EA02025

TEXAS INSTRUMENTS, INC.'S

09/10/03 LETTER TO ODI

REQUEST 10

BOX 13

PART A – G

PART D

DuPont High Performance Films
P.O. Box 99
Tel: 740-474-3724
Fax: 740-474-3680

June 19, 1998

Cc: K. Fladger
S. Sharp

Erin Dulac
Texas Instruments, Inc.
MS 23-04
34 Forest Street
Attleboro, MA 02703

Erin,

Enclosed you will find the Kapton® Process Control Plans for each film type you use.

Please let Khadijah or me know if further quality documentation is required

Sincerely,

Thomas E. Clyde
Marketing & Development Manager
High Performance Films

Enc.

HPF-CP-0001
Effective Date: 06/10/98
Expiration Date: 06/10/00

CONTROLLED COPY

Kapton(r) Process Control Plan
Product: 200HN

Process Area	Process Parameters	Product Characteristics	Product/Process Specifications	Evaluation Method	Frequency	Reaction Plan
Receiving Raw Materials	Per OP-TF-100, OP-TF-101	Physical Properties	Per individual raw material specifications	Vendor Certificate of Analysis, Certificate of Conformance, Lab measurements	Each Lot	Identify and segregate affected material pending disposition; notify supplier; enter into the CAR system
Solvent Recycle	Per SR-SOC-DEHY, SR-SOC-DMAC, SR-SOC-SYLTHERM, SR-SOC-TOT	Purity	Per SR-AP-003, SR-SOC-004 and reactivated solvent specifications	The area will release based on lab results. SR-AP-003, SR-AP-004	Each Lot Per SR-AP-006	Adjust to aim, Per SR-AP-003, SR-AP-004, SR-AP-005
Polymerization (Chemical Area)	Per CH2-SOC-HPF, CH-SOC-KA1MU	"A" & "B" Grade Variables per CH2-SOC-HPF	Per CH2-SOC-HPF, OP-CH-210	Screen readouts and observed values per SOC	Per FP Batch #	Adjust to aim; identify and segregate affected material per AP-CH-005
Casting	Per K1 or K2-SOC-200HNH, End Use Code - 820	"A" Grade Variables and per K1 or K2-SOC-200HNH	K1 or K2-SOC-200HNH, Sample Slip, Windup Chart	Release per Lab Spec, Camera System, TP-E-2.1, 2.2, 2.3, 200HNH-GEN	Each Roll Break	Adjust to aim per AP-E-0001, AP-E-0003, identify and segregate; enter into CAR system
Semi-Finished Product Release	Per OP-QC-0001	Physical Properties	Per 200HNH-GEN	Release per Lab Spec	Each Roll Break	OP-QC-0001, Lab Specs
Finishing Area	Per Slitting Chart, SCPI-0004, SCPI-0031	Per End Use Code - 820, Per PSRS-0001	Per SCPI-0004, SCPI-0031	Visual Inspection per Slitting Chart	Each Roll Break	Reject rolls not meeting PSRS. Inform slitting operator of results
Released by Finishing Area Inspectors	Per End Use Code - 820, Per PSRS-0001	Per End Use Code - 820, Per PSRS-0001	Per PSRS-0001, End Use Code - 820	Visual Inspection per Slitting Chart	Each Roll Break, Visual Inspection per Slitting Chart	Reject rolls not meeting PSRS. Inform slitting operator of results
Packing / Shipping	PSCH - PI50, Numeric Pack Code - 712, Computer Graphics	Per roll I.D., O.D., & width, Rolls per Container, CSZN Codes	Per numeric Pack Code - 712	Visual Inspection per pack method	Each order	Identify affected material, notify supplier, enter into CAR system

Approvals:

Area Supt. - HPF Manufacturing — June 8, 1998 — Date

Area Supt. - HPF Integrated Operations — 6/8/98 — Date

TL-NHTSA 017922

HPF-CP-0002
Effective Date: 06/10/98
Expiration Date: 06/10/00

CONTROLLED COPY

Kapton(r) Process Control Plan
Product: 300HN

Process Area	Process Parameters	Product Characteristics	Product/Process Specifications	Evaluation Method	Frequency	Reaction Plan
Receiving Raw Materials	Per OP-TF-100, OP-TF-101	Physical Properties	Per individual raw material specifications	Vendor Certificate of Analysis, Certificate of Conformance, Lab measurements	Each Lot	Identify and segregate affected material pending disposition; notify supplier; enter into the CAR system
Solvent Recycle	Per SR-SOC-DEHY, SR-SOC-DMAC, SR-SOC-SYLTHERM, SR-SOC-TOT	Purity	Per SR-AP-003, SR-SOC-004 and recovered solvent specifications	The area will release based on lab results. SR-AP-003, SR-AP-004	Each Lot Per SR-AP-006	Adjust to aim, Per SR-AP-003, SR-AP-004, SR-AP-005
Polymerization (Chemical Area)	Per CH2-SOC-HPP, CH-SOC-KASMU	"A" & "B" Grade Variables per CH2-SOC-HPP	Per CH2-SOC-HPP, OP-CH-210	Screen readouts and observed values per SOC	Per PP Batch #	Adjust to aim; identify and segregate affected material per AP-CH-005
Casting	Per K1 or K2-SOC-300HNH, End Use Code - 820	"A" Grade Variables and per K1 or K2-SOC-300HNH	K1 or K2-SOC-300HNH, Sample Slip, Windup Chart	Release per Lab Specs, Camera System, TP-K-2.1, 2.2, 2.3, 300HNH-DIA	Each Roll Break	Adjust to aim per AP-K-0001, AP-K-0003, identify and segregate, enter into CAR system
Semi-Finished Product Release	Per OP-QC-0001	Physical Properties	Per 300HNH-DIA	Release per Lab Specs	Each Roll Break	OP-QC-0001, Lab Specs
Finishing Area	Per Slitting Chart, SCPI-0004, SCPI-0031	Per End Use Code - 820, Per PSRS-0001	Per SCPI- 0004, SCPI-0031	Visual Inspection per Slitting Chart	Each Roll Break	Reject rolls not meeting PSRS. Inform slitting operator of results
Released by Finishing Area Inspectors	Per End Use Code - 820, Per PSRS-0001	Per End Use Code - 820, Per PSRS-0001	Per PSRS-0001, End Use Code - 820	Visual Inspection per Slitting Chart	Each Roll Break, Visual Inspection per Slitting Chart	Reject rolls not meeting PSRS. Inform slitting operator of results
Packing / Shipping	PICS - F150, Numeric Pack Code - 71Z, Computer Graphics	Per roll I.D., O.D., & width, Rolls per Container, CEZN Codes	Per numeric Pack Code - 71Z	Visual Inspection per pack method	Each order	Identify affected material, notify supplier, enter into CAR system

Approvals:

Greg Sparks — Area Supt. - HPF Manufacturing — June 8, 1998 — Date

Cheryl A. Yarnoch — Area Supt. - HPF Integrated Operations — 6/8/98 — Date

TI-NHTSA 017923

HPF-CP-0003
Effective Date: 06/10/98
Expiration Date: 06/10/00

CONTROLLED COPY

Kapton(r) Process Control Plan
Product: 500HN

Process Area	Process Parameters	Product Characteristics	Product/Process Specifications	Evaluation Method	Frequency	Reaction Plan
Receiving Raw Materials	Per OP-TF-100, OP-TF-101	Physical Properties	Per individual raw material specifications	Vendor Certificate of Analysis, Certificate of Conformance, Lab measurements	Each Lot	Identify and segregate affected material pending disposition; notify supplier; enter into the CAR system
Solvent Recycle	Per SR-SOC-DEHY, SR-SOC-DMAC, SR-SOC-SYLTHERM, SR-SOC-TOT	Purity	Per SR-AP-003, SR-SOC-004 and recovered solvent specifications	The area will release based on lab results. SR-AP-003, SR-AP-004	Each Lot Per SR-AP-005	Adjust to aim, Per SR-AP-003, SR-AP-004, SR-AP-005
Polymerization (Chemical Area)	Per CH2-SOC-HPP, CH-SOC-KASMU	"A" & "B" Grade Variables per CH2-SOC-HPP	Per CH2-SOC-HPP, OP-CH-210	Rheon readouts and observed values per SOC	Per PP Batch #	Adjust to aim; identify and segregate affected material per AP-CH-005
Casting	Per K1 or K2-SOC-500HNH, End Use Code - 820	"A" Grade Variables and per K1-SOC-500HNH, K2-SOC-500HNH	K1-SOC-500HNH, K2-SOC-500HNH, Sample Slip, Window Chart	Release per Lab Spec, Camera System, TF-K-2.1, 2.2, 2.3, 500HNH-GEN	Each Roll Break	Adjust to aim per AP-K-0001, AP-K-0003, identify and segregate; enter into CAR system
Semi-Finished Product Release	Per OP-QC-0001	Physical Properties	Per 500HNH-CTS	Release per Lab Specs	Each Roll Break	OP-QC-0001, Lab Specs
Finishing Area	Per Slitting Chart, SCPI-0004, SCPI-0031	Per End Use Code - 820, Per FSRS-0001	Per SCPI- 0004, SCPI-0031	Visual Inspection per Slitting Chart	Each Roll Break	Reject rolls not meeting FSRS. Inform slitting operator of results
Released by Finishing Area Inspectors	Per End Use Code - 820, Per FSRS-0001	Per End Use Code - 820, Per FSRS-0001	Per FSRS-0001, End Use Code - 820	Visual Inspection per Slitting Chart	Each Roll Break, Visual Inspection per Slitting Chart	Reject rolls not meeting FSRS. Inform slitting operator of results
Packing / Shipping	PICH - F130, Numeric Pack Code - 71Z, Computer Graphics	Per roll I.D., O.D., & width, Rolls per Container, CEZN Codes	Per numeric Pack Code - 71Z	Visual Inspection per pack method	Each order	Identify affected material, notify supplier, enter into CAR system

Approvals:

Area Supt. - HPF Manufacturing — June 8, 1998 — Date

Area Supt. - HPF Integrated Operations — 6/8/98 — Date

TI-NHTSA 017924

HPF-CP-0004
Effective Date: 06/10/98
Expiration Date: 06/10/00

CONTROLLED COPY

Kapton(r) Process Control Plan
Product: 300FN929

Process Area	Process Parameters	Product Characteristics	Product/Process Specifications	Evaluation Method	Frequency	Reaction Plan
Receiving Raw Materials	Per OP-TP-100, OP-TP-101	Physical Properties	Per individual raw material specifications	Vendor Certificate of Analysis, Certificate of Conformance, Lab measurements	Each Lot	Identify and segregate affected material pending disposition; notify supplier; enter into the CAR system
Solvent Recycle	Per SR-SOC-DEBY, SR-SOC-DMAC, SR-SOC-SYLTHERM, SR-SOC-TOT	Purity	Per SR-AP-003, SR-SOC-004 and reserved solvent specifications	The area will release based on lab results SR-AP-005, SR-AP-004	Each Lot Per SR-AP-006	Adjust to aim, Per SR-AP-003, SR-AP-004, SR-AP-005
Polymerization (Chemical Area)	Per CH2-SOC-HPP, CH-SOC-KASMU	"A" & "B" Grade Variables per CH2-SOC-HPP	Per CH2-SOC-HPP, OP-CH-210	Screen readouts and observed values per SOC	Per PP Batch #	Adjust to aim; identify and segregate affected material per AP-CH-005
Casting	Per K1-SOC-300HNH-LAM, End Use Code - 820	"A" Grade Variables and per K1-SOC-200HNH-LAM	K1-SOC-300HNH-LAM, Sample Slip, Wiring Chart	Release per Lab Specs, Camera System, TP-K-2.1, 2.2, 2.3,	Each Roll Break	Adjust to aim per AP-K-0001, AP-K-0003, identify and segregate; enter into CAR system
Semi-Finished Product Release	Per OP-QC-0001	Physical Properties	Spec 300HNH-LAM, 300EC20, 300FN929	Release per Lab Specs	Each Roll Break	OP-QC-0001, Lab Specs
Finishing Area	Per SOC-CKL34-300FN929, Slitting Chart, SCPI-0004, SCPI-0031	Per "A" & "B" grade variables, End Use Code - 820	Per SOC-CKL34-300FN929, SCPI-0004, SCPI-0031	Release per Lab Specs, Visual Inspection	Each Roll Break, Each Slit Roll	Identify and segregate affected material, notify laminator operator, adjust to aim per SOC
Released by Finishing Area Inspectors	Per End Use Code - 820, PSRS-0001	Per End Use Code - 820, PSRS-0001	Per End Use Code - 820, PSRS-0001	Visual Inspection	Each Slit Roll	Reject slit roll not meeting PSRS, inform slitting operator
Packing / Shipping	PICS - FI50, Numeric Pack Code - 71Z, Computer Graphics	Per roll I.D., O.D., & width, Rolls per Container, CSZN Codes	Per numeric Pack Code - 71Z	Visual Inspection per pack method	Each order	Identify affected material, notify supplier, enter into CAR system

Approvals:

Area Supt. - HPF Manufacturing — Date: June 8, 1998

Area Supt. - HPF Integrated Operations — Date: 6/8/98

TI-NHTSA 017925

HPF-CP-0005
Effective Date: 06/10/98
Expiration Date: 06/10/00

CONTROLLED COPY

Kapton(r) Process Control Plan
Product: 500FN131

Process Area	Process Parameters	Product Characteristics	Product/Process Specifications	Evaluation Method	Frequency	Reaction Plan
Receiving Raw Materials	Per OP-TP-100, OP-TP-101	Physical Properties	Per individual raw material specifications	Vendor Certificate of Analysis, Certificate of Conformance, Lab measurements	Each Lot	Identify and segregate affected material pending disposition; notify supplier; enter into the CAR system
Solvent Recycle	Per HR-SOC-DEHY, HR-SOC-DMAC, HR-SOC-SYLTHERM, HR-SOC-TOT	Purity	Per HR-AP-003, HR-SOC-004 and recovered solvent specifications	The area will release based on lab results. HR-AP-003, HR-AP-004	Each Lot Per HR-AP-006	Adjust to aim, Per HR-AP-003, HR-AP-004, HR-AP-005
Polymerization (Chemical Area)	Per CH2-SOC-HPF, CH-SOC-KA5M3	"A" & "B" Grade Variables per CH2-SOC-HPF	Per CH2-SOC-HPF, OP-CH-210	Known residuals and observed values per SOC	Per PF Batch #	Adjust to aim; identify and segregate affected material per AP-CH-005
Casting	Per K1-SOC300/HNH-DIA, End Use Code - 820	"A" Grade Variables used per K3-SOC-300HNH-DIA	K1-SOC-300HNH-DIA, Sample Slip, Winding Chart	Release per Lab Specs, Camera System, TP-K-2.1, 2.2, 2.3	Each Roll Break	Adjust to aim per AP-K-0001, AP-K-0003, identify and segregate, enter into CAR system
Semi-Finished Product Release	Per OP-QC-0001	Physical Properties	Spec 300HNH-DIA, MBEC20, 500FN-1311.	Release per Lab Specs	Each Roll Break	OP-QC-0001, Lab Specs
Finishing Area	Per SOC-CELM-500FN131, Slitting Chart	Per "A" & "B" grade variables per SOC, End Use Code - 820	Per SOC-CELM-500FN131, SCPI-0004, SCPI-0031	Release per Lab Specs, Visual Inspection	Each Roll Break, Each Slit Roll	Identify and segregate affected material, notify laminator operator, adjust to aim per SOC
Released by Finishing Area Inspectors	Per End Use Code - 820	Per End Use Code - 820	Per FSRS-0001	Visual Inspection	Each Slit Roll	Reject slit roll not meeting FSRS, inform slitting operator
Packing / Shipping	PICS - FI50, Numonic Pack Code - 71Z, Computer Graphics	Per roll I.D., O.D., & width, Rolls per Container, CHZN Codes	Per numeric Pack Code - 71Z	Visual Inspection per pack method	Each order	Identify affected material, notify supplier, enter into CAR system

Approvals:

Greg Sanko — Area Supt. - HPF Manufacturing — June 8, 1998 — Date

Cheryl A. Yarnoch — Area Supt. - HPF Integrated Operations — 6/8/98 — Date

TI-MHTSA 017926

PRESS RELEASE

WILMINGTON DE, MAY 13 -- DuPont Engineering Plastics announced today that it experienced a fire on May 7 at the hexamethylenediamine (HMD) unit at its Orange, Texas plant. HMD is a key intermediate in the production of Zytel® and Minlon® engineering resins.

"We're very grateful that no one was injured in the fire and there was no adverse environmental impact resulting from it," said Diane Gulyas, Global Director Zytel® resins. "And we deeply regret how this will affect our customers."

As a result of this force majeure event, DuPont production of HMD will be reduced approximately 50 percent for six weeks in North America. Availability of DuPont Zytel® and Minlon® resins will be directly affected and will vary by specific product, depending on inventories and production capabilities.

"We've advised our customers that our remaining supply will be allocated on a fair and reasonable basis," Gulyas said. "We're extremely concerned about the impact of this event on the marketplace and are doing everything we can to help our customers through this difficult period."

The situation is extremely complex and it could be several days before the impact on specific products and market segments will be known. The company will work with its customers on an individual basis as the situation becomes more clear.

REGARDS,

MIKE CRICKENBERGER
AMERICAS ZYTEL(r) BUSINESS MGR

ROUTE TO: _____

TEXAS INSTRUMENTS

ATTLEBORO, MASSACHUSETTS 02703

REPORT OF DISCREPANT IN-PROCESS MATERIAL

No. 033831

DWG NO. & NAME	☐ SPC CHECKED	REV.	INSPECTOR	DATE	Mfg. Supervision Review:

SOURCE	DEVICE	PROD. CODE	QUANTITY

ITEM	ATTRIBUTE/REQUIREMENT	ACTUAL	MINOR	AC	RE	MAJOR

MATL/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:

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

MRB SIGNATURES

PURCHASING	
MFG ENG.	
QRA ENG	
RE MGR	
DE MGR	
QRA MGR	

REWORK PROCEDURE: (MFG./ENG.)

ESTIMATED TIME _____

INSPECTION AFTER REWORK	MINOR	AC	RE	MAJOR	INSPECTION	DATE	DISPOSITION (ACCEPTED/REJECTED)

REWORK COMPLETE ON | BY | ACTUAL SITE HOURS | GOOD FOR REWORK

MRB CORRECTIVE ACTION

TI
- — CHANGE DRAWING/SPEC (COPIES 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

S RECEIVER NO.	DISP. CODE	AREA	LOCATION	ACTION TAKEN TO PREVENT RECURRENCE
9561	RTS	2	Cage	

REJECT VALIDATION INITIAL	DATE	SUPPLIER NOTIFIED INITIAL	DATE
	1-12		

PROCUREMENT ASSURANCE — DO NOT WRITE BELOW THIS LINE

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

SIGNATURE | DATE

FORM [illegible]

ROUTE TO U

TEXAS INSTRUMENTS
ATTLEBORO, MASSACHUSETTS 02703

REPORT OF DISCREPANT IN-PROCESS MATERIAL

No. 033831

DWG NO. & NAME	REV.	INSPECTOR	DATE	Mfg. Supervision Review:
KAPTON #272252		8085CA	5-20-98	KSMartin
SOURCE: 291 171011	DEVICE	PROD. CODE	QUANTITY: 2.2 lbs	

ITEM	ATTRIBUTE/REQUIREMENT	ACTUAL	SAMP	AQ	RE	#DEF
	Free from wrinkles or dents.	Wrinkles in strip also damage from dent				

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: WRINKLED KAPTON AND DENT IN ROLLS DENTS MAY HAVE CAUSED DURING SHIPPING.

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

MRB SIGNATURES		DATE
PURCHASING	[signature]	6/2/98
MFG ENG	[signature]	6/2/98
QRA ENG		
MFG MGR		
ENG MGR		
QRA MGR		

REWORK PROCEDURE: (MFG./ENG.)
MH 300133

ESTIMATED TIME ____

OPC = 20

REWORK COMPLETE ON / BY / ACTUAL STD. HOURS / GOOD FOR RESHIPPING

INSPECTION AFTER REWORK	SAMP	AQ	RE	#DEF	INSPECTOR	DATE	QRA ENG.

MRB CORRECTIVE ACTION

TI
— CHANGE DRAWING/SPEC (REVISION 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 8D FOR WRINKLES. NEED IMPROVED SOLUTION OVER SIMILAR 8D-TI JOINT

RECEIVING INSPECTION BUYER 507

RI SEQUENCE NO.	DISP. CODE	AREA	LOCATION
9561	RTS	P	Cage

SUBJECT VALIDATION: [signature] 6/2/98 — INITIAL / DATE

SUPPLIER NOTIFIED — INITIAL / DATE

ACTION TAKEN TO PREVENT RECURRENCE: [signature] 6/2/98 B39166

PROCUREMENT ASSURANCE

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

wrinkles

[signature] 6/29/98 — SIGNATURE / DATE

DO NOT WRITE BELOW THIS LINE

TI-NHTSA 017929

TEXAS INSTRUMENTS
ATTLEBORO, MASSACHUSETTS 02703

REPORT OF DISCREPANT IN-PROCESS MATERIAL

No. 033831

DWG NO. & NAME	SPC CERTIFIED	REV.	INSPECTOR	DATE	Mfg. Supervision Review:
[redacted] 272252	☐		9045/A	5-20-98	LS Martin
SOURCE: 291 171011	DEVICE		PROD. CODE	QUANTITY: 2,2 lbs	

ITEM	ATTRIBUTE/REQUIREMENT	ACTUAL	#INSP	AC	RE	#DEF
	Free from wrinkles or dents.	Wrinkles in strip also damage from dent				

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: WRINKLED KAPTON AND DENT IN ROLL. DENTS MAY HAVE CAUSED DURING SHIPPING.

MRB SIGNATURES		DATE
PURCHASING	[signature]	6/1/98
MRB ENG	[signature]	6/1/98
QRA ENG		
MFG MGR		
CM MGR		
QRA MGR		

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

REWORK PROCEDURE: (MFG./ENG.)

MH 300133

ESTIMATED TIME ________

OPC = 20

REWORK COMPLETE: ON / BY / ACTUAL STD. HOURS / SCRAP POS. REMAINING

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

MRB CORRECTIVE ACTION

TI
— CHANGE DRAWING/SPEC (COMMON 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: TRAVELER 2D FOR WRINKLES. NEED IMPROVED SOLUTION OVER SIMILAR DETECTION

RECEIVING INSPECTION Buyer 507

R.I. SEQUENCE NO.	DISP. CODE	AREA	LOCATION	ACTION TAKEN TO PREVENT RECURRENCE
9561	RTS	4	Cage	

REJECT VALIDATION: [signature] 6/2/98 — 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 02070

TI-NHTSA 017930

ROUTE TO_____

TEXAS INSTRUMENTS

ATTLEBORO, MASSACHUSETTS 02703

REPORT OF DISCREPANT IN-PROCESS MATERIAL

No. 033831

DWG NO. & NAME	☐ SPC CONTROL	REV.	INSPECTOR	DATE	Mfg. Supervision Review:
SOURCE	DEVICE		PROD. CODE	QUANTITY	

ITEM	ATTRIBUTE/REQUIREMENT	ACTUAL	#NISP	AC	RE	#DISP

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:

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

MRB SIGNATURES	DATE
PURCHASING	
MFG MGR	
QRA MGR	
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	#REJ	INSPECTOR	DATE	QRA SIG. (Sampling method if rel.)

MRB CORRECTIVE ACTION

TI
— CHANGE DRAWING/SPEC (DESIGN 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

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

REJECT VALIDATION — INITIAL _____ DATE _____

SUPPLIER NOTIFIED — INITIAL _____ DATE _____

PROCUREMENT ASSURANCE

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

DO NOT WRITE BELOW THIS LINE

SIGNATURE _____ DATE _____

TI-NHTSA 017931

FORM 8827A

DMR S-2129 Rev

PURCHASED MATERIAL RELEASE NO. B 37136

P.O. 5008310187

L.P.

BUYER Darlene Sanville

PHONE: (508) 236- 3163

TEXAS INSTRUMENTS
INCORPORATED
MATERIALS & CONTROLS GROUP
ATTLEBORO, MA. 02703

DUNS NO. 00480 0685

Vendor: The material originally ordered on our Purchase Order is being returned for the reason(s) indicated below, reference your returns authorization No.: 01120

TI REJECTION NO. 033832

VENDOR NUMBER	VENDOR TERMS	PAY DATE
171811	0/07	✓

SHIPPING MEMO	DEBIT MEMO
☐ SHIPPING ORDER ONLY NOT A PURCHASE ORDER!	☐ CREDIT ONLY. NO REPLACEMENT NECESSARY.
☐ REPAIR/PROCESS - CONTACT BUYER WITH PRICE AND AVAILABILITY FOR PO.	☐ CREDIT OUT ACCOUNT. SHIP AND REBILL FOR SATISFACTORY MATERIAL.

☐ RETURN SHIPMENT TO:

SHIP TO: E-Z Internal Materials
XX Depot
US RT.23S
Circleville, OH. 43113

CHARGE TO:

DELIVERY REQUIRED:

QUANTITY	PART NUMBER-SERIAL NUMBER	DESCRIPTION	ACCOUNT NUMBER	PRICE	EXTENSION
7.21lb	27225-2	Kapton	050-1301-0060	$97.50/lb	$702.00

TI-NHTSA 017932

PACKING SLIP MUST ACCOMPANY ALL SHIPMENTS. IN ORDER TO AVOID DELAYS IN PAYMENT, THE PURCHASE ORDER NUMBER AND PROPER SHIP TO ADDRESS MUST BE CLEARLY MARKED ON ALL PACKAGES.

TI SHIPPING		
APPROVED BY TRAFFIC	SHIPPED BY— DATE SHIPPED	SHIP ☐ ☐
WAYBILL NO./BL NO.	CARRIER	

VENDOR TRANSPORTATION INSTRUCTIONS

☐ This shipment is released freight collect F.O.B. origin. Any replacements made as a result of this PMR will be F.O.B. destination freight prepaid.

☐ This shipment is released freight prepaid F.O.B. destination. Return shipment freight collect F.O.B. origin per routing on P.O.

CLERICAL SERVICES RELEASE

BY Darlene Sanville DATE 7/6/98

REQUESTED EVALUATION OF MATERIAL

ROUTE TO _____

TEXAS INSTRUMENTS

ATTLEBORO, MASSACHUSETTS 02703

REPORT OF DISCREPANT IN-PROCESS MATERIAL

No. 033841

DWG NO. & NAME		REV.	INSPECTION	DATE	Mfg. Supervision Review:
2702252 Kapton	☐ SPC CONTROLLED		3053A	7-30-98	K St Martin
SOURCE	DEVICE		PROD. CODE	QUANTITY	
391				1 Roll	

ITEM	ATTRIBUTE/REQUIREMENT	ACTUAL	#INSP	AC	RE	#DEF
	SHOULD BE FREE OF WRINKLES	WRINKLES in Kapton STRIP	1			1

MATL/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: KAPTON DUST / CONTAMINATION FOUND ON BOTH SIDES OF FILM. DISPOSITION: DUST BELIEVED ON FILM ONLY.

NOTE — IF DISP. OTHER THAN R2S - MRB CORRECTIVE ACTION MUST BE COMPLETED

MRB SIGNATURES	DATE
PURCHASING	
MFG MGR	8/4/98
QRA ENG	
MAT MGR	
ENG MGR	
QRA MGR	

REWORK PROCEDURE: (MFG./ENG.)

