of test:
Sample Rate (pts/sec): 16.206
Crosshead Speed (in/min): 2.0000
Full Scale Load Range (lbs): 200.0000

Sample Type: ASTM

Humidity (%): 80
Temperature (deg. F): 73

Dimensions:

	Spec. 1	Spec. 2
Width (in)	.75000	.75000
Thickness (in)	.00300	.00300
Spec gauge len (in)	1.9913	1.9913
Grip distance (in)	2.0000	2.0000

Sample comments:

Specimen Number	TEST#\DIR.	TENSILE LOAD (LBS)	TENSILE STRENGTH (KPSI)
1	NEW	43.7	19.4
2	OLD	44.0	19.6