ATTEMPT TO CUT IK AND INSPECT PARTS FOR WRINKLES, IF OK - USE REEL IF NOT - REJECT REEL

ESTIMATED TIME: _____

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

REWORK COMPLETE

OK
BY
ACTUAL MFG. HOURS
GOOD FOR REMARKS

MRB CORRECTIVE ACTION

TI
— CHANGE DRAWING/SPEC (COPY/ON 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

IF REQUIRED NO.	DISP. CODE	AREA	LOCATION	ACTION TAKEN TO PREVENT RECURRENCE

REJECT VALIDATION — INITIAL _____ DATE _____

SUPPLIER NOTIFIED — INITIAL _____ DATE _____

PROCUREMENT ASSURANCE

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

SIGNATURE _____ DATE _____

DO NOT WRITE BELOW THIS LINE

FORM 8567F

TI-NHTSA 017933

ROUTE TO _____

TEXAS INSTRUMENTS
ATTLEBORO, MASSACHUSETTS 02703

REPORT OF DISCREPANT IN-PROCESS MATERIAL

No. 033857

DWG NO. & NAME	APP CERTIFIED	REV.	INSPECTOR	DATE	Mfg. Supervision Review:
7935-2 Kapton	☐		33194	7.26.94	
SOURCE: Kapton 171011	DEVICE		PROD. CODE	QUANTITY: 7.6 lbs	Marion Lodge

ITEM	ATTRIBUTE/REQUIREMENT	ACTUAL	MINOR	MAJ	REJ	CRIT
	Should be free of wrinkles	Wrinkles in Kapton Strip	1			1
	Roll IK - Wrinkles are still present in Cut Kapton Pieces.					

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: ATTEMPTED TO USE. RESULTED IN WRINKLED KAPTON.

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

MRB SIGNATURES	DATE
PURCHASING	
MFG MGR	8/24/94
QRA MGR	
MAT MGR	
DE MGR	
QRA MGR	

REWORK PROCEDURE: (MFG./ENG.)

DFC = 20

ESTIMATED TIME _____

m 4442957

REWORK COMPLETE: DT _____ BY _____ ACTUAL ENG. HOURS _____ GOOD FOR REWORK _____

INSPECTION AFTER REWORK	ACCEPT	AQ	REJ	SORT	INSPECTOR	DATE	QRA MGR. SIGNATURE (TI)

MRB CORRECTIVE ACTION

TI
- ☐ — CHANGE DRAWING/SPEC (DRAWN 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: SD

RECEIVING INSPECTION — Buyer 507

RI RECEIPT NO.	DISP. CODE	AREA	LOCATION	ACTION TAKEN TO PREVENT RECURRENCE:
9553	RTS	F	Cage	

AGENT VALIDATION: INITIAL Jennifer Lilley DATE 9/9/94

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 33570

TI-NHTSA 017934

DATE: 7/27/98

TEXAS INSTRUMENTS

FACSIMILE TRANSMITTAL

TO: ALMA PERRY

FROM: DARLENE SANVILLE
TEXAS INSTRUMENTS. INC. MS 23-04

Phone Number: (508) 236-3363
FAX Number: (508) 236-3131

SUBJECT: DEBT MEMO re 37066

Total number of pages (including header page):

TI-NHTSA 017935

DRM 8-31570 7/84

PURCHASED MATERIAL RELEASE NO. B 37066

P.O. 5000830107

R.P.

BUYER Darlene Sawville

PHONE: (508) 236- 3363

TEXAS INSTRUMENTS
INCORPORATED
MATERIALS & CONTROLS GROUP
ATTLEBORO, MA. 02703

DUNS NO. 00406 8886

Vendor: The material originally ordered on our Purchase Order is being returned for the reason(s) indicated below, reference your return authorization No.: 81100

TI REJECTION NO. 013831

VENDOR NUMBER	VENDOR TERMS	PAY DATE
171 011	06 UP	✓

SHIPPING MEMO

- ☐ SHIPPING ORDER ONLY NOT A PURCHASE ORDER!
- ☐ REPAIR/PROCESS - CONTACT BUYER WITH PRICE AND AVAILABILITY FOR PO.

DEBIT MEMO

- ☐ CREDIT ONLY. NO REPLACEMENT NECESSARY.
- ☐ CREDIT OUT ACCOUNT. SHIP AND REBILL FOR SATISFACTORY MATERIAL.

☐ RETURN SHIPMENT TO:

DELIVERY REQUIRED:

SHIP TO:
K-T Returned Materials
Bi Dupont
US RT. 23S
Circleville, OH 43113

CHARGE TO:

QUANTITY		PART NUMBER-SERIAL NUMBER	DESCRIPTION	ACCOUNT NUMBER	PRICE		EXTENSION
7.2	lb	27215-2	Kapton	830-1301-0040	$97.50/lb		$702.00

Shipped 11/10/88

MH 360133

PACKING SLIP MUST ACCOMPANY ALL SHIPMENTS. IN ORDER TO AVOID DELAYS IN PAYMENT, THE PURCHASE ORDER NUMBER AND PROPER SHIP TO ADDRESS MUST BE CLEARLY MARKED ON ALL PACKAGES.

TI-NHTSA 017936

TI SHIPPING			VENDOR TRANSPORTATION INSTRUCTIONS	CLERICAL SERVICES RELEASE
APPROVED BY TRAFFIC	SHIPPED BY — DATE SHIPPED	SHIP ☐ PREPAID ☐ COLLECT	☐ This shipment is released freight collect F.O.B. origin. Any reallowances made as a result of this PMR will be F.O.B. destination freight prepaid. ☐ This shipment is released freight prepaid F.O.B. destination. Return shipment freight collect F.O.B. origin per routing on P.O.	BY Darlene Sawville DATE 8/18/88 BUYER'S SIGNATURE
WAYBILL NO./BL NO.	CARRIER			SIGNATURE OF ALLOCATION OF MATERIAL

FORM F-21370 7/84

PURCHASED MATERIAL RELEASE NO. B 37066

P.O. 5000320107

R.P.

BUYER Darlene Sawville

PHONE: (508) 236- 3363

TEXAS INSTRUMENTS
INCORPORATED
MATERIALS & CONTROLS GROUP
ATTLEBORO, MA. 02703

DUNS NO.: 00496 0868

Vendor: The material originally ordered on our Purchase Order is being returned for the reason(s) indicated below, reference your return authorization No.: 81180

TI REJECTION NO. 033831

VENDOR NUMBER	VENDOR TERMS	PAY DATE
171 311	Net 30	✓

SHIPPING MEMO	DEBIT MEMO
☐ SHIPPING ORDER ONLY NOT A PURCHASE ORDER!	☐ CREDIT ONLY, NO REPLACEMENT NECESSARY.
☐ REPAIR/PROCESS - CONTACT BUYER WITH PRICE AND AVAILABILITY FOR PO.	☐ CREDIT OUT ACCOUNT. SHIP AND REBILL FOR SATISFACTORY MATERIAL.

☐ RETURN SHIPMENT TO:

DELIVERY REQUIRED:

SHIP TO:
K-T Returned Materials
KI Depot
US RT. 23S
Circleville, OH 43113

CHARGE TO:

QUANTITY	PART NUMBER-SERIAL NUMBER	DESCRIPTION	ACCOUNT NUMBER	PRICE	EXTENSION
7.2 lb	27225-2	Kapton	050-1301-0060	997.50/lb	$782.80

PACKING SLIP MUST ACCOMPANY ALL SHIPMENTS. IN ORDER TO AVOID DELAYS IN PAYMENT, PURCHASE ORDER NUMBER AND PACKER SLIP TO ADDRESS MUST BE CLEARLY MARKED ON ALL PACKAGES.

TI SHIPPING		
APPROVED BY TRAFFIC	SHIPPED BY — DATE SHIPPED	SHIP ☐ ☐
WAYBILL NO./BL NO.	CARRIER	

VENDOR TRANSPORTATION INSTRUCTIONS

☐ This shipment is released freight collect F.O.B. origin. Any reshipments made as a result of this PMR will be F.O.B. destination freight prepaid.

☐ This shipment is released freight prepaid F.O.B. destination. Return shipment freight collect F.O.B. origin per routing on P.O.

CLERICAL SERVICES RELEASE

BY Darlene Sawville DATE 5/18/98
BUYER'S SIGNATURE

SUBMITTED BY/LOCATION OF MATERIAL

TI-NHTSA 017937

TEXAS INSTRUMENTS
INCORPORATED
MATERIALS & CONTROLS GROUP
ATTLEBORO, MA. [illegible]

DUNS NO. [illegible]

FORM [illegible]

PURCHASED MATERIAL RELEASE NO. B 36953

P.O. [illegible]

R.P.

BUYER [illegible]

PHONE [illegible] [illegible]

Vendor: The material originally ordered on our Purchase Order is being returned for the reason(s) indicated below, reference your return authorization No.: [illegible]

TI REJECTION NO. [illegible]

VENDOR NUMBER	VENDOR TERMS	PAY DATE
[illegible]		

SHIPPING MEMO	DEBIT MEMO
☐ SHIPPING ORDER ONLY NOT A PURCHASE ORDER!	[illegible] CREDIT ONLY. NO REPLACEMENT [illegible]
☐ REPAIR/PROCESS - CONTACT BUYER WITH PRICE AND AVAILABILITY FOR P.O.	☐ [illegible] OUR ACCOUNT. SHIP AND [illegible] FOR SATISFACTORY [illegible]

☐ RETURN SHIPMENT TO:

SHIP TO: [illegible]

CHARGE TO:

DELIVERY REQUIRED:

QUANTITY		PART NUMBER-SERIAL NUMBER	DESCRIPTION	ACCOUNT NUMBER	PRICE		EXTENSION
2.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]

[illegible]

TI SHIPPING		SHIP	VENDOR TRANSPORTATION INSTRUCTIONS	CLERICAL SERVICES RELEASE
APPROVED BY TRAFFIC	SHIPPED BY — DATE SHIPPED	☐ [illegible]	☐ This shipment is released freight collect F.O.B. origin. Any shipments made as a result of this PMR will be F.O.B. destination freight prepaid.	BY [illegible] DATE [illegible]
WAYBILL NO./B/L NO.	CARRIER	☐ [illegible]	☐ This shipment is released freight prepaid F.O.B. destination. Return shipment freight collect F.O.B. origin per routing on P.O.	REQUESTED BY/LOCATION OF MATERIAL

TI-NHTSA 017938

09/08/98 14:13 :01/01 NO:529

DuPont Circleville
P.O. Box 69
Circleville, OH 43113

DuPont Circleville

DATE: 9-8-98

FROM: R. Butterfield

TO: DARLENE DANVILLE *

FAX: 508-236-3131

PLEASE SUPPLY THE FOLLOWING INFORMATION TO PROCESS RETURN AND ISSUE RR #

PURCHASE ORDER # 500830107-1

RELEASE # IF APPLIES

DUPONT ORDER #

DUPONT ITEM #

PRODUCT 500FN131 - 31/32" width

QUANTITY ROLLS / POUNDS 1 - 2.6#

SHIPDATE

REASON FOR REJECT wrinkles

* Darlene — Can I get a copy of your debit memo on this? TIA
Thanks

PLEASE RETURN COMPLETED FORM TO KT CUSTOMER SERVICE FAX NO. - 800-879-4481 OR 614-474-0909
THIS FORM WILL BE SENT BACK TO YOU ONCE A RR NUMBER IS ASSIGNED.

RETURN NUMBER 91154

MATERIAL RETURN ADDRESS:

K-T RETURNED MATERIALS
ATTN. JEANETTE GERHART
DUPONT CO.
US RT 23S
CIRCLEVILLE, OH 43113

PLEASE HAVE FREIGHT COMPANY BILL DUPONT.
ACCEPTANCE OF RETURN REQUEST AND /OR ISSUING OF CREDIT , (IF ANY) IS DETERMINED BY DUPONT.

ROUTE TO______

TEXAS INSTRUMENTS
ATTLEBORO, MASSACHUSETTS

REPORT OF DISCREPANT IN-PROCESS MATERIAL

No. 033857

DWG NO. & NAME	REV.	INSPECTOR	DATE	Mfg. Supervision Review:
21225-2 Kapton		25194	9-26-91	Marlon Lopp
SOURCE	DEVICE	PROD. CODE	QUANTITY 2.6 lbs	

ITEM	ATTRIBUTE/REQUIREMENT	ACTUAL	SMP	AC	RE	DEF
	Should be free of wrinkles	Wrinkles in Kapton strip				
	Rew IR - Wrinkles are still present in cut Kapton pieces.					

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: ATTEMPTED TO USE: RESULTED IN WRINKLED KAPTON.

MRB SIGNATURES		DATE
PURCHASING	[signature]	9/26/91
MFG ENG	[signature]	9/26/91
QRA ENG		
MFG MGR		
DIE MGR		
QRA MGR		

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

REWORK PROCEDURE: (MFG./ENG.)

ESTIMATED TIME ______

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

INSPECTION AFTER REWORK	SMP	AC	RE	DEF	INSPECTOR	DATE	QRA ENG. (Remaining)

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: 8D

RECEIVING INSPECTION

SEQUENCE NO. | DEF. 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

TI-NHTSA 017940

DuPont High Performance Films

October 14, 1998

Ron Souza
Texas Instruments
34 Forest Street
MS 11-09
Attleboro, MA 02730-0964

Dear Ron,

Sorry for the delay in my response. At this time Kapton® does not have a color specification for the product Texas Instruments purchases.

Kapton® film can and does vary in color for several reasons. The two primary reasons are raw materials and heat exposure. Kapton®'s raw materials, although controlled very tightly, can vary to some degree. Any minor change in purity is magnified by its high curing temperature. Kapton® is cured above 400 degrees Celsius. The film that Texas Instruments purchases is a grade of film that is designed to have as even properties as possible in all directions.

To make this film we must adjust Kapton®'s heat profile on a cation. These adjustments to our process cause the film's color to vary.

I hope this has helped to clarify the color differences. If you have any questions, or believe the color differences are having an impact on your product, please let me know.

Sincerely,

Mark McAlees
Kapton® Technical Service Representative

Texas Instruments Incorporated

Ron Souza
34 Forest Street
P.O. Box 2964
Mail Stop 11-08
Attleboro MA 02703-0964

(508) 236-3988

TEXAS
INSTRUMENTS

April 2, 1998

Mr.Mark McAlees
E.I. Dupont De Nemours & Co.
US ROUTE 23 South and Dupont Rd.
Circleville, OH 43113-0000
740-474-0725

Dear Mr McAlees,

Enclosed is some sample material for your analysis. We have noted a significant shade change in the Kapton material identified a TI part number 27225-4 (Dupont 300HN). We are not overly concerned, the color difference as we might be if this is as a result of a material change or material error.

The attached sample are identified as "old" and "new" The "new" material is darker than the old.

Our concern is heightened by the fact that we sell our product to the automotive industry, and whenever they see something different, they question it and then make us jump through hoops. I would like to avoid this if we can, or at least be prepared to respond.

Your assistance in providing a clear explanation of what it is we are witnessing would be appreciated.

Sincerely,
Ron Souza
Ron Souza

DuPont Corporate
P.O. Box 49
Circleville, OH 43113

DuPont Circleville

Brian Digg
34 Forest Street
Attleboro MA, 02703
Fax 508-236-3586

February 23, 1999

Dear Brian

I have checked our records and have not found any test data on Kapton® FN type film and break field exposure in our files.

I have also spoken to several colleagues and we are unaware of any issues with the Kapton® FN that has been used in automotive diaphragms.

Sorry we can not be of more help If you have any questions please call.

Regards,

Mark McAlees
Sr. Tech Service Rep Kapton®
740-474-0295

To: Brian	From: Mark
Co./Dept.: Retention	Co.
Phone #:	Phone #:
Fax #: 315-390-5165	

DuPont Circleville
[illegible]

DuPont Circleville

Brian Digg[illegible]
34 Forest Street
Attleboro MA, 02703
Fax 508-236-3536

February 23, 1999

Dear Brian

I have checked our records and have not found any test data on Kapton® FN type film and brake fluid exposure in our files.

I have also spoken to several colleagues and we are unaware of any issues with the Kapton® FN that has been used in automotive diaphragms.

Sorry we can not be of more help. If you have any questions please call.

Regards,

Mark McAlees
Sr. Tech Service Rep. Kapton®
740-474-6725

Post-it® Fax Note 7671	Date [illegible]
To [illegible]	From
Co./Dept. [illegible]	Co.
Phone #	Phone #
Fax # 315-390-[illegible]	

Summary of Chemical Properties
3/2/99

The following pages were supplied by Dupont and show chemical and physical properties for Teflon and Kapton. In summary, water will degrade the mechanical properties of Kapton, but Teflon is unaffected by water. This is the reason why the Teflon-Kapton-Teflon system was selected for Texas Instruments switch diaphragm (3 mil thick Kapton layer coated with 1 mil Teflon on both sides). Page 1 (marked with "A") indicates that the Teflon is non-reactive with water. While page 2 shows Teflon has a relatively low vapor transmission rate (marked with "B"). Page 3 shows how the mechanical properties of Kapton degrade with water and temperature exposure (marked with "C").

End of document.

Chemical Properties

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

In circumstances where end-use temperatures are close to the upper service limit 205°C (400°F), 30% sodium hydroxide, metal hydrides, aluminum chloride, ammonia, and certain amines ($R\text{-}NH_2$) may attack the film in a manner similar to molten alkali metals. Special testing is required when such extreme reducing or oxidizing conditions are evident.

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

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

The chemical substances listed in Table 6 are representative of those with which DuPont FEP film has been found to be nonreactive.

Table 6
Typical Chemicals with Which DuPont FEP Film is Nonreactive[1]

Abietic acid	Cyclohexanone	Hydrofluoric acid	Phenolic acid
Acetic acid	Dibenzyl phenaline	Hydrogen peroxide	Pin ene
Acetic anhydride	Dibutyl sebacate	Lead	Pin ene hydrate
Acetone	Diethyl carbonate	Magnesium chloride	Polyacrylic acids
Acetophenone	Diethyl ether	Mercury	Potassium acetate
Acrylic anhydride	Dimethyl formamide	Methyl ethyl ketone	Potassium hydroxide
Alkyl acetate	Di-isobutyl adipate	Methacrylic acid	Potassium permanganate
Alkyl methacrylate	Dimethylacetamide	Methanol	Pyridine
Aluminum chloride	Dimethylhydrazine, unsymmetrical	Methyl methacrylate	Soaps and detergents
Ammonia, liquid	Dioxane	Naphthalene	Sodium bromide
Ammonium chloride	Ethyl acetate	Naphthols	Sodium hypochlorite
Aniline	Ethyl alcohol	Nitric acid	Sodium peroxide
Benzaldehyde	Ethyl ether	Nitrobenzene	Solvents, aliphatic and petroleum[2]
Benzyl chloride	Ethyl formate	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	Tetrabromo methane
Bromine	Ferric phosphate	n-Octadecyl alcohol	Tetrachloro ethylene
n-Butyl amine	Fluoronaphthalene	Oils, animal and vegetable	Trichloroacetic acid
Butyl acetate	Fluoronitrobenzene	Ozone	Trichloroethylene
Butyl methacrylate	Formaldehyde	Perchloroethylene	Triethyl phosphate
Calcium chloride	Formic acid	Perfluorobenzamide	Triethanolamine
Carbon disulfide	Furane	Perfluorotoluene	Vinyl methacrylate
Casein	Gasoline	Phenol	Water
Chlorine	Hexamethylethene	Phosphoric acid	Xylene
Chloroform	Hexane	Phosphorus pentachloride	Zinc chloride
Chlorosulfonic acid	Hydrazine		
Chromic acid	Hydrochloric acid		
Cyclohexane			

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

[2] Some aromatic solvents may cause moderate swelling.

TEFLON FEP

Physical Properties

Absorption

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

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

Permeability

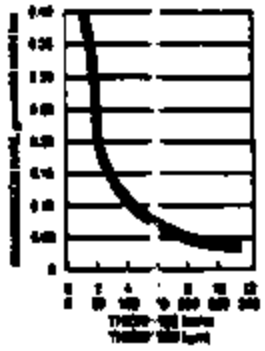
Many gases and vapors permeate FEP films at a much lower rate than for other thermoplastics (see Figure 12). In general, permeation increases with temperature, pressure, and surface contact area and decreases with increased film thickness. Table 6 lists rates at which various gases are transmitted through DuPont FEP fluorocarbon film, while Table 7 lists rates of vapor permeability for some representative substances. Note that the pressure for each material is its vapor pressure at the indicated temperature.

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

Gas	Permeability Rate* cm³/m²·s·Pa	Permeability Rate* in·cm/h·cm²·atm
Carbon Dioxide	28.9 × 10^{-8}	
Hydrogen	34.1 × 10^{-8}	
Nitrogen	5.6 × 10^{-8}	
Oxygen	11.8 × 10^{-8}	

*To convert to cm³/(100 in² 24 h·cm), multiply by 2.8645.

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



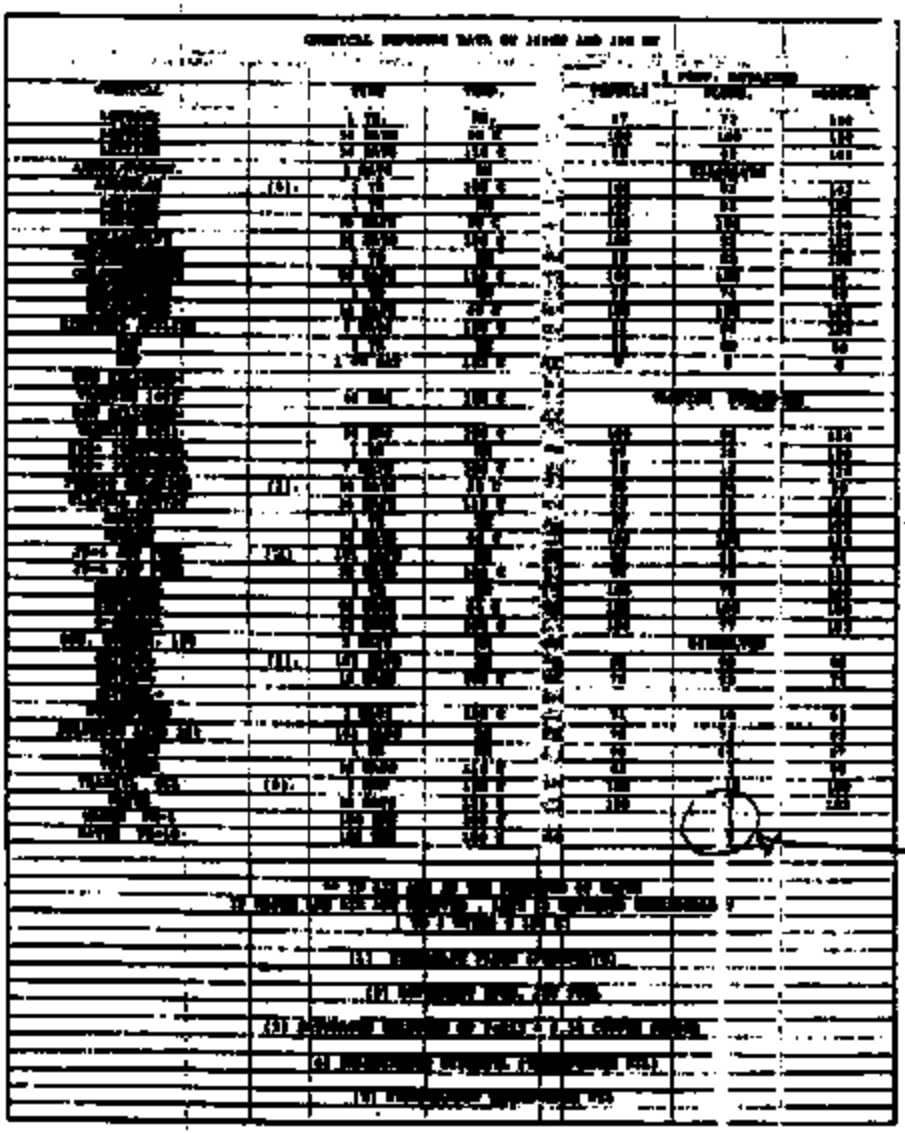
Notes: Values are average + only and not for specification purposes. To convert the permeation values for 100 in² 24 hours to 1 m², multiply by 15.5.

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

Vapor	Temperature °C	Temperature °F	Vapor Transmission Rate SI Unit* g/m²·h	Vapor Transmission Rate English Units* g/100 in²·d
Acetic Acid	38	100	6.3	0.41
Acetone	38	100	14.7	0.95
Benzene	38	100	9.9	0.64
Carbon Tetrachloride	38	100	4.8	0.31
Ethyl Acetate	38	100	11.7	0.76
Ethyl Alcohol	38	100	10.7	0.69
Freon® F-12	23	73	372.9	24.0
Hexane	38	100	8.7	0.56
Hydrochloric Acid	25	77	<0.2	<0.01
Nitric Acid (Red Fuming)	25	77	160.0	10.3
Sodium Hydroxide, 50%	25	77	<0.2	<0.01
Sulfuric Acid, 98%	25	77	3 × 10^{-4}	1 × 10^{-4}
Water	38	100	7.6	0.49

Page 2

CRITICAL EXPOSURE DATA ON KAPTON



Page 7

DUPONT

Date 2/25/99

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Circleville, OH 43113
HPF - SP Resin

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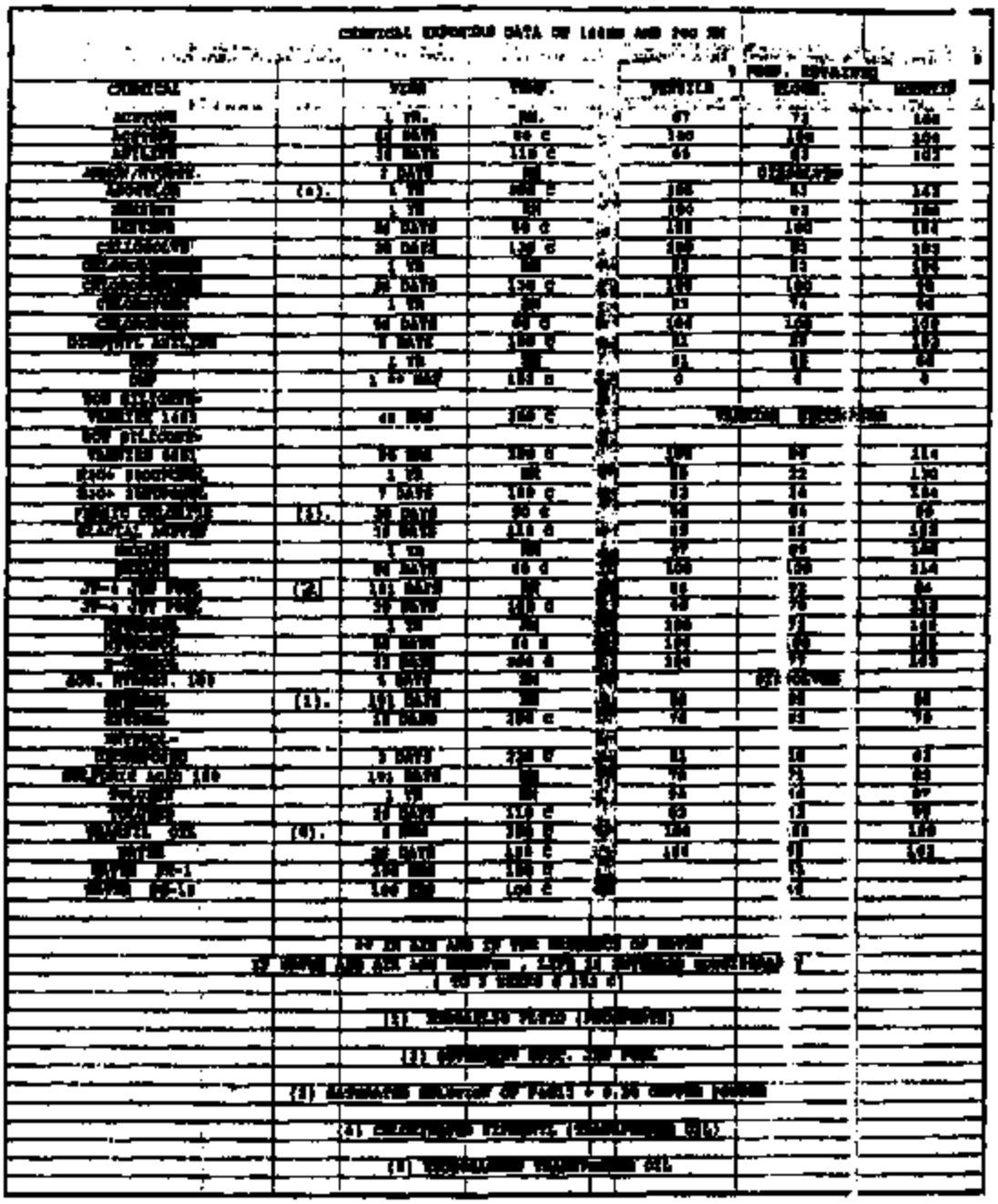
CHEMICAL RESISTANCE DATA ON KAPTON



TEFLON FEP

Chemical Properties

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

In circumstances where end-use temperatures are close to the upper service limit 205°C (400°F), 50% sodium hydroxide, metal hydrides, aluminum chloride, ammonia, and certain amines ($R\text{-}NH_2$) may attack the film in a manner similar to molten alkali metals. Special testing is required when such extreme reducing or oxidizing conditions are evident.

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

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

The chemical substances listed in Table 6 are representative of those with which DuPont FEP film has been found to be nonreactive.

Table 6
Typical Chemicals with Which DuPont FEP Film is Nonreactive*

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

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

**Some halogenated solvents may cause moderate swelling.

TEFLON FEP.

Physical Properties

Absorption

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

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

Permeability

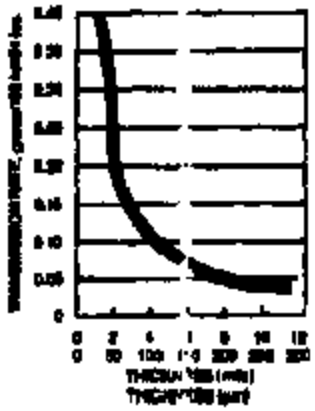
Many gases and vapors permeate FEP films at a much lower rate than for other thermoplastics (see Figure 13). In general, permeation increases with temperature, pressure, and surface contact area and decreases with increased film thickness. Table 6 lists rates at which various gases are transmitted through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

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

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

*To convert to cm³/(100 in²·24 h·atm), multiply by 0.6546.

Figure 13. Water Vapor Transmission Rate of DuPont FEP Film at 49°C (120°F) per ASTM E-96 (Modified)



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

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

Vapor	Temperature °C	Temperature °F	Vapor Transmission Rate SI Units* g/(m²·d)	Vapor Transmission Rate English Units g/(100 in²·d)
Acetic Acid	38	99	6.3	0.41
Acetone	38	99	14.7	0.95
Benzene	38	99	8.8	0.54
Carbon Tetrachloride	38	99	4.8	0.31
Ethyl Acetate	38	99	11.7	0.75
Ethyl Alcohol	38	99	10.7	0.69
Freon® F-12	23	73	372.0	24.0
Hexane	38	99	8.7	0.56
Hydrochloric Acid	28	77	<0.2	<0.01
Nitric Acid (Red Fuming)	25	77	160.0	10.5
Sodium Hydroxide, 50%	28	77	<0.2	<0.01
Sulfuric Acid, 98%	28	77	1 × 10⁻⁴	1 × 10⁻⁶
Water	38.5	101	7.0	0.40

Summary of Chemical Properties
3/2/99

The following pages were supplied by Dupont and show chemical and physical properties for Teflon and Kapton. In summary, water will degrade the mechanical properties of Kapton, but Teflon is unaffected by water. This is the reason why the Teflon-Kapton-Teflon system was selected for Texas Instruments switch diaphragm (3 mil thick Kapton layer coated with 1 mil Teflon on both sides). Page 1 (marked with "A") indicates that the Teflon is non-reactive with water. While page 2 shows Teflon has a relatively low vapor transmission rate (marked with "B"). Page 3 shows how the mechanical properties of Kapton degrade with water and temperature exposure (marked with "C").

End of document.

TEFLON

Chemical Properties

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

In circumstances where end-use temperatures are close to the upper service limit 205°C (400°F), 50% sodium hydroxide, metal hydrides, aluminum chloride, ammonia, and certain amines ($R\text{-}NH_2$) may attack the film in a manner similar to molten alkali metals. Special testing is required when such extreme reducing or oxidizing conditions are evident.

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

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

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

Table 5
Typical Chemicals with Which DuPont FEP Film is Nonreactive[a]

Abietic acid	Cyclohexanone	Hydrofluoric acid	Phthalic acid
Acetic acid	Dibutyl phthalate	Hydrogen peroxide	Pinene
Acetic anhydride	Dibutyl sebacate	Lead	Piperidine
Acetone	Diethyl carbonate	Magnesium chloride	Polyacrylonitrile
Acetophenone	Diethyl ether	Mercury	Potassium acetate
Acrylic anhydride	Dimethyl formamide	Methyl ethyl ketone	Potassium hydroxide
Allyl acetate	Di-isobutyl adipate	Methacrylic acid	Potassium permanganate
Allyl methacrylate	Dimethylformamide	Methanol	Pyridine
Aluminum chloride	Dimethylhydrazine, unsymmetrical	Methyl methacrylate	Soap and detergents
Ammonia, liquid	Dioxane	Naphthalene	Sodium hydroxide
Ammonium chloride	Ethyl acetate	Naphthols	Sodium hypochlorite
Aniline	Ethyl alcohol	Nitric acid	Sodium peroxide
Benzonitrile	Ethyl ether	Nitrobenzene	Solvents, aliphatic and aromatic[b]
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	Tetrachloroethylene
n-Butyl amine	Fluoronaphthalene	Oils, animal and vegetable	Trichloroacetic acid
Butyl acetate	Fluoronitrobenzene	Ozone	Trichloroethylene
Butyl methacrylate	Formaldehyde	Perchloroethylene	Triaryl phosphate
Calcium chloride	Formic acid	Pentachloro-benzamide	Triethanolamine
Carbon disulfide	Furane	Perfluorokylene	Vinyl methacrylate
Cesine	Gasoline	Phenol	Water (A)
Chlorine	Hexachloroethane	Phosphoric acid	Xylene
Chloroform	Hexane	Phosphorus pentachloride	Zinc chloride
Chlorosulfonic acid	Hydrazine		
Chromic acid	Hydrochloric acid		
Cyclohexane			

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

[b] Some halogenated solvents may cause moderate swelling.

TEFLON FEP

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.

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

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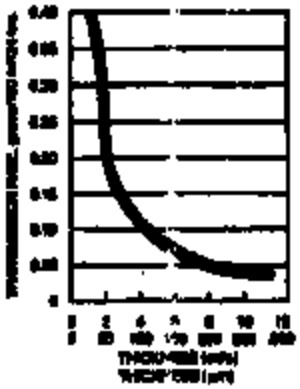
Typical Gas Permeability Rates of DuPont FEP Fluorocarbon Film, 25 µm (1 mil) Thickness
(Test Method: ASTM D-1434 at 25°C (77°F))

Gas	Permeability Rate* cm³/(m²·24 h·atm)
Carbon Dioxide	28.9 × 10³
Hydrogen	34.1 × 10³
Nitrogen	6.0 × 10³
Oxygen	11.8 × 10³

*To convert to cm³/(100 in² 24 h·atm), multiply by 0.6645.

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



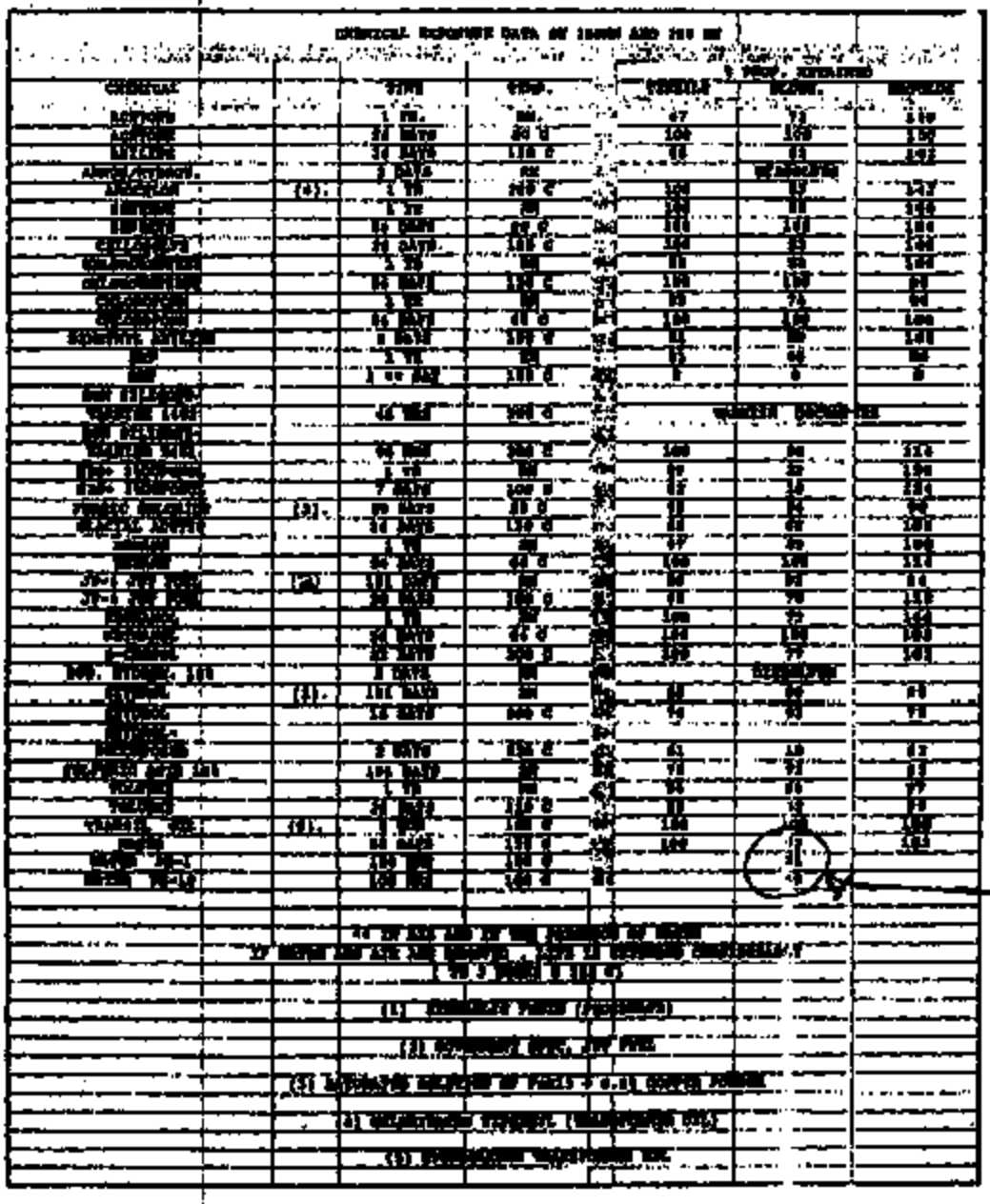
Notes: Values are averaged only and not for specification purposes. To convert the permeation values for 100 in² to those for 1 m², multiply by 15.5.

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

Vapor	Temperature °C	Temperature °F	Vapor Transmission Rate SI Units (g/m²·d)	Vapor Transmission Rate English Units (g/100 in²·d)
Acetic Acid	38	96	6.3	0.41
Acetone	38	96	14.7	0.95
Benzene	38	96	9.8	0.64
Carbon Tetrachloride	38	96	4.8	0.31
Ethyl Acetate	38	96	11.7	0.76
Ethyl Alcohol	38	96	10.7	0.69
Freon® F-12	23	73	372.0	24.0
Hexane	38	96	8.7	0.56
Hydrochloric Acid	38	77	<0.2	<0.01
Nitric Acid (Red Fuming)	20	77	160.0	10.3
Sodium Hydroxide, 50%	38	77	<0.2	<0.01
Sulfuric Acid, 98%	38	77	2×10^{-1}	1×10^{-2}
Water	38.6	103	7.0	0.45

(B)

CHEMICAL RESISTANCE DATA ON KAPTON



(C)

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Phone:
Fax phone: 908-236-3586
CC:

From:
JEFF WALSH
DUPONT
Phone: 740-474-0913
Fax phone: (740) 474-0244

REMARKS: ☐ Urgent ☑ For your review ☐ Reply ASAP ☐ Please comment

RESULTS OF OXALIC ACID TEST, TO 100 HRS ALONG WITH CONTROL SAMPLES,

Should you occur problems while sending, contact 740-474-0491 or 740-474-0242

CONFIDENTIALITY NOTE

Sample Identification: CONTROL Test Date: 10 May 1999

Out of 3 specimens, 0 excluded.
Sample comments: DOWN CONTROL

Specimen Number	STRESS AT MAX. LOAD (Kpsi)	% ELONG. AT MAX. LOAD (%)	MODULUS (USER LIMS 1.0-3.0) (Kpsi)	STRESS @ 3% ELONG (P3) (Kpsi)	STRESS @ 5% ELONG (P5) (Kpsi)	STRESS @ 50% ELON @ (P50) (Kpsi)	STRESS @THRESHOLD YIELD (Kpsi)	LOAD AT MAX.LOAD (Lbs)
1	34.74	77.84	451.0	9.644	13.14	29.14	22.31	52.11
2	30.83	97.82	439.2	9.897	13.08	29.06	22.21	50.24
3	36.31	79.06	462.4	9.799	13.23	29.30	22.41	52.97
Mean:	36.29	84.91	451.2	9.647	13.15	29.19	22.31	54.44
Standard Deviation:	2.21	11.20	11.6	.103	.06	.17	.10	3.32
Minimum:	34.74	77.84	439.2	9.897	13.08	29.06	22.21	52.11
Maximum:	36.83	97.82	462.4	9.799	13.23	29.30	22.41	50.24
Coef of Var:	6.10	13.19	2.58	1.06	.50	.57	.45	6.10

E.I. DUPONT
DUPONT ROAD
CIRCLEVILLE, OH 43113

Sample Identification: 100005 Test Date: 19 May 1999

Out of 3 specimens, 0 excluded.
Sample comments: SOAKED IN 0.5 % OXCALIC ACID SOLUTION @ ROOM TEMPERATURE

Specimen Number	STRESS AT MAX. LOAD (Kpsi)	% ELONG. AT MAX. LOAD (%)	MODULUS (USER LIM 1.0-3.0) (Kpsi)	STRESS @ 3% ELONG (FS) (Kpsi)	STRESS @ 4% ELONG (FS) (Kpsi)	STRESS @ 50% ELON @ (FSO) (Kpsi)	STRESS @THRESHOLD YIELD (Kpsi)	LOAD AT MAX.LOAD (lbs)
1	34.06	99.85	432.0	9.222	12.30	25.23	20.04	52.27
2	36.75	114.80	431.7	9.129	12.26	25.90	19.80	55.13
3	35.00	102.00	432.0	9.146	12.30	26.10	16.02	52.62
Mean:	35.54	105.60	431.9	9.166	12.32	26.16	18.09	53.34
Standard Deviation:	1.04	7.50	.2	.050	.06	.10	1.79	1.56
Minimum:	34.04	99.85	431.7	9.129	12.26	25.90	16.02	52.27
Maximum:	36.75	114.80	432.0	9.222	12.30	26.33	20.04	55.13
Cof of Var:	2.93	7.19	.05	.54	.51	.67	9.49	2.93

Sample Identification: [illegible] Test Date: 10 May 1999

Out of 3 specimens, 0 excluded.
Sample pretreated: [illegible] IN 5.0% OXALIC ACID SOLUTION @ ROOM TEMPERATURE

Specimen Number	STRESS AT MAX. LOAD (Kpsi)	% ELONG. AT MAX. LOAD (%)	MODULUS (USER LIMITS 1.0-3.0) (Kpsi)	STRESS @ 1% ELONG (FS) (Kpsi)	STRESS @ 0% ELONG (FS) (Kpsi)	STRESS @ 00% ELONG @ (PSO) (Kpsi)	STRESS @THRESHOLD YIELD (Kpsi)	LOAD AT MAX.LOAD (lbs)
1	34.37	98.20	437.6	9.107	12.38	26.10	18.63	51.34
2	38.00	102.40	439.2	9.220	12.34	26.02	19.40	52.62
3	33.87	91.80	439.2	9.290	12.42	26.31	19.07	50.36
Mean:	34.34	97.37	438.7	9.233	12.36	26.14	19.36	51.51
Standard Deviation:	.75	5.00	.9	.052	.05	.15	.45	1.13
Minimum:	33.87	91.80	437.6	9.107	12.31	26.02	18.63	50.36
Maximum:	35.00	102.40	439.2	9.290	12.42	26.31	19.07	52.62
Coef of Var:	2.20	5.53	.21	.56	.42	.57	3.37	2.20

Sample Identification: 100MPA Test Date: 10 May 1999

Out of 3 specimens, 0 excluded.
Sample comments: 300HR IN 0.5% OXALIC ACID SOLUTION @ 90 DEGREES C

Specimen Number	STRESS AT MAX. LOAD (Kpsi)	% ELONG. AT MAX. LOAD (%)	MODULUS (USER LIMS 1.0-3.0) (Kpsi)	STRESS @ 2% ELONG (F3) (Kpsi)	STRESS @ 5% ELONG (F6) (Kpsi)	STRESS @ 50% ELON G (F50) (Kpsi)	STRESS @THRESHOLD YIELD (Kpsi)	LOAD AT MAX.LOAD (lbs)
1	26.13	52.31	439.2	10.31	13.32	25.89	19.78	38.90
2	26.13	67.79	439.2	10.41	13.36	25.46	19.58	39.00
3	26.39	70.21	439.2	10.48	13.38	25.83	19.14	42.56
Mean:	26.95	60.11	439.2	10.40	13.35	25.52	19.48	40.02
Standard Deviation:	1.27	9.17	.0	.08	.03	.06	.27	1.91
Minimum:	25.93	52.31	439.2	10.31	13.32	25.46	19.14	38.90
Maximum:	26.39	70.21	439.2	10.48	13.38	25.89	19.78	42.56
Coef of Var:	4.73	15.26	.00	.79	.24	.25	1.39	4.73

Sample Identification: 100805 Test Date: 10 May 1999

Out of 3 specimens, 0 excluded.
Sample comments: 30MIN IN 5.0% OXALIC ACID SOLUTION @ 90 DEGREES C

Specimen Number	STRESS AT MAX. LOAD (Kpsi)	% ELONG. AT MAX. LOAD (%)	MODULUS (USER LIMS 1.0-3.0) (Kpsi)	STRESS @ 3% ELONG (FS) (Kpsi)	STRESS @ 5% ELONG (FS) (Kpsi)	STRESS @ 500 ELON G (FSO) (Kpsi)	STRESS AT THRESHOLD YIELD (Kpsi)	LOAD AT MAX.LOAD (lbs)
1	23.85	39.35	427.5	10.52	13.49	----------	19.30	35.31
2	24.73	44.30	432.8	10.46	13.45	----------	19.83	37.09
3	23.99	36.80	439.8	10.70	13.64	----------	16.72	35.98
Mean:	24.19	30.15	433.1	10.60	13.53	----------	18.36	36.13
Standard Deviation:	.89	5.60	6.2	.17	.10	----------	1.63	.89
Minimum:	23.85	33.35	427.5	10.46	13.45	----------	16.72	35.31
Maximum:	24.73	44.30	439.8	10.70	13.64	----------	19.30	37.09
Cof of Var:	2.46	16.68	1.43	1.61	.76	----------	7.79	2.46

Sample Identification: CONTROL Test Date: 10 May 1999

Out of 3 specimens, 0 excluded.
Sample comments: 990709I9 CONTROL

Specimen Number	STRESS at MAX. LOAD (Kpsi)	% ELONG. AT MAX. LOAD (%)	MODULUS (USER LIMS 1.0-3.0) (Kpsi)	STRESS @ 3% ELONG (FS) (Kpsi)	STRESS @ 5% ELONG (FS) (Kpsi)	STRESS @ 600 ELON @ (FS0) (Kpsi)	STRESS @THRESHOLD YIELD (Kpsi)	LOAD AT MAX.LOAD (lbs)
1	24.49	87.09	349.0	7.619	9.677	19.43	10.97	36.73
2	23.20	79.37	348.5	7.606	9.727	19.43	11.00	34.92
3	23.70	83.39	351.7	7.606	9.662	19.36	14.13	35.67
Mean:	23.80	83.55	347.7	7.634	9.689	19.41	13.97	35.77
Standard Deviation:	.61	4.27	6.4	.045	.034	.04	.17	.91
Minimum:	23.20	79.37	348.0	7.606	9.662	19.36	11.00	34.92
Maximum:	24.49	87.09	351.7	7.606	9.727	19.43	14.13	36.73
Cof of Var:	2.54	5.10	1.27	.59	.35	.20	1.20	2.54

Sample Identification: 104885 Test Date: 10 May 1999

Out of 3 specimens, 0 excluded.
Sample comments: 30MY0929 IN 0.8% OXALIC ACID SOLUTION @ ROOM TEMPERATURE

Specimen Number	STRESS AT MAX. LOAD (Kpsi)	% ELONG. AT MAX. LOAD (%)	MODULUS (USER LIMS 1.0-3.0) (Kpsi)	STRESS @ 3% ELONG (F3) (Kpsi)	STRESS @ 5% ELONG (F5) (Kpsi)	STRESS @ 99% ELON @ (F50) (Kpsi)	STRESS @THRESHOLD YIELD (Kpsi)	LOAD AT MAX.LOAD (lbs)
1	30.96	92.02	359.0	7.679	10.000	23.47	16.02	46.44
2	30.49	92.28	369.4	7.702	9.989	23.17	15.88	45.73
3	32.20	90.76	351.9	7.597	9.903	23.34	16.32	48.30
Mean:	31.21	91.35	360.1	7.659	9.965	23.33	16.07	46.82
Standard Deviation:	.88	3.83	10.2	.066	.054	.15	.22	1.32
Minimum:	30.49	92.02	351.9	7.597	9.903	23.17	15.88	45.73
Maximum:	32.20	90.76	369.8	7.702	10.000	23.47	16.32	48.30
Cof of Var:	2.83	4.06	2.81	.72	.55	.65	1.39	2.83

Sample Identification: 109HDS Test Date: 10 May 1999

Out of 3 specimens, 0 excluded.
Sample comments: 300FR929 IN 5.0% CHROMIC ACID SOLUTION @ ROOM TEMPERATURE

Specimen Number	STRESS AT MAX. LOAD (Kpsi)	% ELONG. AT MAX. LOAD (%)	MODULUS (USER LIM 1.0-3.0) (Kpsi)	STRESS @ 3% ELONG (FS) (Kpsi)	STRESS @ 5% ELONG (FS) (Kpsi)	STRESS @ 5% ELOG @ (FSO) (Kpsi)	STRESS @THRESHOLD YIELD (Kpsi)	LOAD AT MAX.LOAD (lbs)
1	31.02	88.97	360.0	7.729	10.10	23.93	16.02	46.54
2	31.89	88.45	361.2	7.799	10.20	24.36	16.85	47.39
3	30.82	85.00	365.8	7.830	10.24	24.26	16.95	45.78
Mean:	31.06	86.97	362.3	7.775	10.18	24.18	16.47	46.57
Standard Deviation:	.54	2.48	3.0	.054	.07	.22	.47	.80
Minimum:	30.62	85.00	360.0	7.729	10.10	23.93	16.02	45.78
Maximum:	31.59	88.45	365.8	7.830	10.24	24.36	16.95	47.39
Coef of Var:	1.73	3.08	.84	.72	.70	.93	2.85	1.73

Sample Identification: [illegible] Test Date: 10 May 1999

Out of 3 specimens, 0 excluded.
Sample comments: [illegible]

Specimen Number	STRESS AT MAX. LOAD (Kpsi)	% ELONG. AT MAX. LOAD (%)	MODULUS (USER LIMS 1.0-3.0) (Kpsi)	STRESS @ 3% ELONG (F3) (Kpsi)	STRESS @ 5% ELONG (F5) (Kpsi)	STRESS @ 50% ELON (F50) (Kpsi)	STRESS AT THRESHOLD YIELD (Kpsi)	LOAD AT MAX.LOAD (lbs)
1	24.22	57.42	366.0	8.809	11.12	23.12	15.31	36.54
2	23.29	51.41	366.0	8.774	11.06	23.05	15.91	34.93
3	24.93	63.02	354.1	8.730	11.01	23.01	16.02	37.39
Mean:	24.15	57.28	362.4	8.771	11.06	23.06	15.75	36.22
Standard Deviation:	.82	5.80	6.9	.002	.06	.06	.30	1.24
Minimum:	23.29	51.41	354.1	8.730	11.01	23.01	15.31	34.93
Maximum:	24.93	63.02	366.0	8.809	11.12	23.12	16.02	37.39
Cof of Var:	3.41	10.13	1.90	.98	.51	.26	2.42	3.41

Sample Identification: 100HB3 Test Date: 10 May 1999

Out of 3 specimens, 0 excluded.
Sample comments: 2000N929 IN 5.0% OXALIC ACID SOLUTION @ 90 DEGREES C

Specimen Number	STRESS AT MAX. LOAD (Kpsi)	% ELONG. AT MAX. LOAD (%)	MODULUS (USER LIMS 1.0-3.0) (Kpsi)	STRESS @ 30 ELONG (PS) (Kpsi)	STRESS @ 50 ELONG (PS) (Kpsi)	STRESS @ 600 ELONG @ (PS@) (Kpsi)	STRESS @THRESHOLD YIELD (Kpsi)	LOAD AT MAX.LOAD (lbs)
1	22.00	46.12	384.1	0.566	10.74	----------	15.20	33.12
2	20.70	36.06	384.0	0.622	10.75	----------	15.40	31.06
3	21.67	41.34	366.0	0.601	10.82	----------	15.31	32.21
Mean:	21.82	41.83	358.0	0.656	10.77	----------	16.39	32.13
Standard Deviation:	.69	4.68	6.9	.001	.05	----------	.08	1.03
Minimum:	20.70	36.06	384.0	0.622	10.74	----------	15.31	31.06
Maximum:	22.00	46.12	366.0	0.501	10.82	----------	15.40	33.12
Coef of Var:	3.21	11.28	1.92	.36	.43	----------	.55	3.21

Sample Identification: CONTROL Test Date: 10 May 1999

Out of 3 specimens, 0 excluded.
Sample comments: 500FW131 CONTROL

Specimen Number	STRESS AT MAX. LOAD (Kpsi)	% ELONG. AT MAX. LOAD (%)	MODULUS (SECN LINR 1.0-3.0) (Kpsi)	STRESS @ 3% ELONG (FS) (Kpsi)	STRESS @ 4% ELONG (FS) (Kpsi)	STRESS @ 50% ELON G (FS0) (Kpsi)	STRESS @THRESHOLD YIELD (Kpsi)	LOAD AT MAX.LOAD (lbs)
1	24.96	110.0	314.0	6.969	8.966	10.68	13.90	62.39
2	25.00	111.0	321.7	7.007	8.994	10.66	12.01	62.69
3	25.56	116.0	317.4	6.991	8.966	10.64	13.46	63.90
Mean:	25.20	112.9	317.8	6.989	8.972	10.63	13.18	63.00
Standard Deviation:	.32	3.4	3.9	.019	.020	.02	1.02	.80
Minimum:	24.96	110.0	314.0	6.969	8.966	10.68	12.01	62.39
Maximum:	25.56	116.0	321.7	7.007	8.994	10.64	13.90	63.90
Cof of Var:	1.27	3.01	1.21	.28	.23	.13	7.76	1.27

Sample Identification: [illegible] Test Date: 10 May 1999

Out of 3 specimens, 0 excluded.
Sample comments: [illegible]

Specimen Number	STRESS AT MAX. LOAD (Kpsi)	% ELONG. AT MAX. LOAD (%)	MODULUS (USER LIMS 1.0-3.0) (Kpsi)	STRESS @ 3% ELONG (FS) (Kpsi)	STRESS @ 4% ELONG (FS) (Kpsi)	STRESS @ 500 ELON G (FSO) (Kpsi)	STRESS @THRESHOLD YIELD (Kpsi)	LOAD AT MAX.LOAD (lbs)
1	26.21	123.0	299.7	6.420	8.426	10.49	13.62	65.52
2	24.04	104.4	296.3	6.136	8.214	10.25	13.26	60.09
3	25.24	116.9	306.7	6.327	8.296	10.24	13.38	63.11
Mean:	26.16	118.0	300.9	6.297	8.308	10.32	13.42	62.91
Standard Deviation:	1.09	9.8	5.3	.148	.108	.14	.18	2.72
Minimum:	24.04	104.4	296.3	6.136	8.214	10.24	13.26	60.09
Maximum:	26.21	123.0	306.7	6.438	8.426	10.49	13.62	65.52
Cof of Varr	4.32	8.58	1.76	1.36	1.38	.78	1.37	4.32

Sample Identification: 100005 Test Date: 10 May 1999

Out of 3 specimens, 0 excluded.
Sample comments: SOAKED IN 6.0% OXALIC ACID SOLUTION @ ROOM TEMPERATURE

Specimen Number	STRESS AT MAX. LOAD (Kpsi)	% ELONG. AT MAX. LOAD (%)	MODULUS (USER LIM% 1.0-3.0) (Kpsi)	STRESS @ 2% ELONG (F2) (Kpsi)	STRESS @ 5% ELONG (F5) (Kpsi)	STRESS @ 50% ELON (F50) (Kpsi)	STRESS @THRESHOLD YIELD (Kpsi)	LOAD AT MAX.LOAD (lbs)
1	25.82	119.8	297.5	6.377	8.378	10.27	13.46	63.89
2	25.88	118.9	306.5	6.372	8.164	10.28	13.51	63.69
3	25.72	121.6	300.2	6.370	8.376	10.24	13.18	64.20
Mean:	25.57	119.8	304.7	6.376	8.306	10.25	13.39	63.93
Standard Deviation:	.13	1.6	5.7	.176	.122	.02	.19	.32
Minimum:	25.88	118.8	297.8	6.372	8.164	10.24	13.18	63.69
Maximum:	25.72	121.6	300.2	6.370	8.376	10.28	13.54	64.20
Coef of Var:	.50	1.33	1.89	2.81	1.47	.12	1.42	.81

Sample Identification: 100003 Test Date: 10 May 1999

Out of 3 specimens, 0 excluded.
Sample comments: 50DFN131 IN 0.5% NITRIC ACID SOLUTION @ 90 DEGREES C

Specimen Number	STRESS AT MAX. LOAD (Kpsi)	% ELONG. AT MAX. LOAD (%)	MODULUS (USER LIMS 1.0-3.0) (Kpsi)	STRESS @ 3% ELONG (FS) (Kpsi)	STRESS @ 4% ELONG (FS) (Kpsi)	STRESS @ 5PT ELON @ (FS0) (Kpsi)	STRESS @ 0.2% OFFSET YIELD (Kpsi)	LOAD AT MAX.LOAD (lbs)
1	19.49	66.52	314.0	7.364	9.236	17.00	12.62	48.73
2	19.21	61.09	312.5	7.502	9.379	18.15	13.20	48.02
3	18.25	51.73	299.7	7.404	9.299	18.05	11.85	45.61
Mean:	18.98	59.78	309.1	7.422	9.304	18.03	12.59	47.46
Standard Deviation:	.65	7.48	8.2	.071	.072	.11	.73	1.63
Minimum:	18.25	51.73	299.7	7.364	9.236	17.00	11.85	45.61
Maximum:	19.49	66.52	314.0	7.502	9.379	18.15	13.20	48.73
Coef of Var:	3.44	12.51	2.64	.96	.78	.75	5.75	3.44

Sample Identification: 100HB0 Test Date: 09 May 1999

Out of 3 specimens, 0 excluded.
Sample comments: SOAKED IN 0.05 HCL ACID SOLUTION @ 90 DEGREES C

Specimen Number	STRESS AT MAX. LOAD (Kpsi)	% ELONG. AT MAX. LOAD (%)	MODULUS (USER LIM 1.0-3.0) (Kpsi)	STRESS @ 3% ELONG (PS) (Kpsi)	STRESS @ 5% ELONG (PS) (Kpsi)	STRESS @ 50% ELON % (PSO) (Kpsi)	STRESS @THRESHOLD YIELD (Kpsi)	LOAD AT MAX.LOAD (lbs)
1	17.00	38.04	313.8	7.429	9.312	----------	12.57	42.49
2	17.06	40.57	319.5	7.430	9.274	----------	11.33	42.69
3	17.34	42.72	310.1	7.410	9.276	----------	12.61	43.99
Mean:	17.30	40.71	314.4	7.426	9.287	----------	12.17	42.76
Standard Deviation:	.18	1.90	6.8	.014	.021	----------	.73	.91
Minimum:	17.00	38.04	310.1	7.410	9.274	----------	11.33	42.49
Maximum:	17.34	42.72	319.5	7.430	9.312	----------	12.61	43.99
Coef of Var:	.72	4.77	1.61	.19	.23	----------	6.01	.72

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ADDRESSEE (S): NAME	COMPANY/BUSINESS GROUP	FAX NUMBER
BRIAN PAGUE		508-236-3586

SENDER: NAME	BUSINESS SECTOR	LOCATION
JEFF WELLS		716-774-0913

4 PAGES TO FOLLOW THIS SHEET

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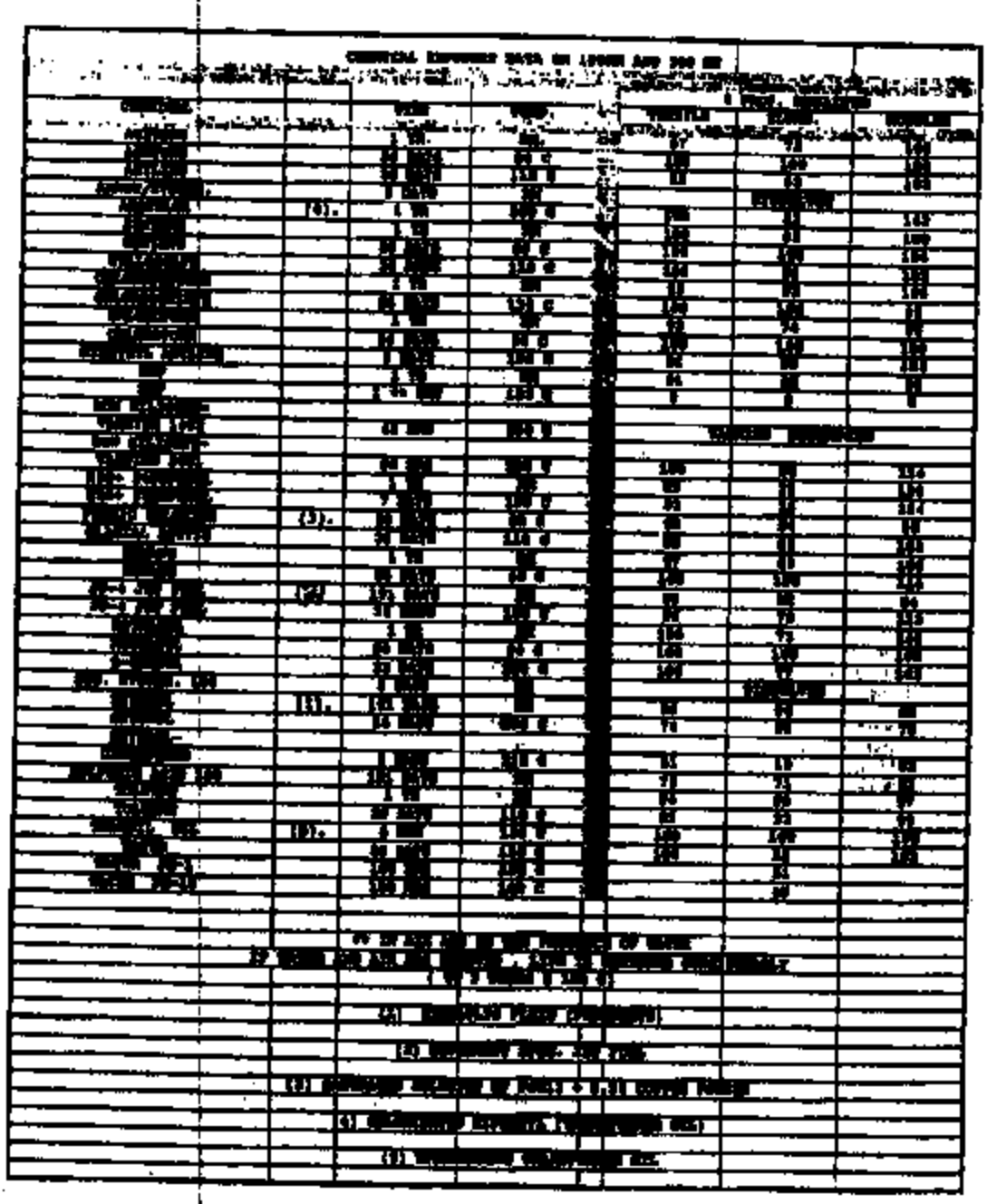
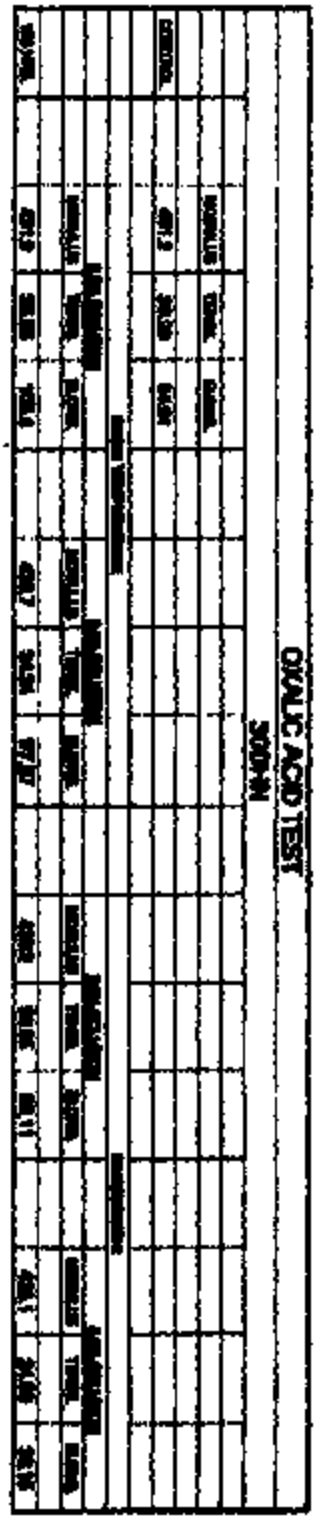
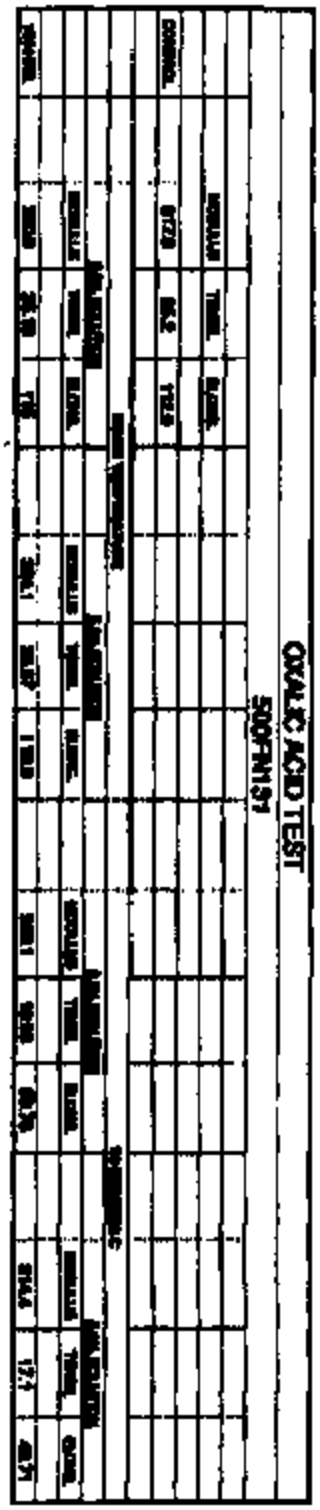



OXALIC ACID TEST
300HN


OXALIC ACID TEST
300 HRS


OXALIC ACID TEST
500FN191

DuPont P.O. Box 89, Circleville, Ohio 43113

FAX

Date: 9-16-99

Number of pages including cover sheet: 4

To:
BRIAN OAGUE

Phone:

Fax phone: 508-236-3586

CC:

From:
JEFF WALLS

Phone: 740-474-0913

Fax phone: (740) 474-0244

REMARKS: ☐ Urgent ☐ For your review ☐ Reply ASAP ☐ Please comment

BRIAN,
HERE ARE THE LATEST DATA POINTS ON THE OXALIC ACID TEST SAMPLE. IN THE FUTURE, BILL CHAFFIN WILL BE RUNNING THE SAMPLES. I AM MOVING TO A NEW JOB ON SITE. HIS NUMBER WILL BE THE SAME AS MINE.

Should you occur problems while sending, contact 740-474-0491 or 740-474-0242

OXALIC ACID TEST AVGS. 500FN131																
		MODULUS	TENS.	ELONG.												
CONTROL		[illegible]	[illegible]	[illegible]												
		[illegible]								[illegible]						
		[illegible]				[illegible]				[illegible]				[illegible]		
		MODULUS	TENS.	ELONG.		MODULUS	TENS.	ELONG.		MODULUS	TENS.	ELONG.		MODULUS	TENS.	ELONG.
[illegible]		[illegible]	25.1[illegible]	115		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		314.4	17.1	[illegible]
[illegible]		327.4	[illegible]	111.7		[illegible]	25.3	107.6		341.3	[illegible]	16.5		346	13.85	[illegible]
[illegible]		321.7	[illegible]	[illegible]		[illegible]	21.7[illegible]	[illegible]		[illegible]	[illegible]	4.3[illegible]		[illegible]	[illegible]	4.13[illegible]
[illegible]		314.9	22.17	[illegible]		314.6	21.41	61.5[illegible]		[illegible]	6.577	[illegible]		341.9	[illegible]	3.27[illegible]

TI-NHTSA 017979

OXALIC ACID TEST AVGS.

306HN

	Modulus	Tensl.	Elong.
control	491.2	[illegible]	94.61

	[illegible]										
	[illegible] solution			[illegible] solution			[illegible] solution			[illegible] solution	
	Modulus	Tensl.	Elong.	Modulus	Tensl.	Elong.	Modulus	Tensl.	Elong.	Modulus	Tensl.	Elong.
[illegible]	494.9	[illegible]	105.4	458.7	34.31	87.57	439.2	[illegible]	69.11	488.1	34.09	28.16
[illegible]	496.5	32.21	89.57	476.7	31.25	[illegible]	[illegible]	21.35	17.88	516.3	17.91	[illegible]
[illegible]	478.6	31.4	[illegible]	471	29.85	76.82	[illegible]	15.39	4.148	514.3	14.16	[illegible]
[illegible]	[illegible]	[illegible]	76.55	471	28.84	69.41	[illegible]	14.3	4.99	472.7	[illegible]	[illegible]

OXALIC ACID TEST AVGS.

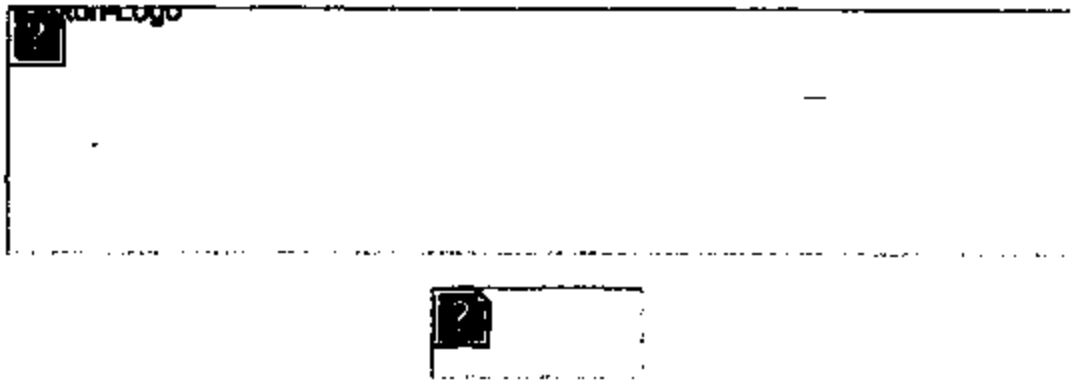
300FN029

	MODULUS	TENSIL.	ELONG.
CONTROL	342.7	[illegible]	[illegible]

	ROOM TEMPERATURE						ELEVATED					
	[illegible] SOLUTION			[illegible] SOLUTION			[illegible] SOLUTION			[illegible] SOLUTION		
	MODULUS	TENSIL.	ELONG.	MODULUS	TENSIL.	ELONG.	MODULUS	TENSIL.	ELONG.	MODULUS	TENSIL.	ELONG.
[illegible]	[illegible].7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21.4[illegible]	41.4[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible].2	31.[illegible]	[illegible]	421.1	10.14	21.[illegible]	[illegible].1	[illegible]	13.[illegible]
[illegible]	[illegible]	27.77	78.[illegible]	[illegible].2	[illegible]	74.[illegible]	421.1	12.[illegible]	4.311	[illegible]	[illegible]	[illegible]
[illegible]	[illegible].4	[illegible]	78.[illegible]	374.4	[illegible]	[illegible]	[illegible]	13.33	[illegible]	418.[illegible]	[illegible]	3.[illegible]

[illegible]

TI-NHTSA 017981



General Specification KAPTON® polyimide film

Table 2. Mechanical Properties of KAPTON® Type HN Polyimide Film

	Property Value - Film Thickness, mil (µm)					
Property	0.30 (7.6)	0.50 (12.7)*	1.00 (25.4)*	2.00 (50.8)*	3.00 (76.2)*	5.00 (127)*
Tensile Strength, psi (MPa) at 23°C (73°F). Machine Direction (MD) and Transverse Direction (TD), min.	15,000 (110)	20,000 (138)	24,000 (165)	24,000 (165)	24,000 (165)	24,000 (165)
Method	ASTM D-882-91, Method A,using an Instron Tensile Tester (specimen size: 0.5" x 8" (12.7 mm x 152 mm); jaw separation: 4" (102 mm); jaw speed: 2"/min (51 mm/min)). Calculate the average of five specimens based on original measured thickness.					
Elongation, %, MD and TD, min.	25	35	40	45	50	50
Method	Same as above.					
Shrinkage, %, MD and TD at 400°C (752°F), max.	4.0	4.0	2.5	2.5	2.5	2.5

Method	MIL-P-46112B. The percent and TD at 400°C shrinkage is obtained for either the MD or TD using the average of three measurements in either direction before and after conditioning. Prior to measurement the 8.5" x 11" (216 mm x 279 mm) specimen is conditioned by freely suspending it for 2 hr** in an oven controlled to 400°C (752°F).					
Moisture Absorption, %, max.	4.0	4.0	4.0	4.0	4.0	4.0
Method	ASTM D-570-98, using 24-hr immersion at 23°C (73°F). Average of three specimens.					

*Also applies to Type VN, except shrinkage, which is shown in Table 5.

**1 hr for 30 and 50 gauge film

General Specification KAPTON® *polyimide film*

Table 2. Mechanical Properties of KAPTON® Type HN Polyimide Film

Property	Property Value - Film Thickness, mil (µm)					
	0.20 (7.6)	0.50 (12.7)*	1.00 (25.4)*	2.00 (50.8)*	3.00 (76.2)*	5.00 (127)*
Tensile Strength, psi (MPa) at 23°C (73°F). Machine Direction (MD) and Transverse Direction (TD), min.	16,000 (110)	20,000 (138)	24,000 (165)	24,000 (165)	24,000 (165)	24,000 (165)
Method	ASTM D-882-91, Method A, using an Instron Tensile Tester (specimen size: 0.5" x 6" (12.7 mm x 152 mm); jaw separation: 4" (102 mm); jaw speed: 2"/min (51 mm/min)). Calculate the average of five specimens based on original measured thickness.					
Elongation, %, MD and TD, min.	25	25	40	45	50	50
Method	Same as above.					
Shrinkage, %, MD and TD at 400°C	4.0	4.0	2.5	2.5	2.5	2.5

(752°F), max.

Method*	MIL-P-46112E. The percent and TD at 400°C shrinkage is obtained for either the MD or TD using the average of three measurements in either direction before and after conditioning. Prior to measurement the 8.5" x 11" (216 mm x 279 mm) specimen is conditioned by freely suspending it for 2 hr** in an oven controlled to 400°C (752°F).					
Moisture Absorption, %, max.	4.0	4.0	4.0	4.0	4.0	4.0
Method	ASTM D-570-92, using 24-hr immersion at 23°C (73°F). Average of three specimens.					

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

Karl Abrahamson

KAP001

MATERIAL SAFETY DATA SHEET

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

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

MATERIAL IDENTIFICATION

PRODUCT NAME	Kapton® Polyimide Film Types H, V, C09, HA, HN, HPP-LT, MT, VN, XC, XC800, 5X4M, XT
CHEMICAL NAME	Aromatic Polyimide plus up to 1% dimethyl acetamide
CAS REGISTRY NUMBER	25036-81-7
TSCA INVENTORY STATUS	All reportable ingredients are listed in the TSCA Chemical Substance Inventory.
DOT HAZARD CLASS	Not regulated
SHIPPING NAME	NA
PREPARER	C. B. Stoufer DATE September 27, 1989

HAZARDOUS COMPONENTS

		MT Types Only	C & CX Types
MATERIAL	Dimethyl acetamide	Alumina	Carbon black
CAS NO.	127-19-5	1344-28-1	1333-86-4
CONCENTRATION %	Up to 1%	35% max	30% max
OSHA PEL	10 ppm(skin)*	10mg/m^3 total dust 5mg/m^3-resp. dust	3.5mg/m^3
ACGIH TLV	10 ppm (skin)*	10mg/m^3	3.5mg/m^3
DUPONT AEL	10 ppm (skin)*	NE	3.5mg/m^3

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

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

PHYSICAL/CHEMICAL DATA

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

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE None known.

PROTECTION INFORMATION

EYE Safety glasses recommended.

SKIN Gloves recommended.

VENTILATION Local exhaust for operations above 200°C.

RESPIRATOR Not required for normal processing.

DISPOSAL

SPILL, LEAK OR RELEASE Pick up to prevent slipping hazard.

WASTE DISPOSAL Landfill or incinerate in compliance with federal, state, and local regulations.

AQUATIC TOXICITY Insoluble.

STORAGE CONDITIONS Store away from flammable materials.

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

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

SECTION 313 SUPPLIER NOTIFICATION

This product contains the following toxic chemicals subject to the reporting requirements of section 313 of the Emergency Planning and Community Right-To-Know Act of 1986 and of 40 CFR 372:

MT types contain up to 35% alumina (1344-28-1) encapsulated in polymer.

This information must be included in all MSDSs that are copied and distributed for this material.

→ BUILD ~ 200 / BA
  * RUBBER
  * FULL RND
  * CTRL
→ CHARACTERIZE ALL 200
  ACT/REL, Δ
→ TRY CHAR @ TEMP
→ TRY TC
→ TRY DRIFT
→ AGING TEST / @ TEMP

VACUUM / DIA LIFE STATUS

TKE 9-22 @ ~ 1.5 KK

BETTER ↑

*	RUBBER DIA	0/6	
*	FULL-RND KAPTON		
*	STD NO VAC	4/6	@ 1.32, 1.35, 1.38, 1.51 KK
*	STD W/ VAC	2/6	@ 0.8, 1.3 KK
*	TEFZEL	6/6	@ 0.8 - 1.4 KK
*	ROUGH HEX FLANGE		

↓ WORSE

RUBBER DIA

MFG CONCERNS:
1. PICK-AND-PLACE
2. SMALL LIP FROM CUTOFF OPERATION
3. EFFECT ON PILOTING + Δ

PERF CONCERNS:
1. EFFECT ON CHAR @ TEMP EXTR.
2. TC LIFE
3. EFFECT ON DRIFT

FULL-[redacted]D

MFG CONCERNS:
1. NEW RND TOOLING QUICK-CHG -OR-
1. NEW RND TOOLING APPLN ON ALL 62-57-77 — HAND-LINE
2. NEW PRESENCE-CHK
3. EFFECT ON PILOTING + Δ

PERF CONCERNS:
1. EFFECT ON CHAR @ TEMP EXTR.
2. DRIFT KNOWN

Kapton

POLYIMIDE FILM

ADHESION TO KAPTON®

KAPTON® polyimide film, made only by Du Pont, is available in three basic film types. Type H KAPTON is 100% polyimide film. Type F is coated on one or both sides with a TEFLON® FEP fluorocarbon adhesive and Type V is a plain polyimide film having superior dimensional stability properties. Typical property information for KAPTON is found in Bulletin E-72087, "Summary of Properties." Specifications are found in Bulletin E-67624, "Industry Specifications Bulletin FC-85-2." For flexible printed circuit applications the trade specification IPC-FC-231/Sheet 1, applies to KAPTON.

ADHESIVE SELECTION

For some applications KAPTON must be bonded to other materials, such as copper foil, which requires the use of an adhesive. Optimum adhesion results are usually obtained from commercially coated KAPTON which is available from a variety of suppliers such as those listed in Bulletin E-72081, "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-74148, "Suppliers of Adhesives to the Electronics Industry," provides a representative listing of adhesive suppliers who can be consulted with for specific adhesive needs.

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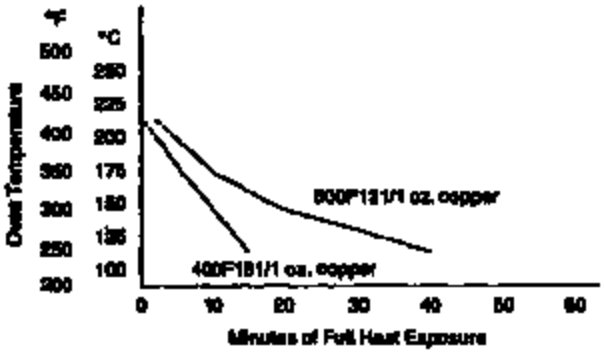
Given in Figure 3 are minimum times to dry laminates of Type F to copper prior to dip soldering. The times are different than in Figure 2 due to the presence of the copper foil.

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-Novalac	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 butyrate 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	78	140	365
Acetone	67	62	160	365
10% Sodium Hydroxide		Degrades		5
Glacial Acetic Acid	85	82	102	30 days @ 363K (110°C)
p-Cresol	100	77	102	22 days @ 473K (200°C)
Transformer Oil	100	100	100	180 days @ 423K (150°C)
Water pH = 1	65	30	100	14 days @ 373K (100°C)
pH = 4.2	65	30	100	14 days @ 373K (100°C)
pH = 7.0	65	20	100	168 days @ 373K (100°C)
pH = 8.9	65	20	100	14 days @ 373K (100°C)
pH = 10.0	60	10	100	4 days @ 373K (100°C)
RADIATION RESISTANCE Gamma (Savannah River)		Still Flexible (180° Bend)		Exposure: 4.16×10^7 Gy
Electron (Van de Graaff)		Retains 50% of Original Elongation		Exposure: 6×10^7 Gy
Neutron plus Gamma (Brookhaven)		Darkened but tough		Exposure: 10^8 Gy
FUNGUS RESISTANCE		Inert		Soil Burial
MOISTURE ABSORPTION		1.3% Type H		50% Relative Humidity at 296K (23°C)
		2.9% Type H & V		Immersion for 24 hours at 296K (23°C)
HYGROSCOPIC COEFFICIENT OF EXPANSION		2.2×10^{-6} m/m/% Relative Humidity		296K (72°F) 20%-80% Relative Humidity
PERMEABILITY Gas		ml/m²-MPa-day (cc/(100 in²) (24 hrs.) (atm/mil))		
Carbon Dioxide		6.9 (45)		ASTM D-1434-63 @ 296K (23°C)
Hydrogen		38 (250)		
Nitrogen		0.9 (6)		
Oxygen		3.8 (25)		
Helium		63 (415)		
Water Vapor		g/m²-day 64 g/(100 in²) (24 hrs.)/mil 5.4		ASTM E-96-63T

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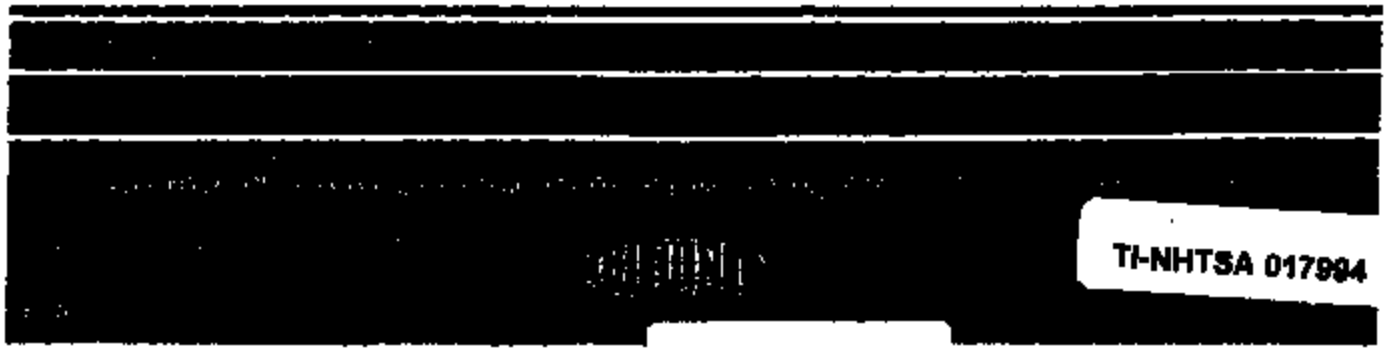

KAPTON® Type V Film

CHEMICAL PROPERTIES

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

KAPTON® Type F Film

CHEMICAL PROPERTIES

PROPERTY	125FN19	150FN11	400FN22
Moisture Absorption @ 296K (25°C), 50% R.H. 98% R.H.	1.3% 2.5%	.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 (0.88) 0.44 (1.07)	8.6 (0.57) 0.35 (0.85)	3.6 (0.23) 0.14 (0.92)

Kapton®
Polymide Film

DuPont
Electronics

High Performance Films

TI-NHTSA 017996

DD/NHTSA No. 3

TI-NHTSA 017997

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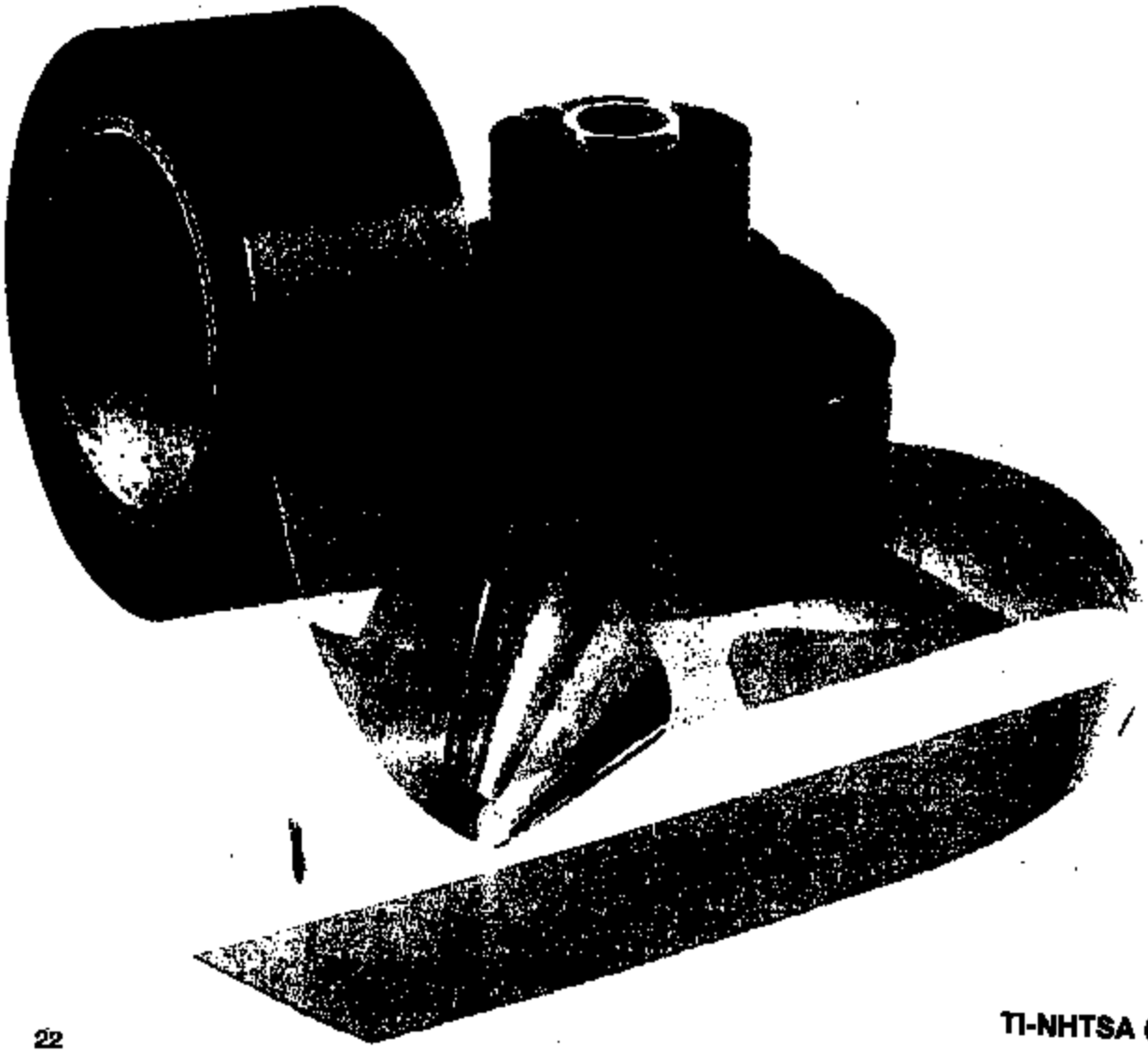
NOMINAL CONSTRUCTION, Type F Film

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 0 is used to represent 13 μm (½ mil) and 6 to represent 2.5 μm (1/10 mil). Example: 120F616 is a 120 gauge structure consisting of a 25 μm (1-mil) base film with a 2.5 μm (1/10 mil) coating of TEFLON on each side. Illustrated are 3 examples of the many types available.

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

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



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Kapton®
POLYIMIDE FILM

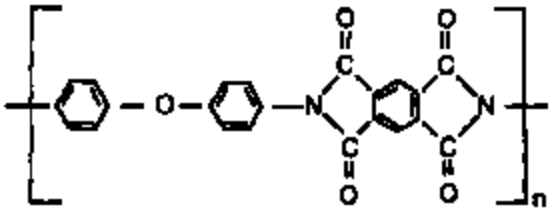
safe handling

Industrial Films Division

SAFETY IN HANDLING AND USE

Introduction

KAPTON polyimide film is a strong, tough, transparent amber-colored plastic film exhibiting excellent physical, chemical and electrical properties over an extremely wide temperature range. It has the structure:



KAPTON is produced in three forms, Type H, Type V, and Type F. Type H is the basic uncoated polyimide film. Type V is similar to Type H but has superior dimensional stability. Type F is coated on one or both sides with Teflon® FEP fluorocarbon resin which imparts heat sealability, provides a moisture barrier, and enhances chemical resistance.

KAPTON is used as insulation for wire and cable, formed coils, magnet wire and transformers, and motor slot liners, among other uses. It also is used as a substrate for flexible printed circuits.

This booklet provides guidelines for the safe handling of KAPTON during processing, use, and disposal.

Users of Type F KAPTON should also refer to DuPont bulletin "Teflon® Fluorocarbon Resins — Safety in Handling and Use."

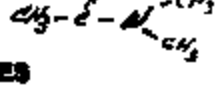
I. GENERAL PROPERTIES

KAPTON Type H and Type V, exhibits no melting point or softening point. A one-mil thick film has a zero-strength temperature of 815°C (1500°F). Zero-strength is measured as the maximum temperature at which the film will sustain a load of 138 KPa (20 psi) for 5 seconds.

KAPTON is insoluble in most common organic solvents after immersion for up to a year (Ref. 1). The hydrolytic stability of KAPTON Type H has been measured after 166 days exposure to boiling water. The film retained 65% of its tensile properties and 20% of its elongation. KAPTON is dissolved by strong acids (Ref. 2, 3) such as fuming nitric and concentrated sulfuric acid, particularly on heating, and is hydrolyzed by alkali and super-heated steam.

KAPTON Type F exhibits better chemical, hydrolytic, and oxidative resistance than Types H and V.

KAPTON may contain up to 1% by weight of dimethyl acetamide residual solvent. At elevated temperatures, some of the solvent may be released and must be removed by exhaust ventilation or diluted to safe levels. OSHA (29 CRF 1910.1000) has established the safe level for dimethyl acetamide as ten parts per million.



II. PYROLYSIS STUDIES

Studies (Ref. 4, 5) have shown the outstanding thermal stability of polyimide film. Its rate of degradation is dependent upon the availability of oxygen. In air at about 500°C (932°F) KAPTON decomposes and completely disappears after twelve hours. At 450°C in air, carbon monoxide may be formed in significant amounts. In a vacuum or inert atmosphere, 60 to 65% of the film remains after prolonged aging at 1000°C (1832°F). The residue retains its original shape but has lost its mechanical strength. The major off-gases are carbon dioxide and carbon monoxide. (See chart)

®Reg. U.S. Pat. & T.M. Off.

Kapton
POLYIMIDE FILM

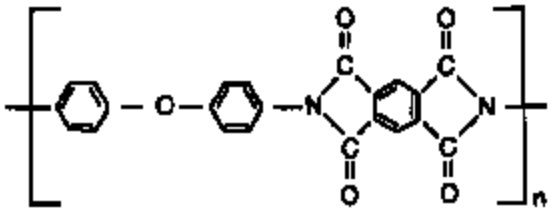
safe handling

Industrial Films Division

SAFETY IN HANDLING AND USE

Introduction

KAPTON polyimide film is a strong, tough, transparent amber-colored plastic film exhibiting excellent physical, chemical and electrical properties over an extremely wide temperature range. It has the structure:



KAPTON is produced in three forms, Type H, Type V, and Type F. Type H is the basic uncoated polyimide film. Type V is similar to Type H but has superior dimensional stability. Type F is coated on one or both sides with Teflon® FEP fluorocarbon resin which imparts heat sealability, provides a moisture barrier, and enhances chemical resistance.

KAPTON is used as insulation for wire and cable, formed coils, magnet wire and transformers, and motor slot liners, among other uses. It also is used as a substrate for flexible printed circuits.

This booklet provides guidelines for the safe handling of KAPTON during processing, use, and disposal.

Users of Type F KAPTON should also refer to DuPont bulletin "Teflon® Fluorocarbon Resins — Safety in Handling and Use."

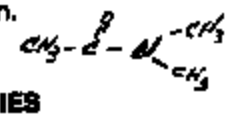
I. GENERAL PROPERTIES

KAPTON Type H and Type V, exhibits no melting point or softening point. A one-mil thick film has a zero-strength temperature of 815°C (1500°F). Zero-strength is measured as the maximum temperature at which the film will sustain a load of 138 KPa (20 psi) for 5 seconds.

KAPTON is insoluble in most common organic solvents after immersion for up to a year (Ref. 1). The hydrolytic stability of KAPTON Type H has been measured after 168 days exposure to boiling water. The film retained 65% of its tensile properties and 20% of its elongation. KAPTON is dissolved by strong acids (Ref. 2, 3) such as fuming nitric and concentrated sulfuric acid, particularly on heating, and is hydrolyzed by alkali and super-heated steam.

KAPTON Type F exhibits better chemical, hydrolytic, and oxidative resistance than Types H and V.

KAPTON may contain up to 1% by weight of dimethyl acetamide residual solvent. At elevated temperatures, some of the solvent may be released and must be removed by exhaust ventilation or diluted to safe levels. OSHA (29 CRF 1910.1000) has established the safe level for dimethyl acetamide as ten parts per million.



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*Reg. U.S. Pat. & T.M. Off.

III. FLAMMABILITY

Lewis and Stabler (Ref. 6) report the flammability characteristics of polyimide film as "self-extinguishing." KAPTON has a 94 VTM-O rating, the highest given in the U.L. 94 vertical burning test for thin films. The oxygen index is 37% for 100 H film (ASTM 2863).

IV. HANDLING PRACTICES

Safe handling of Type H and V KAPTON polyimide films at high temperatures requires adequate ventilation. If small quantities of KAPTON are involved, as is often the case, normal air circulation will be all that is needed in case of overheating. Whether or not existing ventilation is adequate at higher temperatures will depend on the combined factors of film quantity, temperature, and exposure time. For additional information on the Teflon® FEP coatings used on Type F KAPTON, refer to the booklet — "Teflon® Fluorocarbon Resins — Safety in Handling and Use."

A. Soldering and Hot Wire Stripping

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

Ventilation practices should follow the same common sense rules applicable to any soldering procedure. Normal ventilation provided for worker comfort usually provides adequate safety. During hot-wire stripping, it is recommended that exhaust ducts be used at the workbench.

There have been no reports of ill effects during soldering or hot-wire stripping of wire and cable insulated with KAPTON.

B. Welding and Flame Cutting

Direct application of welding arcs and torches can quickly destroy most plastics, including all types of KAPTON film. For practical reasons, therefore, it is best to remove all such parts from equipment to be welded. Where removal is not possible, such as in welding or cutting coated parts, mechanical ventilation should be provided.

Because KAPTON is rated for use at very high temperatures, parts made from it may survive at locations close to the point of direct flame contact. Thus some in-place welding operations can be done. Since the quantity of film heated is usually relatively small (less than one pound), ventilation requirements seldom exceed those for normal welding work. Because of the possibility of inadvertent overheating, however, the use of a small fan or elephant-trunk exhaust is advisable.

C. Scrap Disposal

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

D. Fire Hazards

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

In the event of fire, personnel entering the area should use a fresh air supply or a respirator. This type of equipment is standard in fighting many types of fire. All types of chemical extinguishers may be used to fight fires involving KAPTON. Large quantities of water also may be used to cool and extinguish a fire.

E. Static Electricity

The processing of KAPTON polyimide film can cause the generation of a strong static charge. Unless this charge is bled off as it forms through the use of ionizing radiation or metal tinsel, it can build to many thousands of volts and discharge to people or to metal equipment. In dust or solvent-laden air, a flash fire or explosion could result. Precautions for static charges should also be taken when removing plastic films used as protective packaging for KAPTON.

REFERENCES

1. J. T. Milek, "Polyimide Plastics: A State-of-the-Art-Report," Electronic Properties Information Center, S-8, October 1, 1965, Air Force Systems Command, Contract AF33 (615)-2460, Project 7381: Task 738103.

2. C. E. Sroog, A. L. Endrey, S. V. Abrams, C. E. Berr, W. M. Edwards, and K. L. Oliver, J. Poly. Sci. A, 3(4), 1373-90 (1965).

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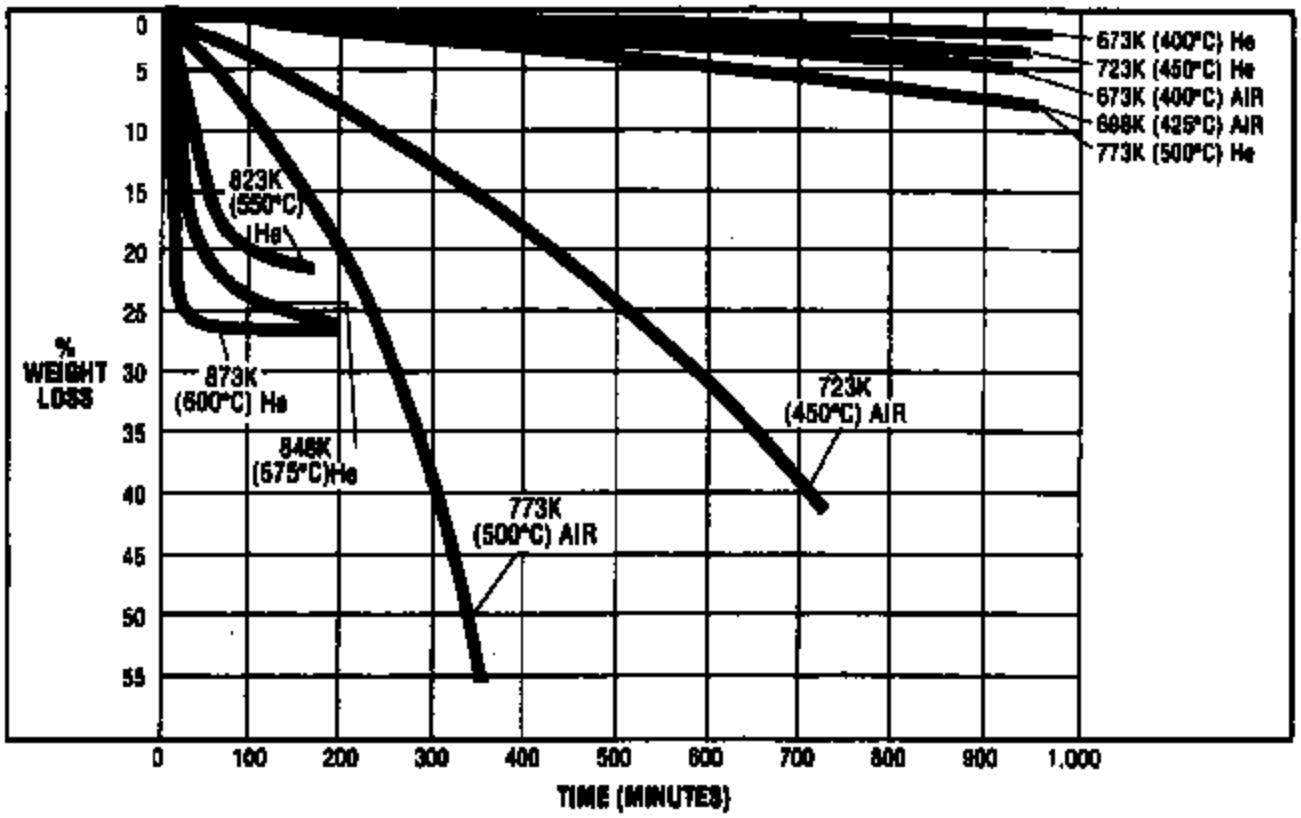
ISOTHERMAL WEIGHT LOSS

(Type H Film 25 μm (1 mil))



3. N. A. Androva, M. I. Bessonov, L. A. Laius, and A. P. Rudakov, "Polyimides — A New Class of Thermally Stable Polymers," Progress in Matls. Sci. Series, Vol. VII, Technomic Publ. Co., Stamford, Conn., 1970, p. 79-85.

4. 1968 Listing of Plastic Materials, etc., P. 10, March 1968, National Sanitation Foundation.

5. General Electric Co. Res. Lab., Research of Dielectric Materials, Rept. #ML-TDR-64-57, May 1964, DDC AD-602 436, NASA N64-26308.

6. R. F. Stabler and L. L. Lewis, "KAPTON Polyimide Film — A New Insulation for Aerospace Wire and Cable," Paper presented at Soc. of Aerospace Materials and Process Engineers Meeting, San Francisco, May 26, 1965.

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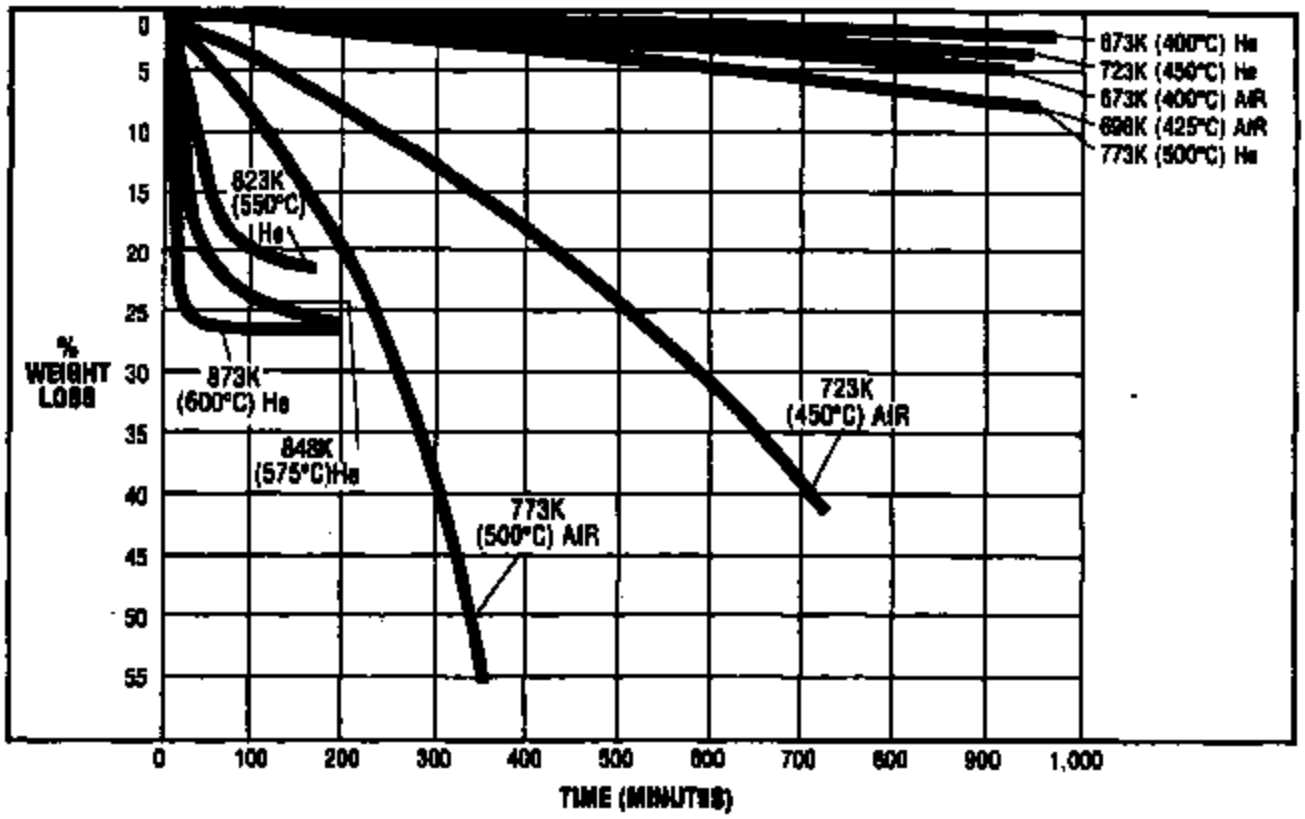

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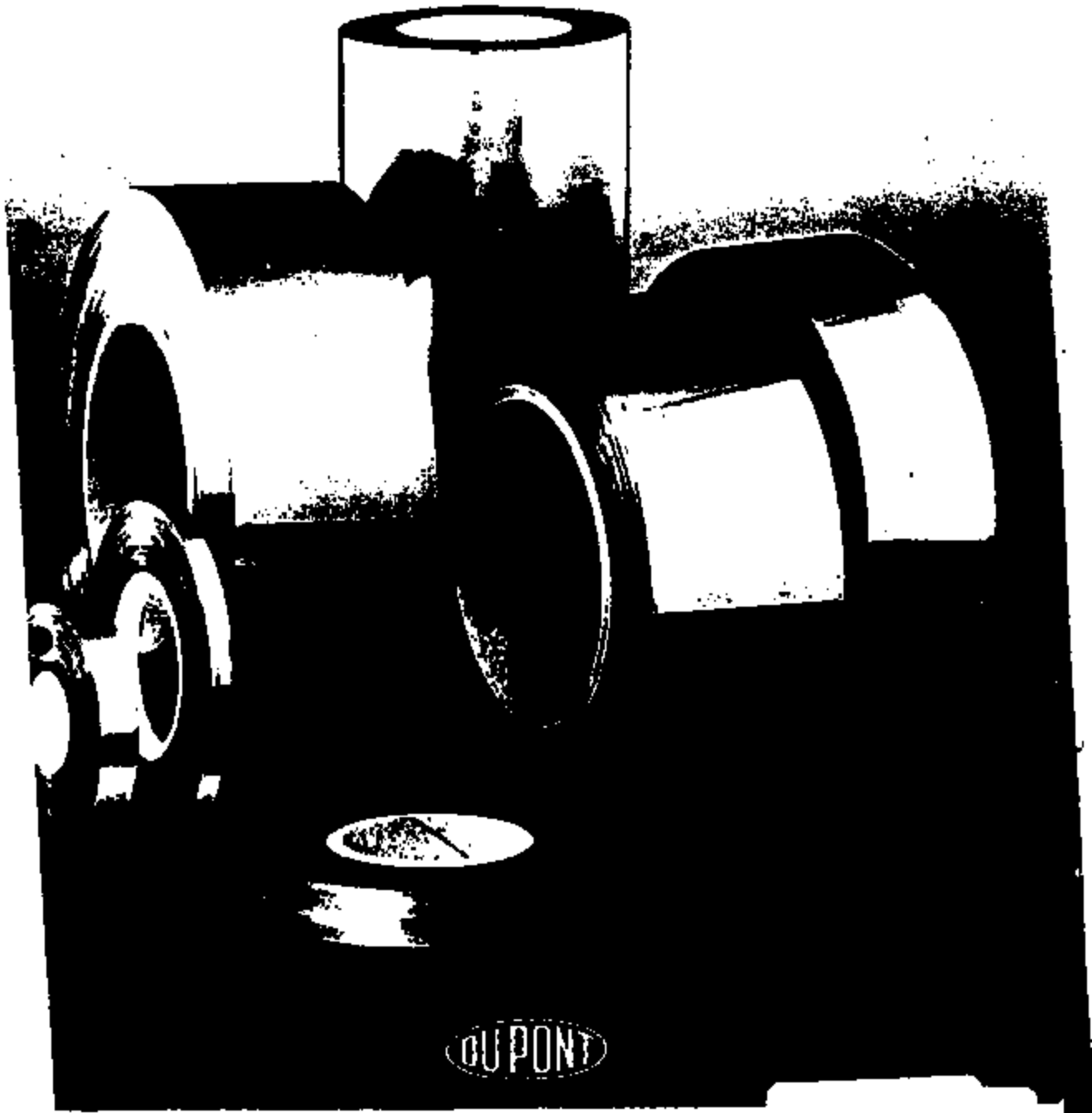
SUMMARY OF PROPERTIES



CONTENTS

Kapton®
POLYIMIDE FILM

GENERAL INFORMATION

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

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

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

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

Du Pont makes three types of KAPTON:

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

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

*Reg. U.S. Pat. Off.

KAPTON® polyimide films retain their physical properties over a wide temperature range. They have been used in field applications where the environmental temperatures have been as low as 4K (−269°C) and as high as 673K (400°C). Complete data are not available at these extreme conditions and the majority of technical data presented in the following pages falls in the 76K (−195°C) to 473K (200°C) range.

KAPTON® Type H Film

25 µm (1 mil)

PHYSICAL PROPERTIES

PHYSICAL PROPERTIES	TYPICAL VALUES 76K (−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	76	90	ASTM D-882-81
Tensile Modulus, GPa (MD) (psi)	3.5 (510,000)	3.0 (430,000)	1.85 (260,000)	ASTM D-882-81
Impact Strength, Izod (kg-cm)		23 (6)		Du Pont Pneumatic Impact Test
Folding Endurance MIT		10,000 cycles		ASTM D-2176-69
Tear Strength—Propagating (Elmendorf), g		6		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 (Sodium Line)		1.78		Encyclopedic Dictionary of Physics, Vol. 1
Poisson's Ratio		.34		Ave. 3 Samples Elongated at 5%, 7%, 10%

MD—Machine Direction

THERMAL PROPERTIES

THERMAL PROPERTIES	TYPICAL VALUES	TEST CONDITION	TEST METHOD
Melting Point	NONE		ASTM E-794-6
Zero Strength Temperature	1066K (793°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)	250 to 311K (−14°C to 38°C)	ASTM D-696-44
Coefficient of Thermal Conductivity, W/m-K $\left(\frac{\text{cal}\ (\text{cm})}{(\text{cm}^2)\ (\text{sec})\ (°\text{C})}\right)$	0.155 (3.7×10^{-3}) 0.163 (3.9×10^{-3}) 0.176 (4.2×10^{-3}) 0.188 (4.5×10^{-3})	296K (23°C) 348K (75°C) 473K (200°C) 573K (300°C)	Model TC-1000 Twin Heatmeter Comparative Tester
Specific Heat	1.09 (.261)	J/g-K (cal/g/°C)	Differential Calorimetry
Flammability	94 VTM-0		UL-94 (1-24-80)
Shrinkage	(See chart on Page 7)		IPC Method 2-2-2-A
Heat Sealability	Not Heat Sealable		
Limiting Oxygen Index	100H-35		ASTM D-2863-77
Smoke Generation	100H — DM = less than 1	NBS Smoke Chamber	NFPA-258 procedures
Glass Transition Temperature (Tg)	A second order transition occurs in KAPTON between 633K (360°C) and 683K (410°C). This is assumed to be the glass transition temperature. Different measurement techniques produce different results within the above temperature range.		

KAPTON® Type V Film

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

KAPTON® Type F Film

PROPERTY	TYPICAL VALUES Film Type*		
	120F616	150F019	250F029
Ultimate Tensile Strength (MD), MPa (psi) 296K (23°C) 473K (200°C)	166 (24,000) 110 (16,000)	117 (17,000) 76 (11,000)	172 (25,000) 110 (16,000)
Yield Point at 3% (MD), MPa (psi) 296K (23°C) 473K (200°C)	62 (9,000) 36 (5,500)	50 (7,300) 26 (4,000)	69 (10,000) 55 (8,000)
Stress at 5% Elongation (MD), MPa (psi) 296K (23°C) 473K (200°C)	86 (12,500) 52 (7,600)	62 (9,000) 36 (5,500)	
Ultimate Elongation (MD) 296K (23°C)% 473K (200°C)%	65 95	78 85	80
Tensile Modulus, MD GPa (psi) 296K (23°C) 473K (200°C)	2.86 (415,000) 1.48 (215,000)	2.21 (320,000) 1.19 (173,000)	
Impact Strength at 296K (23°C) psb (Kg-cm/µm) psb/µ (Kg-cm/mil)	70 (7) 2.3 (6.0)	70 (7) 1.4 (4.8)	
Tear Strength—Propagating (Elmendorf) g g/µm (g/mil)	0.39 (10)	20 0.53 (13.5)	0.47 (12)
Tear Strength—Initial (Graves) g g/µm (g/mil)	19 (750)	650 17 (435)	
Weight % Polyimide Weight % FEP	80 20	57 43	73 27
Density Kg/m³x10⁻³	1.53	1.57	1.57

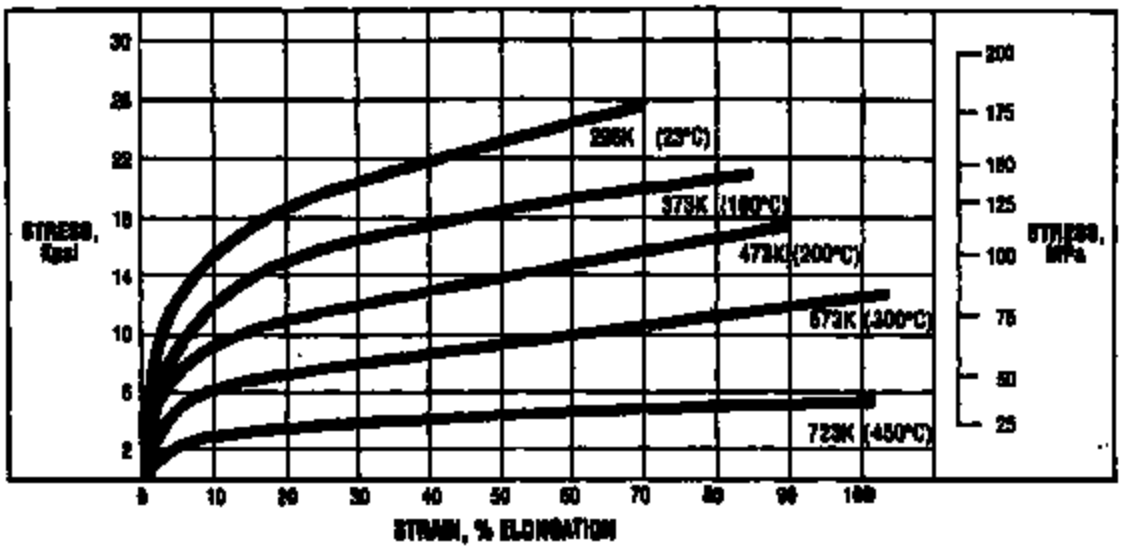
*Since a number of combinations of polyimide film and fluorocarbon coating add up to the same total gauge, it is necessary to distinguish among them. A three digit system is used in which the middle digit represents the nominal thickness of the base KAPTON film in mils. The first and third digits represent the nominal thickness of the coating of TEFLON FEP fluorocarbon resin in mils. The symbol 5 is used to represent 12 µm (½mil), and 0 to represent 2.5 µm (1/10 mil). Example: 150F616 is a 150-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 thetron 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))

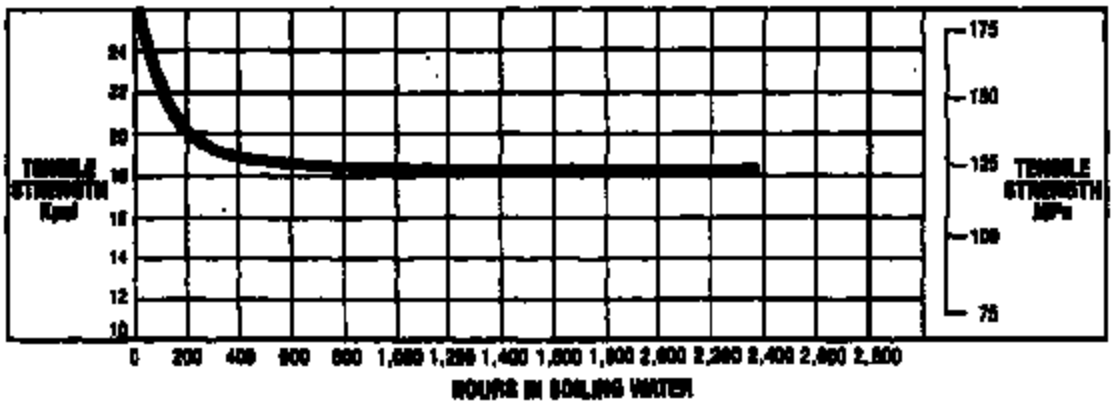


HYDROLYTIC STABILITY

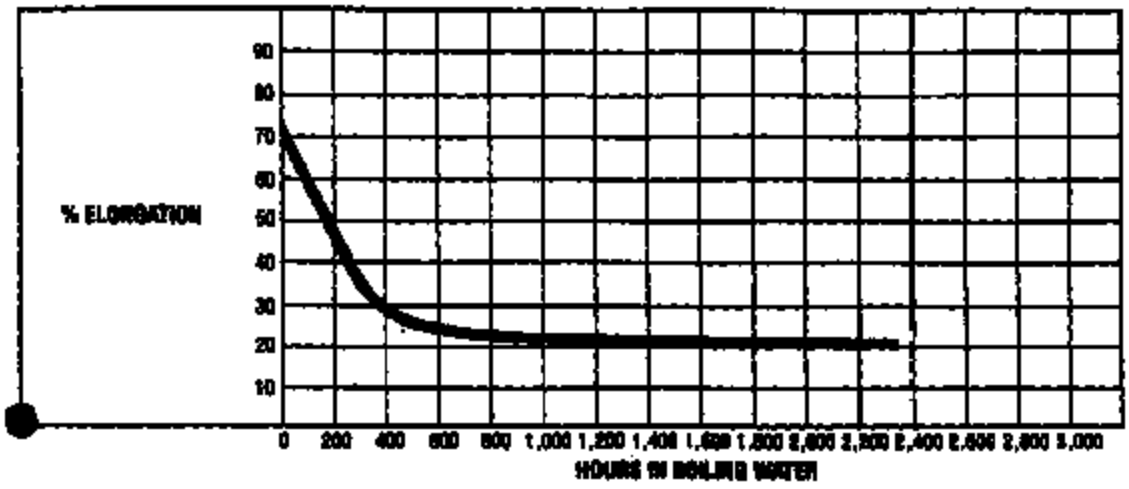
KAPTON® polyimide film is made by a condensation reaction; therefore, its properties are affected by water. Although long-term exposure to boiling water, as shown in the curves below, will reduce the level of film properties, sufficient tensile and elongation remain to insure good mechanical performance.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



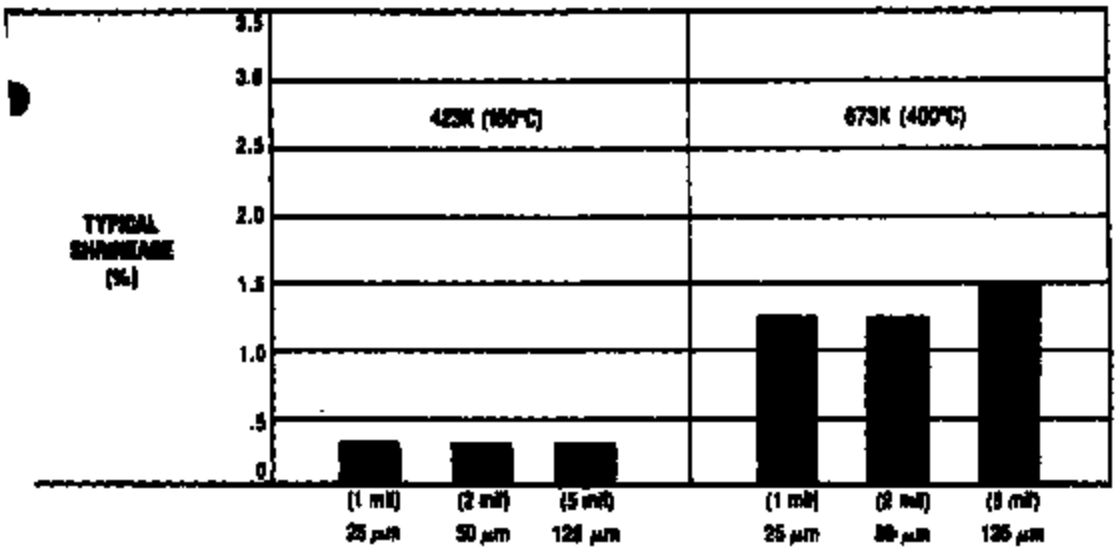
ULTIMATE ELONGATION AFTER EXPOSURE IN 373K (100°C) WATER
(Type H Film 25 μm (1 mil))



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)



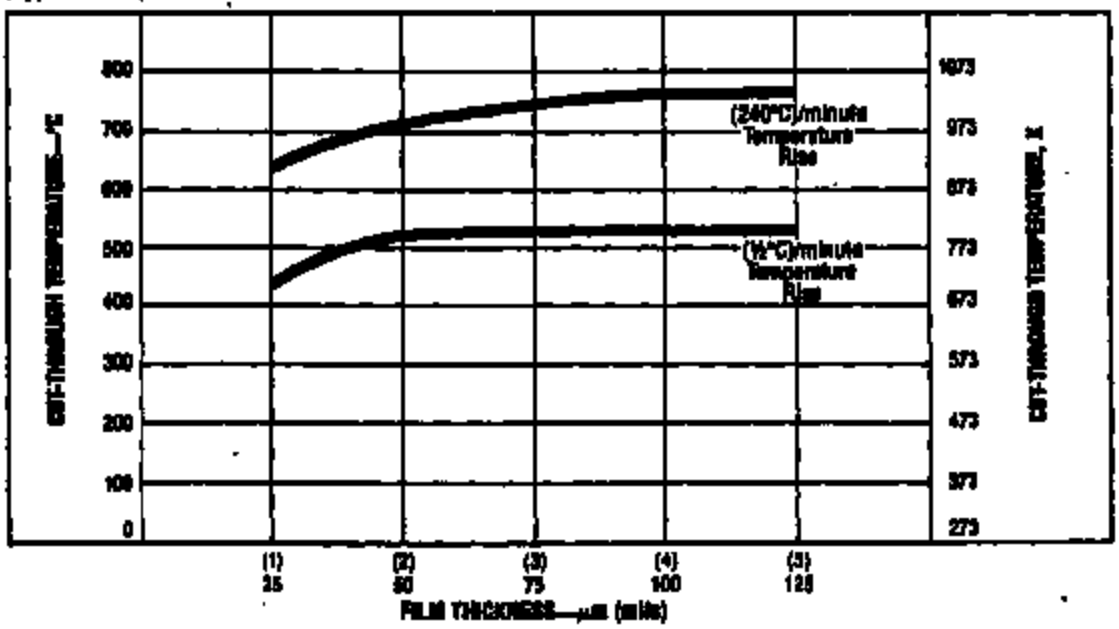
THERMAL COEFFICIENT OF EXPANSION
(Type H Film 25 µm (1 mil)) Thermally Exposed

Temperature Range	"H" m/m-K x 10^{-6}
298-373K (23-100°C)	1.60
373-473K (100-200°C)	3.10
473-573K (200-300°C)	4.65
573-673K (300-400°C)	7.75
298-673K (23-400°C)	4.55

CUT-THROUGH AND COLD FLOW

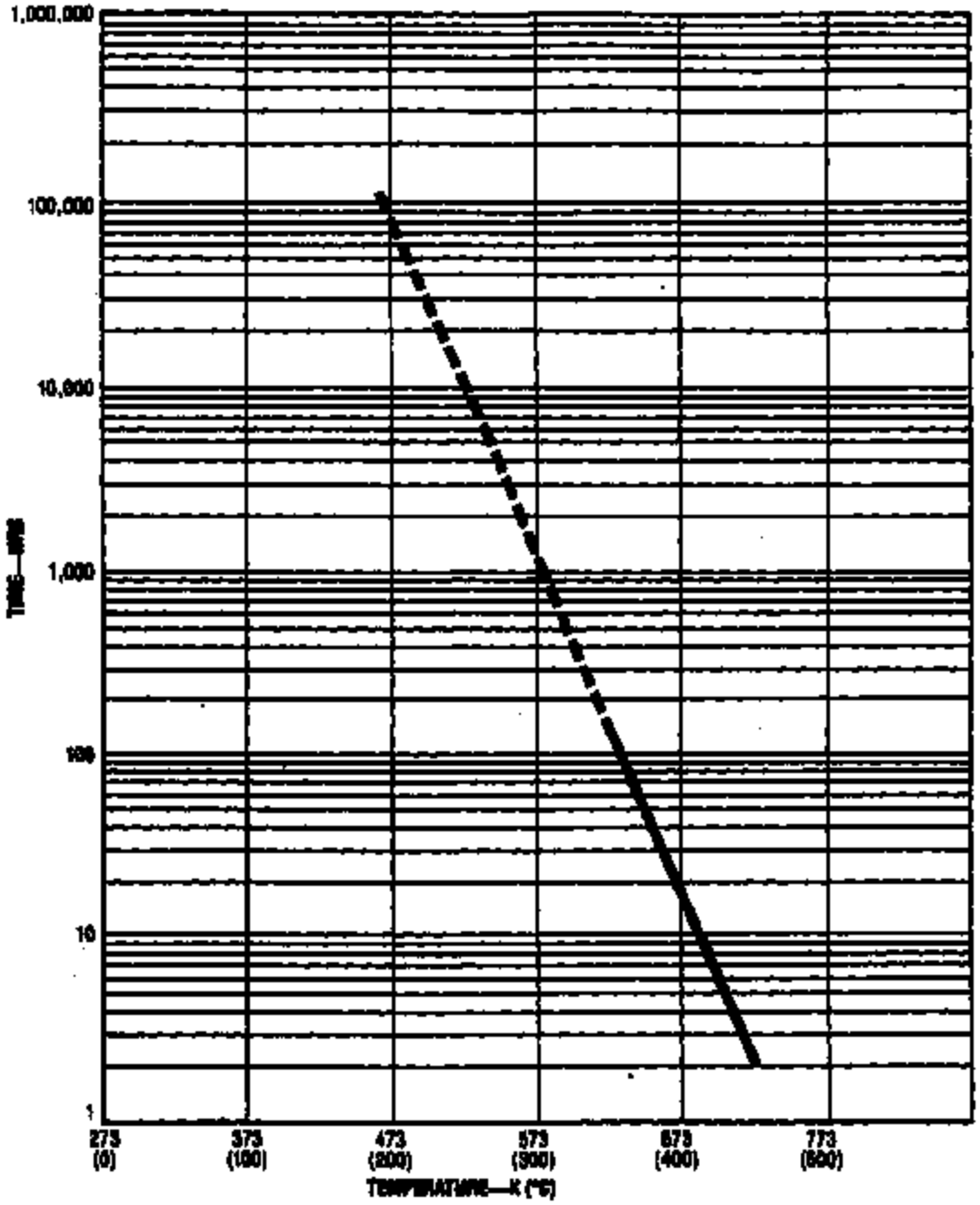
Most organic films exhibit a tendency to flow or thin out under high compressive stresses, especially at elevated temperatures. KAPTON® polyimide film possesses an extremely high resistance to such stresses. Test procedures described in ASTM D-676-81 have been adapted to flat films to provide the data 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

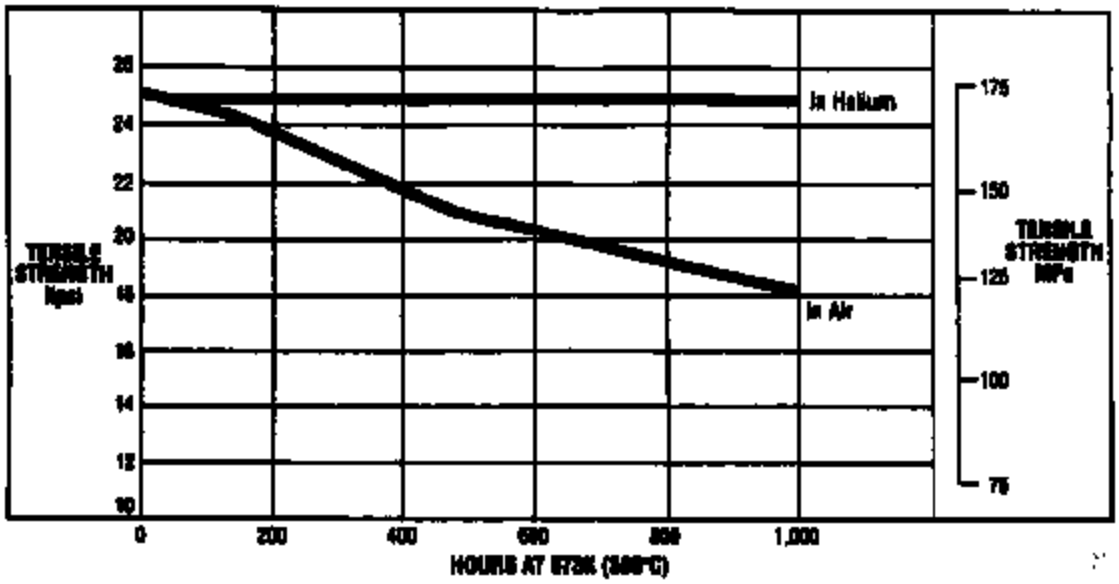
extrapolated

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.

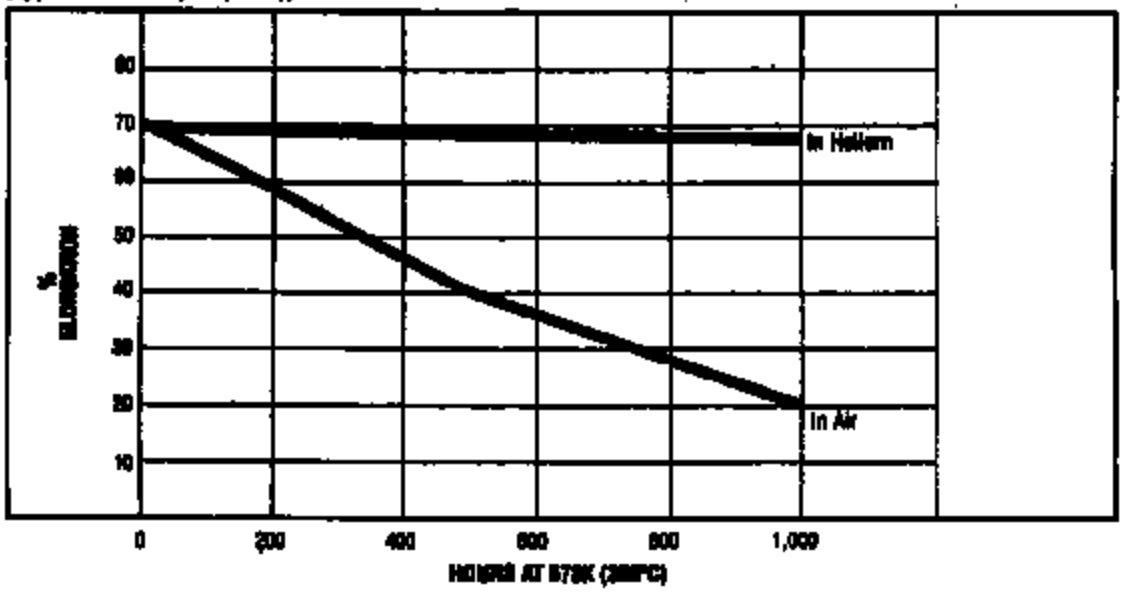
TENSILE STRENGTH VS. AGING AT 573K (300°C)

(Type H Film 25 μm (1 mil))



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

(Type H Film 25 μm (1 mil))



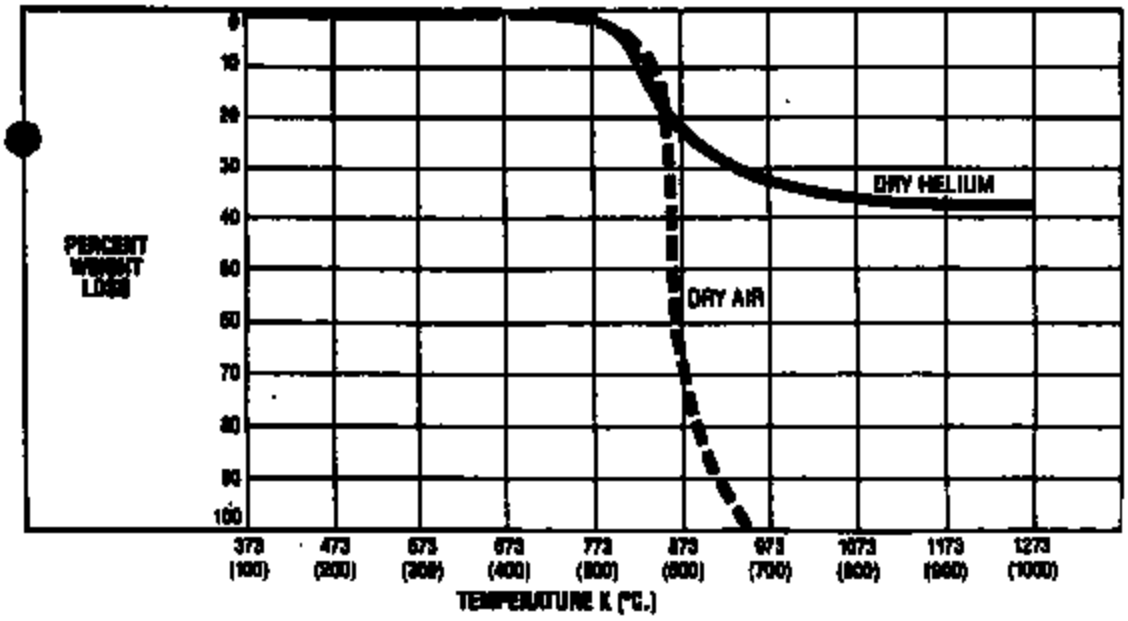
TIME REQUIRED FOR REDUCTION IN ULTIMATE ELONGATION FROM 70% to 1%

(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	—

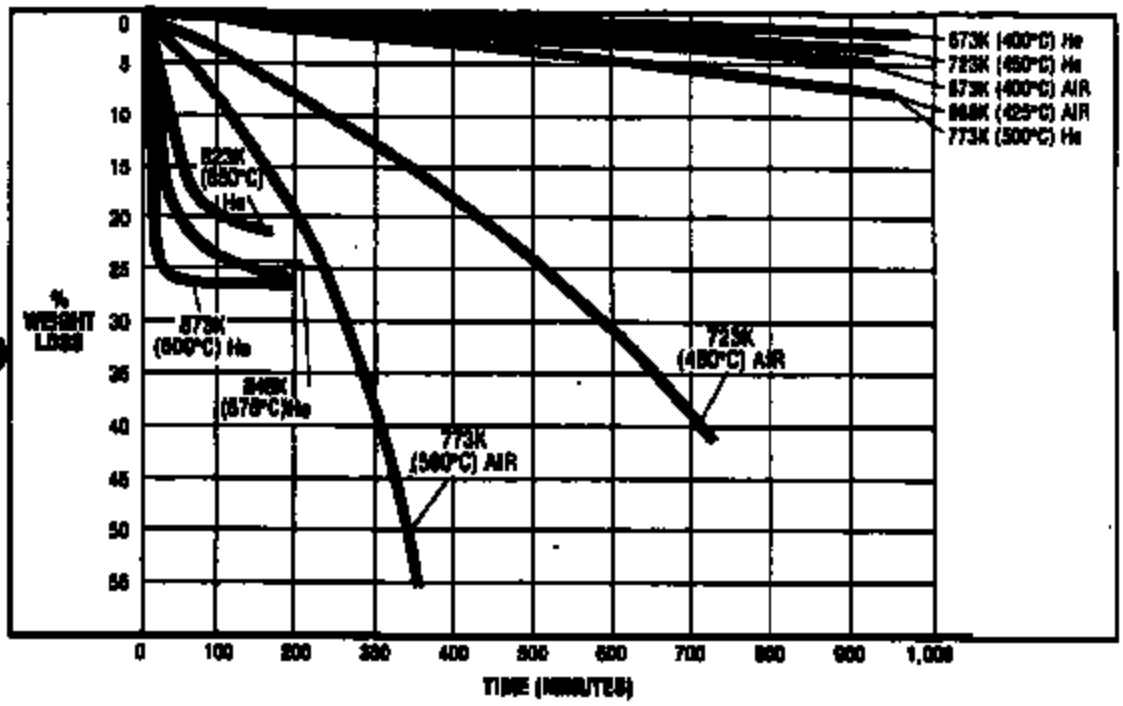
WEIGHT LOSS AT (5°C)/MINUTE TEMPERATURE RISE

(Type H Film 25 μm (1 mil))



ISOTHERMAL WEIGHT LOSS

(Type H Film 25 μm (1 mil))



...TIES

The most common electrical properties of KAPTON® polyimide film in various gauges are shown on the following pages. These values were measured at 25°C (22°C) and 50% relative humidity. The effect of such factors as humidity, temperature, and frequency on these basic values can be found on pages 15-18.

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 ¼" electrodes	ASTM D-149-61
50 µm (2 mil)	213 v/µm (5,400 v/mil)		
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)	3.6	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)	.0026		
125 µm (5 mil)	.0027		
Volume Resistivity			
25 µm (1 mil)	1×10^{17} ohm-m	125 volts	ASTM D-257-78
50 µm (2 mil)	8×10^{16} ohm-m		
75 µm (3 mil)	5×10^{16} ohm-m		
125 µm (5 mil)	1×10^{16} 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 ¼" electrodes	ASTM D-149-61
75 µm (3 mil)	181 v/µm (4,600 v/mil)		
125 µm (5 mil)	142 v/µm (3,600 v/mil)		
Dielectric Constant			
50 µm (2 mil)	3.8	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)	.0026		
125 µm (5 mil)	.0027		
Volume Resistivity			
50 µm (2 mil)	8×10^{16} ohm-m	125 volts	ASTM D-257-78
75 µm (3 mil)	5×10^{16} ohm-m		
125 µm (5 mil)	1×10^{16} ohm-m		

KAPTON® Type F Film

TYPICAL ELECTRICAL PROPERTIES

PROPERTY	120F616	150F018	250F029
Dielectric Strength Total volts volts/μm (volts/mil)	7,500 267 (6,800)	6,300 165 (4,200)	 157 (4,000)
Dielectric Constant	2.8	3.0	
Dissipation Factor	.0022	.0014	
Volume Resistivity ohm-m @ 298K (23°C) (ohm-cm.) ohm-m @ 473K (200°C) (ohm-cm.)	 1.5×10^{14} (1.5×10^{16}) 5×10^{10} (5×10^{12})	 10^{15} (10^{17}) 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 298K (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

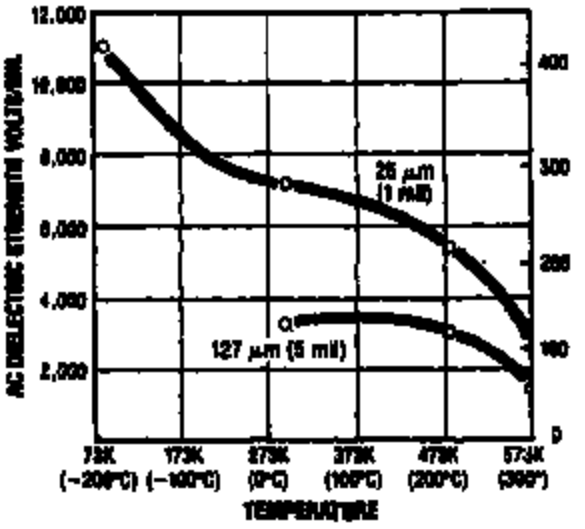
For calculations involving absolute water content, 50% RH in our study is equal to 1.3% water in the film and 100% RH is equal to 3.0% water, the maximum absorption possible regardless of the driving force.

EFFECT OF TEMPERATURE

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

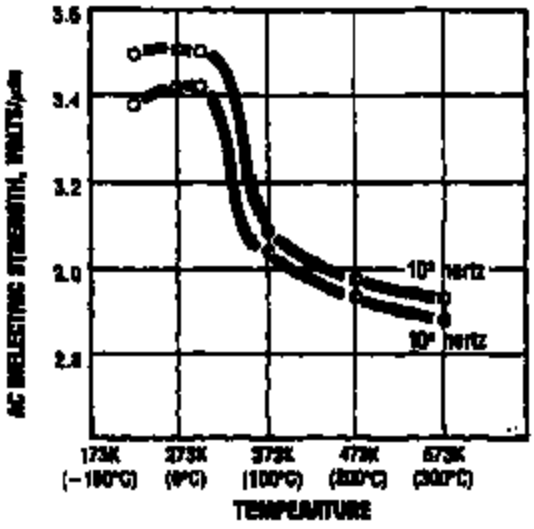
AC DIELECTRIC STRENGTH VS. TEMPERATURE

(Type H Film)



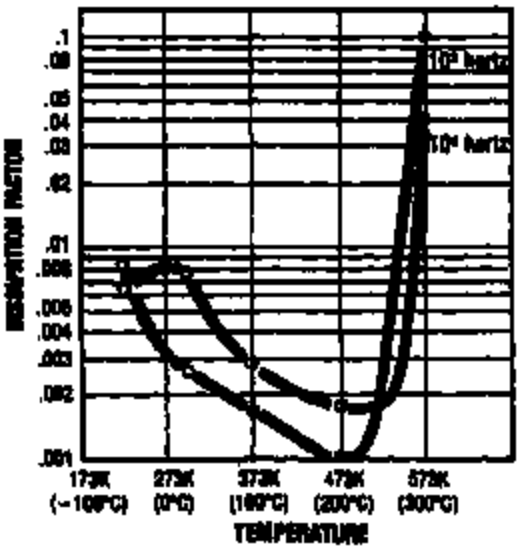
DIELECTRIC CONSTANT VS. TEMPERATURE

(Type H Film—25 µm (1 mil))



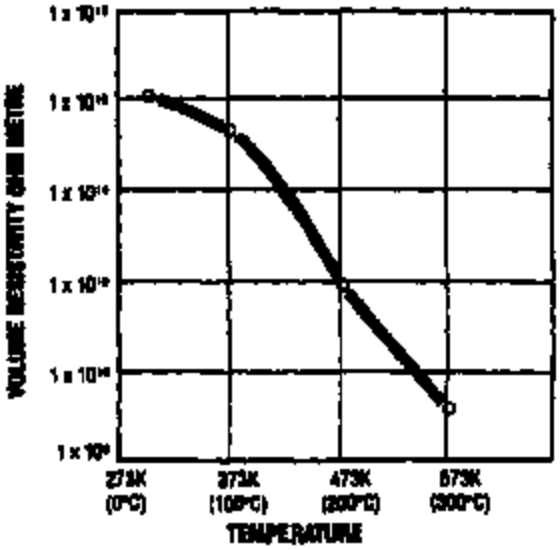
DISSIPATION FACTOR VS. TEMPERATURE

(Type H Film 25 µm (1 mil))



VOLUME RESISTIVITY VS. TEMPERATURE

(Type H Film 25 µm (1 mil))

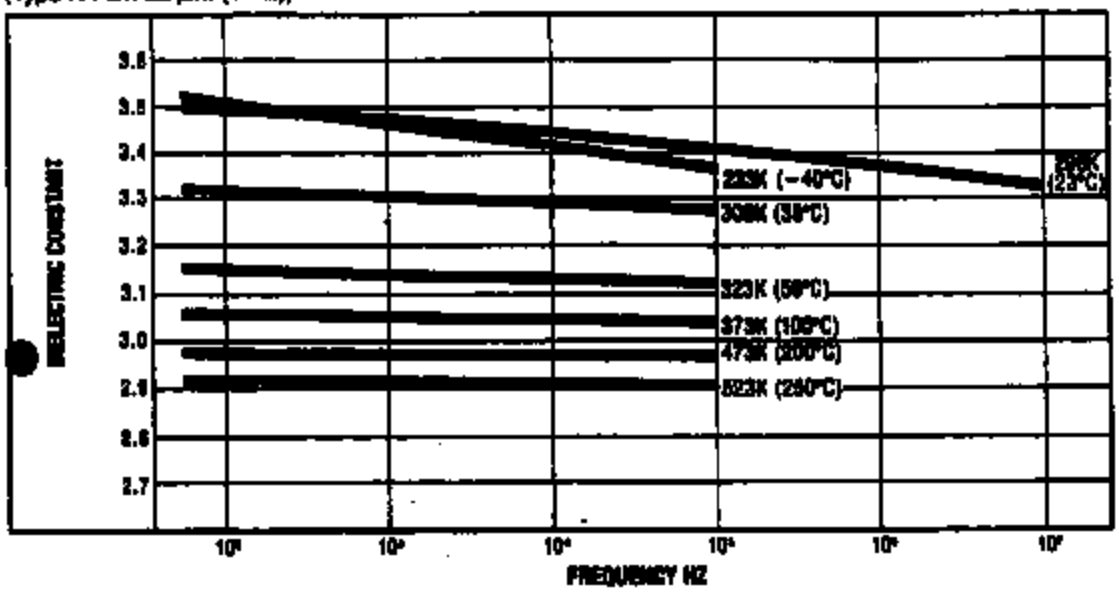


EFFECT OF FREQUENCY

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

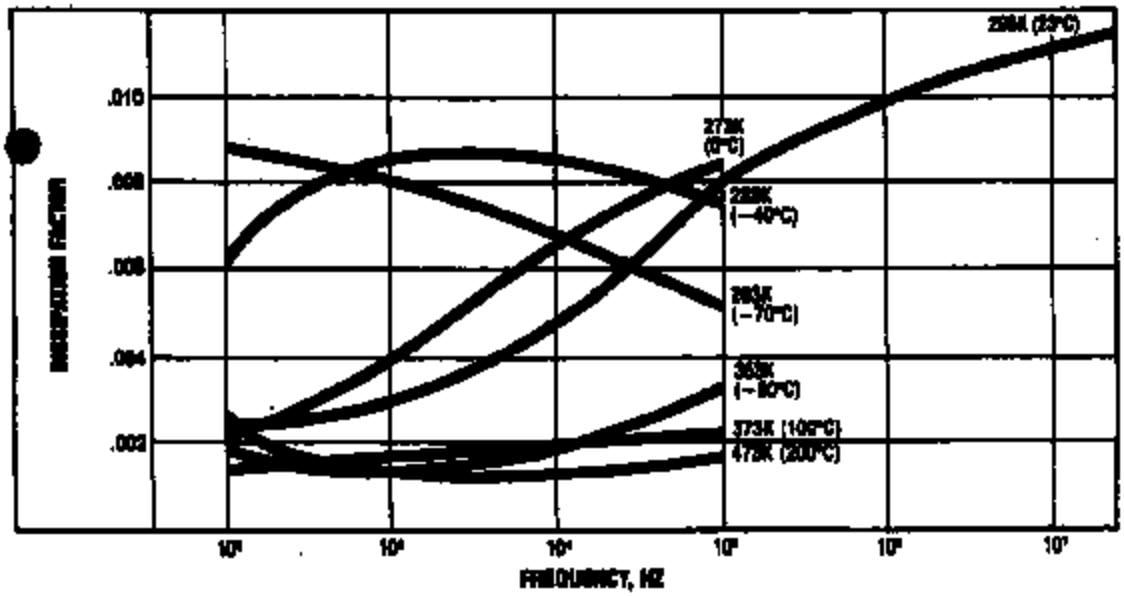
DIELECTRIC CONSTANT VS. FREQUENCY

(Type H Film 25 µm (1 mil))



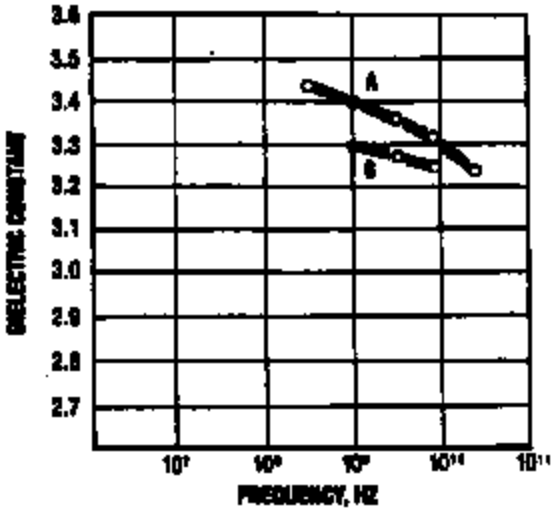
DISSIPATION FACTOR VS. FREQUENCY

(Type H Film 25 µm (1 mil))

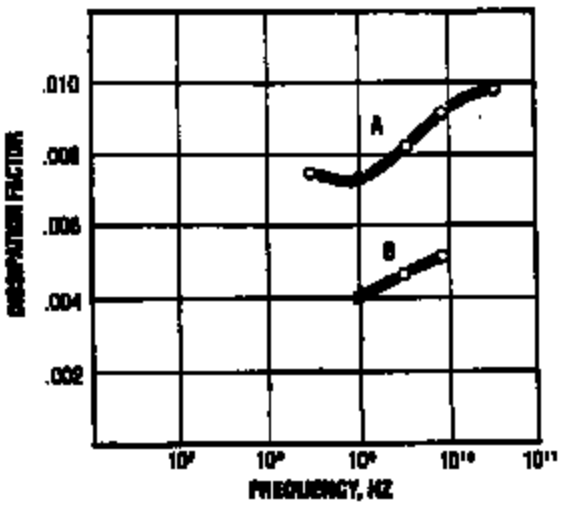


DIELECTRIC PROPERTIES IN GIGAHERTZ FREQUENCY RANGE

(Type H Film, 125μm (5 mil))*



(Type H Film, 125μm (5 mil))*



* Technical Report AFML-TR-78-30—Curve A is 200H KAPTON as received and measured at 23°C and 45% RH with the electric field in the plane of the sheet. Curve B is the same measurement after conditioning the film at 150°C for 48 hours.

TRACKING RESISTANCE

A 125 μm (5 mil) KAPTON® polyimide film, Type H, has a tracking resistance of 180 seconds as measured by ASTM D-495-61. The failure was due to true tracking rather than erosion, etc.

CORONA LIFE

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

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

KAPTON® offers a high degree of chemical resistance to a wide variety of chemicals including solvents and oils. Typical values for some commonly used materials are shown on the following pages.

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	97	82	150	365
10% Sodium Hydroxide		Degrades		5
Glacial Acetic Acid	98	82	102	30 days @ 353K (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	95	30	100	14 days @ 373K (100°C)
pH = 4.2	95	30	100	14 days @ 373K (100°C)
pH = 7.0	95	20	100	168 days @ 373K (100°C)
pH = 8.9	95	20	100	14 days @ 373K (100°C)
pH = 10.0	95	10	100	4 days @ 373K (100°C)
RADIATION RESISTANCE				
Gamma (Savannah River)		Still Flexible (180° Bend)		Exposure: 4.16×10^9 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		296K (72°F) 20%-60% Relative Humidity
PERMEABILITY				
Gas		ml/m²·MPa·day (cc/(100 in²) (24 hrs.) (atm/mil))		
Carbon Dioxide		8.9 (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

KAPTON® Type V Film

CHEMICAL PROPERTIES

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

KAPTON® Type F Film

CHEMICAL PROPERTIES

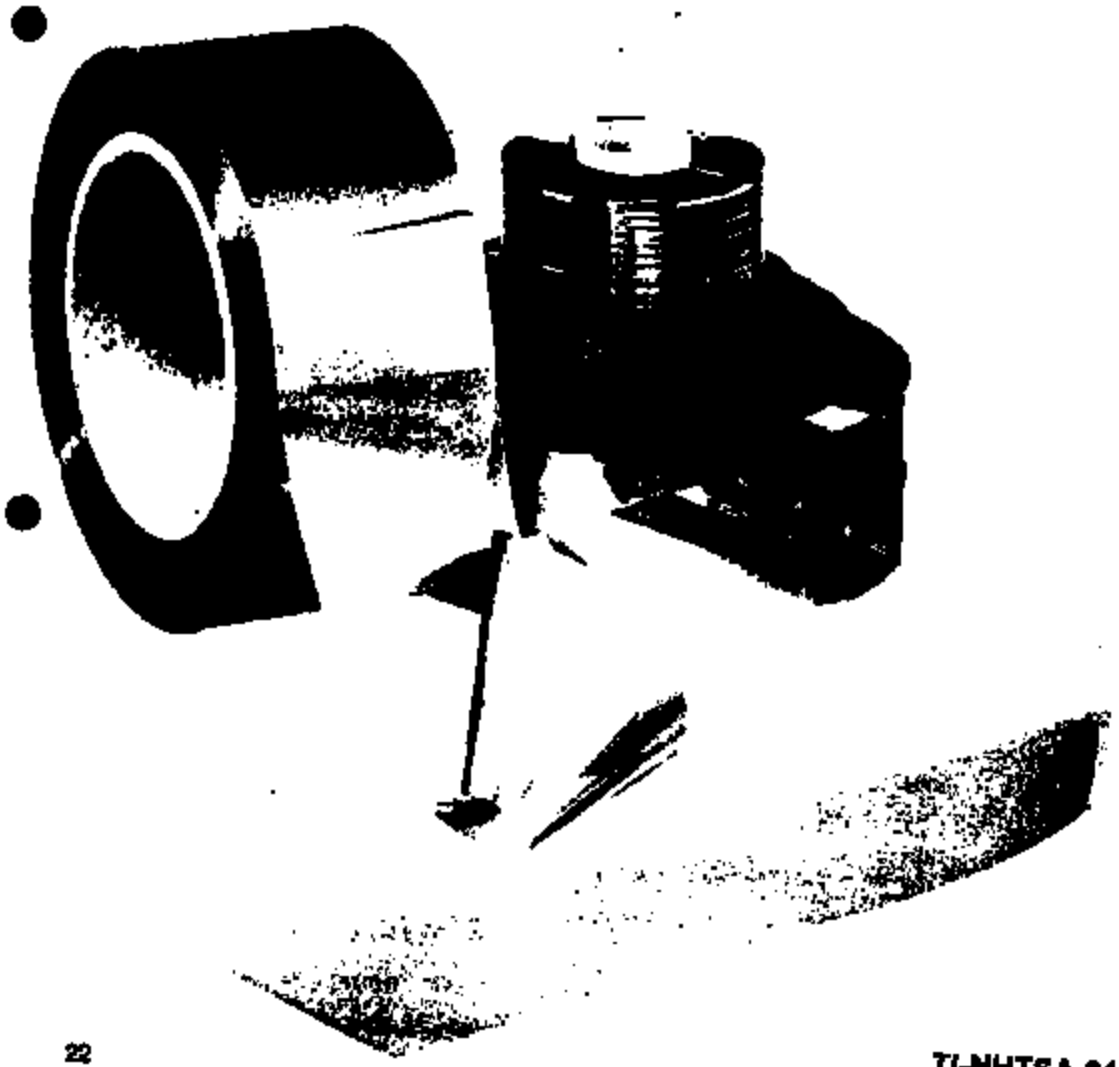
PROPERTY	129F019	159F019	489F022
Moisture Absorption @ 296K (23°C), 50% R.H.	1.3%	.8%	.4%
95% R.H.	2.9%	1.7%	1.2%
Water Vapor Permeability g/m²-d (gm./(100 in²) (24 hrs.)	13.7 (0.88)	8.8 (0.57)	3.6 (0.23)
g/m²-d-μm (g./(100 in²)(24 hrs./mil)	0.44 (1.07)	0.35 (0.86)	0.14 (0.92)

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	⅛-36	21.3	104
150F019	3.18-914	⅛-36	15.8	77
250F029	3.18-914	⅛-36	11.1	49



All inquiries should be directed to:

Du Pont Company
Polymer Products Department
Industrial Films Division
Wilmington, Delaware 19898
Phone: 800-527-2801

In U.S.A.
Du Pont Company
Polymer Products Department
Industrial Films Division
Wilmington, DE 19898
(800) 527-2601

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

In Europe
Du Pont de Nemours International
Polymer Products Department
76-82 Route des Acacias
CH-1211 Geneva 24, Switzerland
(022) 37 81 11

In The Far East
Du Pont Japan Limited
Kowa Building No. 2
11-39 Akasaka 1-chome
Minato-Ku
Tokyo 107, Japan
011-81-3-585-5511

In Brazil
Du Pont do Brasil S/A
Caixa Postal, 35 – Alphaville
06400 Barueri/Sao Paulo, Brazil

Worldwide (Except Europe)
Du Pont Company
International Customer Services
Concord Plaza-Reed Bldg.
Wilmington, DE 19898
(302) 772-6120

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DuPont Electronics

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

Dear Customer:

Thank you for calling Du Pont. Enclosed please find the literature you requested on Kaptone. Your interest in our product is greatly appreciated.

Also enclosed is my business card if additional information or technical assistance is needed.

Sincerely,

Donald J. Farrelly Jr.

Donald J. Farrelly, Jr.

DJF/ tlp
Enclosures

®Du Pont Registered Trademark

DuPont Electronics

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

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MATERIAL SAFETY DATA SHEET

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

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

MATERIAL IDENTIFICATION

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

HAZARDOUS COMPONENTS

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

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

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

PHYSICAL/CHEMICAL DATA

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

MATERIAL SAFETY DATA SHEET

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PHYSICAL/CHEMICAL DATA

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

FIRE AND EXPLOSION HAZARD DATA

FLASH IGNITION TEMPERATURE NA

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

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

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

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

HAZARDOUS REACTIVITY

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

MATERIALS TO AVOID Alkali metal and interhalogen compounds.

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

HEALTH HAZARD DATA

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

ACUTE OR IMMEDIATE EFFECTS: ROUTES OF ENTRY AND SYMPTOMS

INGESTION Not a probable route of exposure.

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

EYE Not a probable route of exposure. Mechanical irritation.

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

Inhalation is not a probable route of exposure for film. For the polymer from which this film is made, du Pont recommends treating polymer dust as

FIRE AND EXPLOSION HAZARD DATA

FLASH IGNITION TEMPERATURE NA

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

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

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

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

HAZARDOUS REACTIVITY

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

MATERIALS TO AVOID Alkali metal and interhalogen compounds.

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

HEALTH HAZARD DATA

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

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Inhalation is not a probable route of exposure for film. For the polymer from which this film is made, du Pont recommends treating polymer dust as

a nuisance particulate, and has established an AEL of 10 mg/m^3 total dust, the same as the TLV for nuisance particulates.

EMERGENCY FIRST AID

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

CHRONIC EFFECTS None known.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE None known.

PROTECTION INFORMATION

EYE Safety glasses recommended.

SKIN Gloves recommended.

VENTILATION Local exhaust for operation above 200°C.

RESPIRATOR Not required for normal processing.

DISPOSAL

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

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

AQUATIC TOXICITY Insoluble

STORAGE CONDITIONS Store away from flammable materials.

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

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

a nuisance particulate, and has established an AEL of 10 mg/m^3 total dust, the same as the TLV for nuisance particulates.

EMERGENCY FIRST AID

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

CHRONIC EFFECTS None known.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE None known.

PROTECTION INFORMATION

EYE Safety glasses recommended.

SKIN Gloves recommended.

VENTILATION Local exhaust for operation above 200°C.

RESPIRATOR Not required for normal processing.

DISPOSAL

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

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

AQUATIC TOXICITY Insoluble

STORAGE CONDITIONS Store away from flammable materials.

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

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

SECTION 313 SUPPLIER NOTIFICATION

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

STATE RIGHT TO KNOW LAWS

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

SUBSTANCES ON THE PENNSYLVANIA HAZARDOUS SUBSTANCES LIST PRESENT AT A CONCENTRATION OF 1% OR MORE:

Dimethyl acetamide (1% maximum)

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

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

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

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

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

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

Dimethyl acetamide (1% maximum).

SECTION 313 SUPPLIER NOTIFICATION

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

STATE RIGHT TO KNOW LAWS

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

SUBSTANCES ON THE PENNSYLVANIA HAZARDOUS SUBSTANCES LIST PRESENT AT A CONCENTRATION OF 1% OR MORE:

Dimethyl acetamide (1% maximum)

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

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

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

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

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

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

Dimethyl acetamide (1% maximum).

Kapton
POLYIMIDE FILM

GENERAL SPECIFICATIONS BULLETIN GS-87-4

GENERAL

INTRODUCTION

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

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

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

Types of Kapton® Polyimide Film

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

Type HN Film

"Kapton" Type HN is a tough aromatic polyimide film, exhibiting an excellent balance of physical, chemical and electrical properties over a wide temperature range, particularly at unusually high temperatures. Chemically, its polyimide polymer make up is the result of a polycondensation reaction between pyromellitic dianhydride and 4,4'-diaminodiphenyl-ether. "Kapton" HN is available in 30, 50, 100, 200, 300 and 500 gauges.

Type FN Film

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

Type VN Film

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

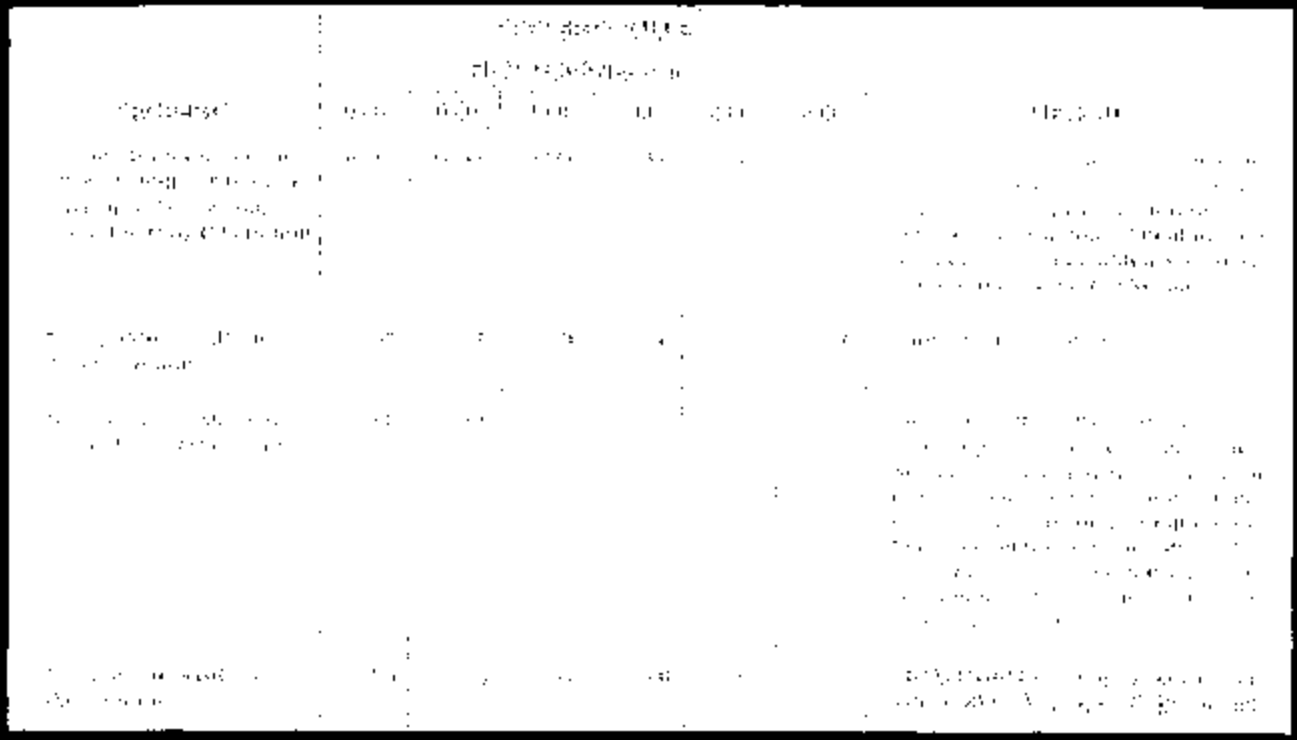
Certification

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

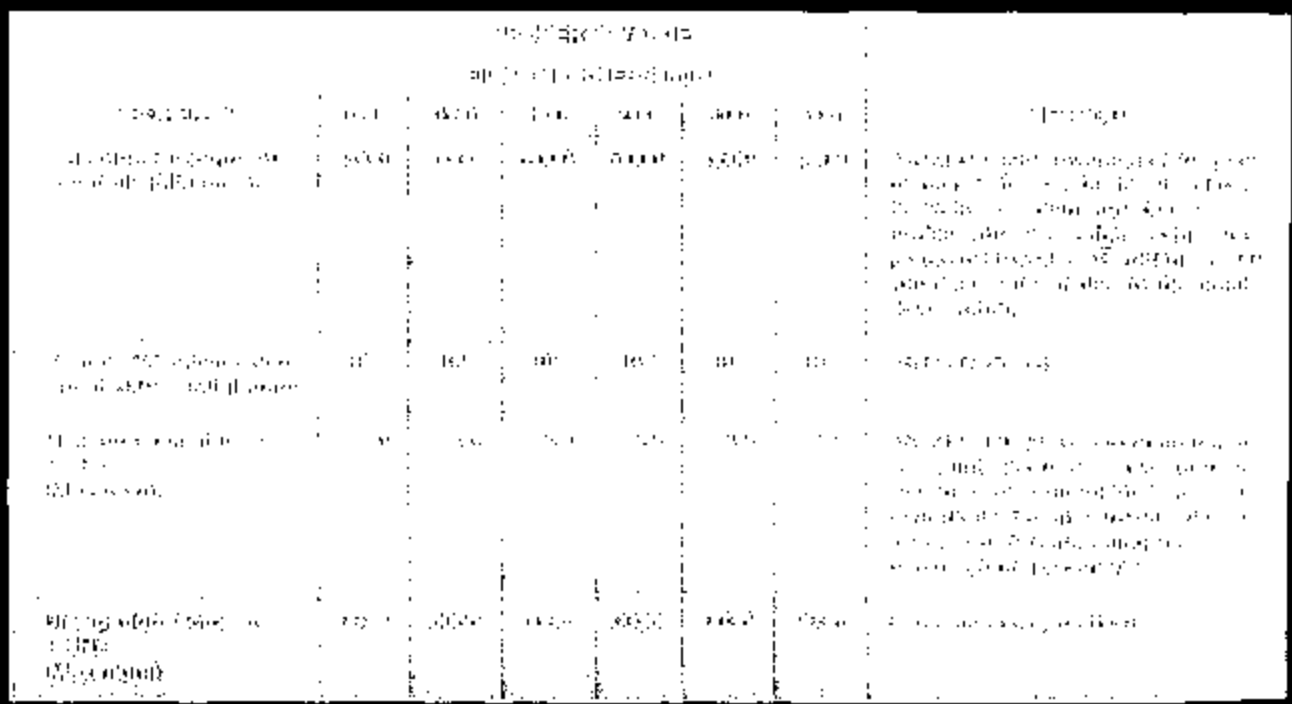
DUPONT

PROPERTIES OF TYPE HN FILM

MECHANICAL



ELECTRICAL



*1 hour for 30 and 50 gauge film.

Thermal Durability

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

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

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

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

*1 hour for 30 & 50 gauge film.

PROPERTIES OF TYPE FN FILM

A. Heat Seal Strength

1. Film to Film Seals

The heat seal peel strength between the coated and uncoated side of one side coated Kapton® polyimide film or the coated to coated side of one or two side coated "Kapton" is measured in the following manner. Seals are made in a jaw sealer at 360°C., 20 psi, 20 sec. dwell time. After cooling, the seals are cut to 1" wide stripe using a Thwing-Albert JDC sample cutter or equivalent. The strength of the seal is measured with an Instron type tensile tester. Seal strength is defined as the peak instantaneous strength occurring in each seal. Five specimen values are averaged.

The minimum peel strength between the coated sides of one or two side coated "Kapton" polyimide film will be 800 gms./inch except for 120FN616 which will be 450 gms./in. The minimum peel strength between the coated and uncoated side of one side coated "Kapton" will be 450 gms./inch.

2. Film to Copper Seals for 120FN616 Film

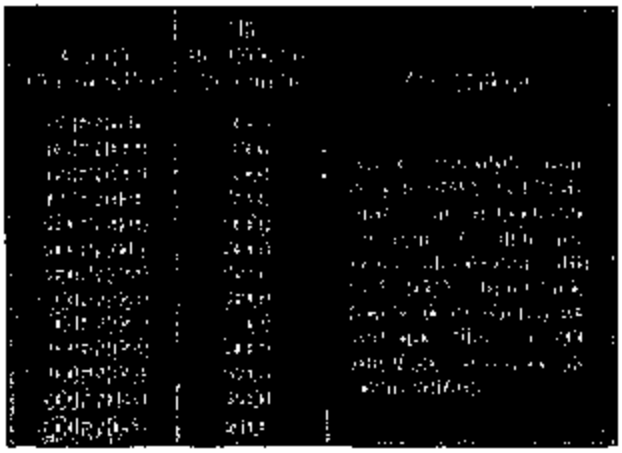
The ability of 120FN616 film to adhere to copper is measured by using the same heat seal peel strength technique as described above.

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

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

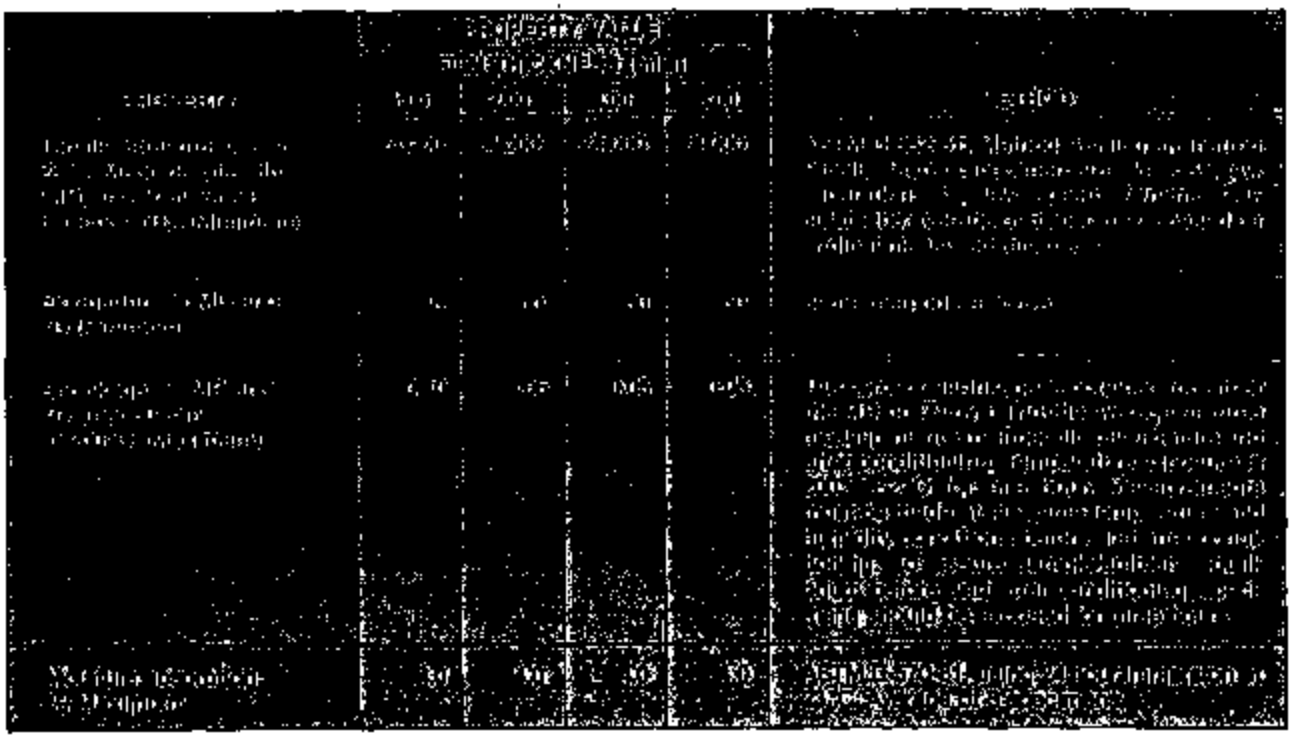
The bond between the Type HN "Kapton" and Teflon® fluorocarbon resin layers on all type FN products except 120FN616 will have a minimum peel strength of 225 gms./in. as measured using an Instron type tensile tester and a 180° peel.

B. Dielectric Strength

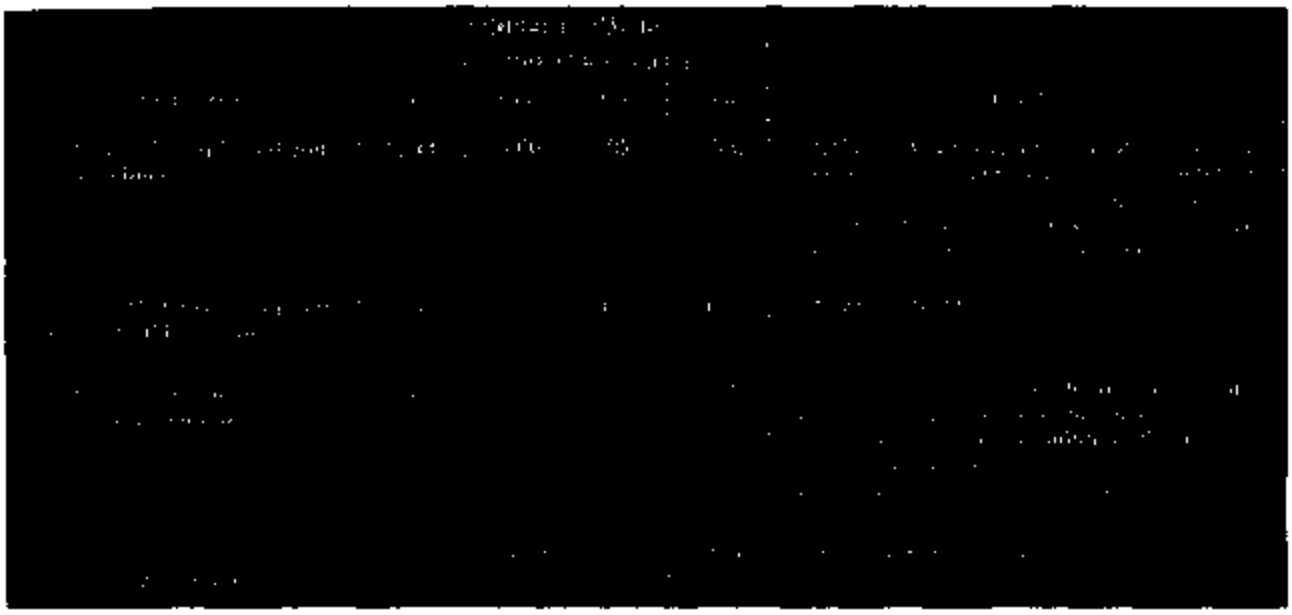


PROPERTIES OF TYPE VN FILM

MECHANICAL



ELECTRICAL



Thermal Durability

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

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

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

GENERAL

A. MATERIAL

Type HN and Type VN Film—A polyimide polymer in the form of a film.

Type FN Film—A combination of Kapton® polyimide film Type HN with Teflon® FEP fluorocarbon resin on one or both sides.

B. UNIFORMITY

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

C. CORES

Cores shall be of sufficient strength to prevent collapsing on handling. Standard core I.D.'s are 3" and 6" with the following specifications: 3" I.D. is 3.032" ± 0.008", 6" I.D. is 6.028" ± 0.010". Core material will be plastic for 3" I.D. cores less than ⅝" wide. Core material will be fibre for 3" I.D. cores wider than ⅝" and 6" I.D. cores. A split 3" I.D. fibre core is standard for all universal rolls. Core width for universal wind is 2¼".

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

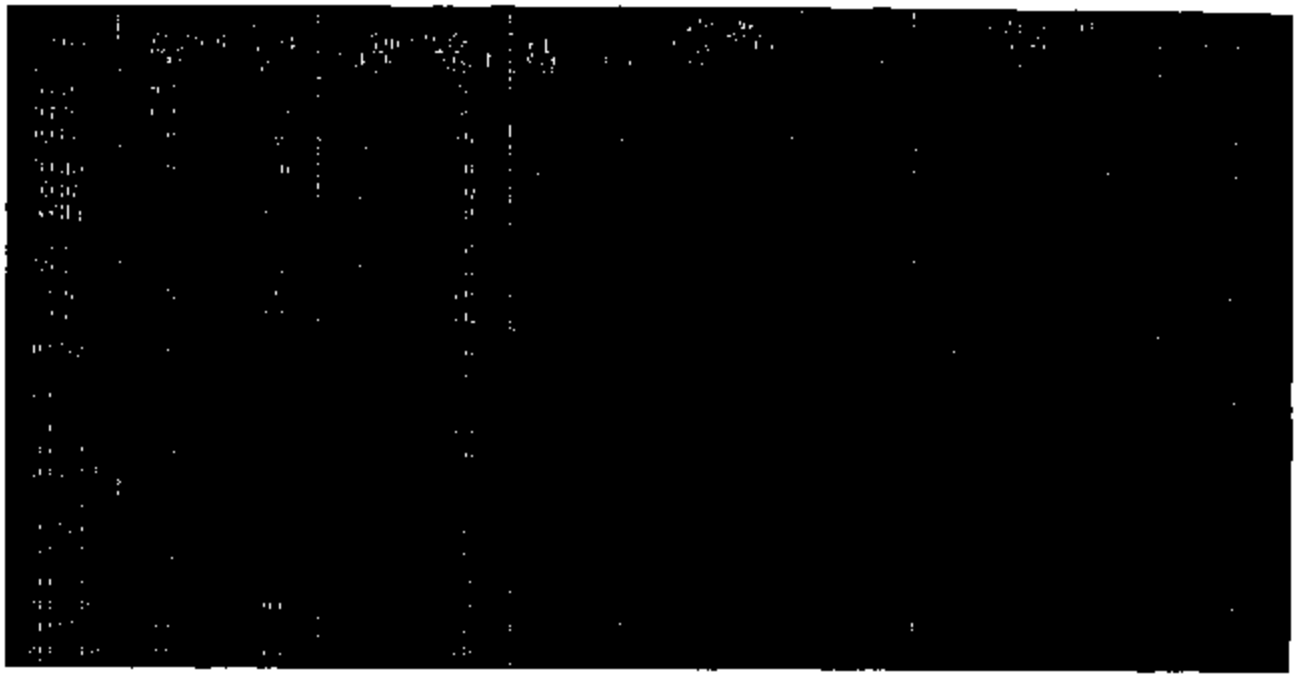
D. WIDTH TOLERANCE

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

Slit Width Range	Tolerance
⅞" or less Universal only	± 7 mils
1" or less	±15 mils
1 1/16"–4"	±30 mils
4 1/16" or wider	±60 mils

E. ROLL TYPES

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



(1) 3" x 6" pad roll is available in widths up to ½" only in 100HN, 200HN, 300HN, 500HN, 160FN016, 200FN011, 200FN012, 250FN029, 400FN021, 500FN025.
* O.D. Tolerance is ±½" for pads and ±¼" for universals.
* Type HN, FN and VN films in pads are supplied in width increments of ⅛". Most films are supplied in width increments of ¼" in widths ½" to 2".
* All universal rolls are available in ⅛" width increments with ½" maximum widths. The minimum width is ½" for 3" x 6" (I.D. x O.D.); the minimum width is ¾" for 3" x 8", and 3" x 12" (I.D. x O.D.).

Specifications for pad rolls are:

1. Core width will be film width $+\frac{1}{8}"$, $-0"$.
2. Core edges shall not project more than $\frac{1}{16}"$ beyond roll face on either side.
3. Core shall not be recessed on either side.
4. The outside and starting ends of the film shall be fastened in such a manner as to prevent unwinding.
5. "Dishing" or "cupping" may not exceed $\frac{1}{16}"$ measured with a straight edge across the diameter of the roll.

Specifications for the universal rolls are:

1. The difference between the length of projecting core on each side shall not exceed $\frac{3}{16}"$.
2. Film shall not project from the main body of the roll more than $\frac{1}{8}"$.
3. The outside and starting ends of the film shall be fastened in such a manner as to prevent unwinding.
4. Roll face depression, the difference between the highest and lowest points unstressed, shall not exceed $\frac{3}{16}"$.
5. Width of traverse is $1\frac{3}{4}"$, $-\frac{1}{4}"$, $+\frac{1}{8}"$.

F. SPLICES

1. Description

Three types of splice are available.

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

Splices will be sufficiently smooth and wrinkle-free so as not to distort adjacent layers of film and approximately centered to $\pm\frac{1}{4}"$.

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

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

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

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

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

2. Maximum Splices per Slit Roll

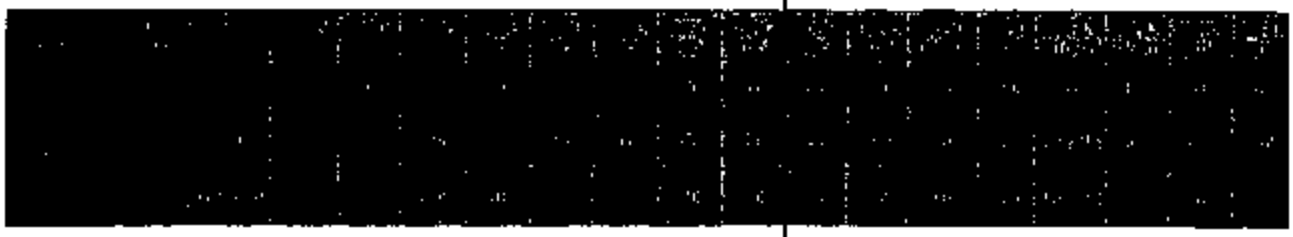
The minimum average footage between splices for most rolls is shown in Table I. To calculate the maximum number of splices in a roll divide the nominal feet per roll by the minimum average length between splices and subtract one.

3. Splice Placement

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

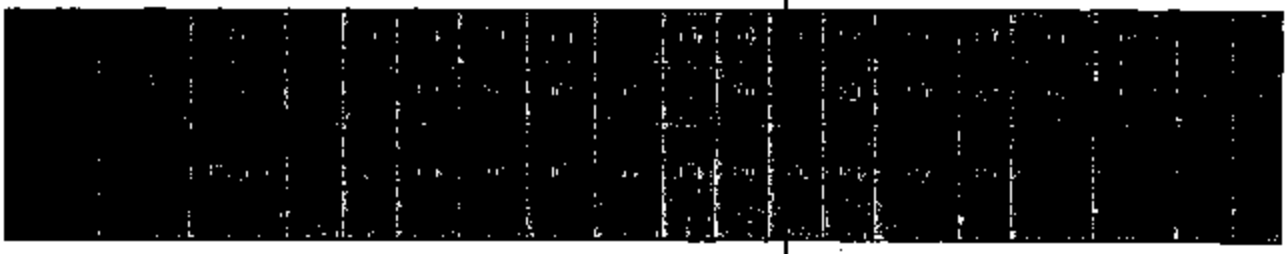
TABLE I

MINIMUM AVERAGE SPLICE FREE LENGTH (FEET)



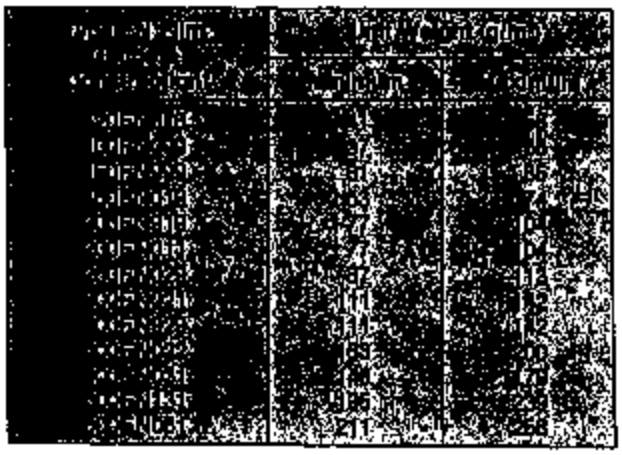
NOTES: [1] To 60" wide for 30HN, 52" wide for 50HN
[2] To 50" wide
[3] To 6" wide
[4] To 18" wide. For widths greater than 18" to the maximum, the minimum average footage will be one half that shown in the table.
[5] ½" to 5" wide

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



G. AVERAGE THICKNESS TOLERANCES (UNIT WEIGHT)

*Applies to Type VN films also.



Test Method and Sampling Procedure

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

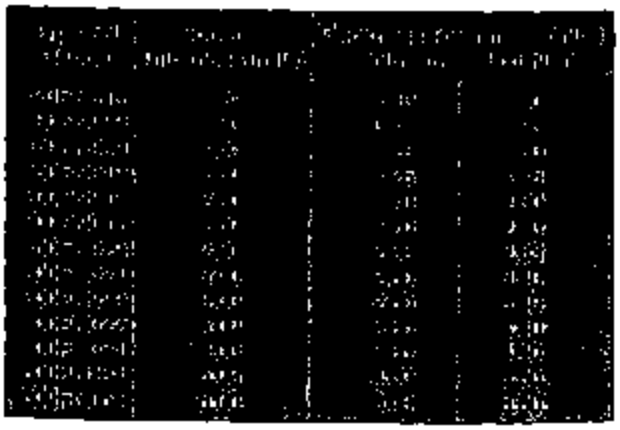
To confirm average thickness tolerances, obtain a sample consisting of a minimum of one specimen from each of several randomly selected slit rolls as follows:

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

H. MICROMETER THICKNESS

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

*Applies to Type VN films also.



Test Method

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

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

Gauge Depression

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

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

Table II lists the maximum allowable depression for most pad rolls. There is no gauge depression standard for universal wind since that roll is limited to a maximum of 7/4" wide.

TABLE II

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

PACKAGING AND MARKING

A. PACKAGING

"Kapton" shall be adequately packed to prevent loss of contents or damage during shipment.

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

B. MARKING

"Kapton" is identified as follows to allow complete traceability back to the raw materials and processing conditions:

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

(a) Affixed to the core on all cores, 2¼" wide and over. Included with the package on all cores less than 2¼" wide.
(b) Inside diameter of core and nominal outside diameter of roll.
(c) Available for up to 12 characters.

DU PONT ELECTRONICS DEPARTMENT

In U.S.A.
Du Pont Company
Electronics Department
Wilmington, DE 19898

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Du Pont do Brazil S/A
Divisao de Plasticos or Elastomers
Caixa Postal, 26 – Alphaville
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Kapton™

POLYIMIDE FILM

ADHESION TO KAPTON®

KAPTON® polyimide film, made only by Du Pont, is available in three basic film types. Type H KAPTON is 100% polyimide film. Type F is coated on one or both sides with a TEFLON® FEP fluorocarbon adhesive and Type V is a plain polyimide film having superior dimensional stability properties. Typical property information for KAPTON is found in Bulletin E-72087, "Summary of Properties." Specifications are found in Bulletin E-67624, "Industry Specifications Bulletin FC-85-2." For flexible printed circuit applications the trade specification IPC-FC-231/Sheet 1, applies to KAPTON.

ADHESIVE SELECTION

For some applications KAPTON must be bonded to other materials, such as copper foil, which requires the use of an adhesive. Optimum adhesion results are usually obtained from commercially coated KAPTON which is available from a variety of suppliers such as those listed in Bulletin E-72061, "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, flll and flow characteristics, flexibility, peel strength, flammability, moisture resistance and insulation resistance. Also to be considered is the ease of processing, lamination temperature and whether the lamination is to be made in continuous roll equipment or in a platen press.

ADHESIVE PROPERTIES

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

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

TABLE 1

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

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

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DU PONT

TI-NHTSA 018057

Kapton

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

TI-NHTSA 016058

DUPONT

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

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

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

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

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

Three types of KAPTON are commercially available.

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

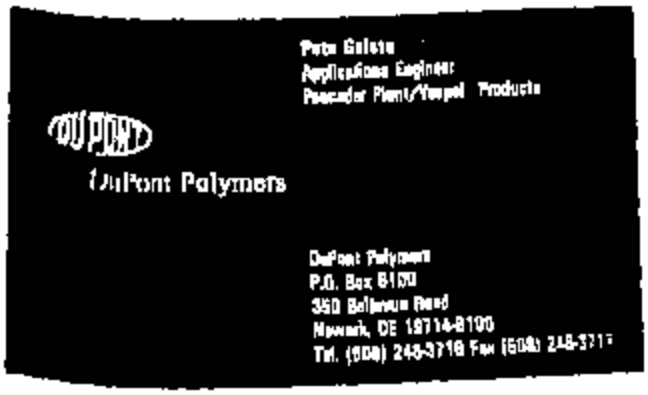
■ KAPTON Type V is an all-purpose, all-polyimide film with all of the properties of Type H film, plus *superior dimensional stability*. It is available in 1, 2, 3, and 5 mil thickness.

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

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

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

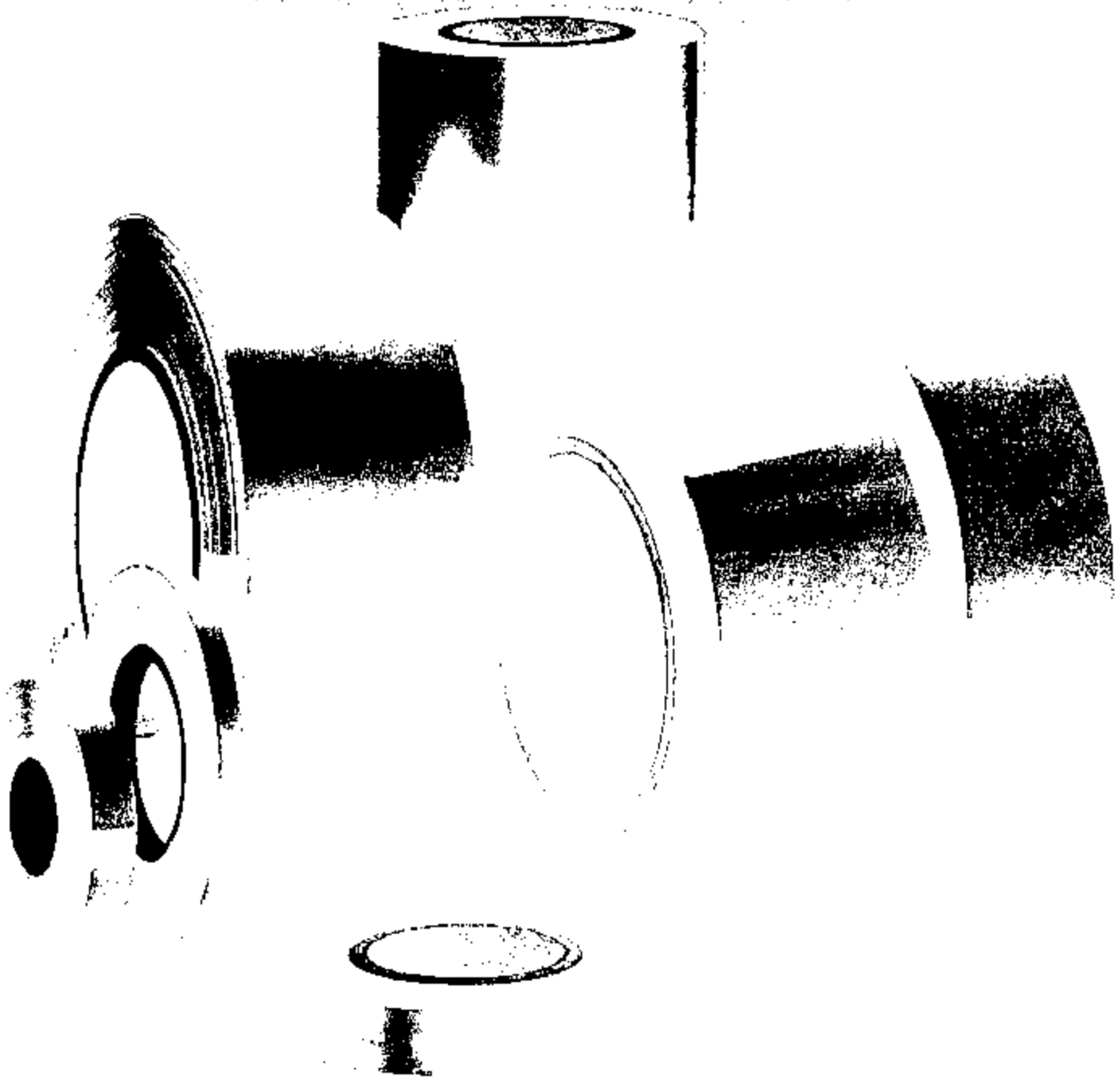
When sufficient business potential exists, our resources can be made available for the joint development of custom-tailored products and programs to fulfill your most stringent design requirements — during the Eighties and beyond.



Kapton

POLYIMIDE FILM

SUMMARY OF PROPERTIES



DUPONT

CONTENTS

Kapton®
POLYIMIDE FILM

GENERAL INFORMATION

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

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

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

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

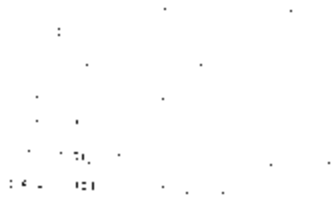
Du Pont makes three types of KAPTON:

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

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

*Reg. U.S. Pat. Off.

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 Strength, MPa (psi) (MD)	241 (35,000)	172 (25,000)	117 (17,000)	ASTM D-882-81
Yield Point at 3%, MPa (psi) (MD)		69 (10,000)	41 (6,000)	ASTM D-882-81
Stress to Produce 5% Elongation, MPa (psi) (MD)		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)	298 to 311K (−14°C to 38°C)	ASTM D-696-44
Coefficient of Thermal Conductivity, W/m·K $\left(\frac{(cal)(cm)}{(cm^2)(sec)(°C)}\right)$	0.155 (3.72×10^{-4}) 0.163 (3.89×10^{-4}) 0.178 (4.26×10^{-4}) 0.189 (4.51×10^{-4})	296K (23°C) 348K (75°C) 473K (200°C) 573K (300°C)	Model TC-1000 Twin 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)	62 (7,500)	38 (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

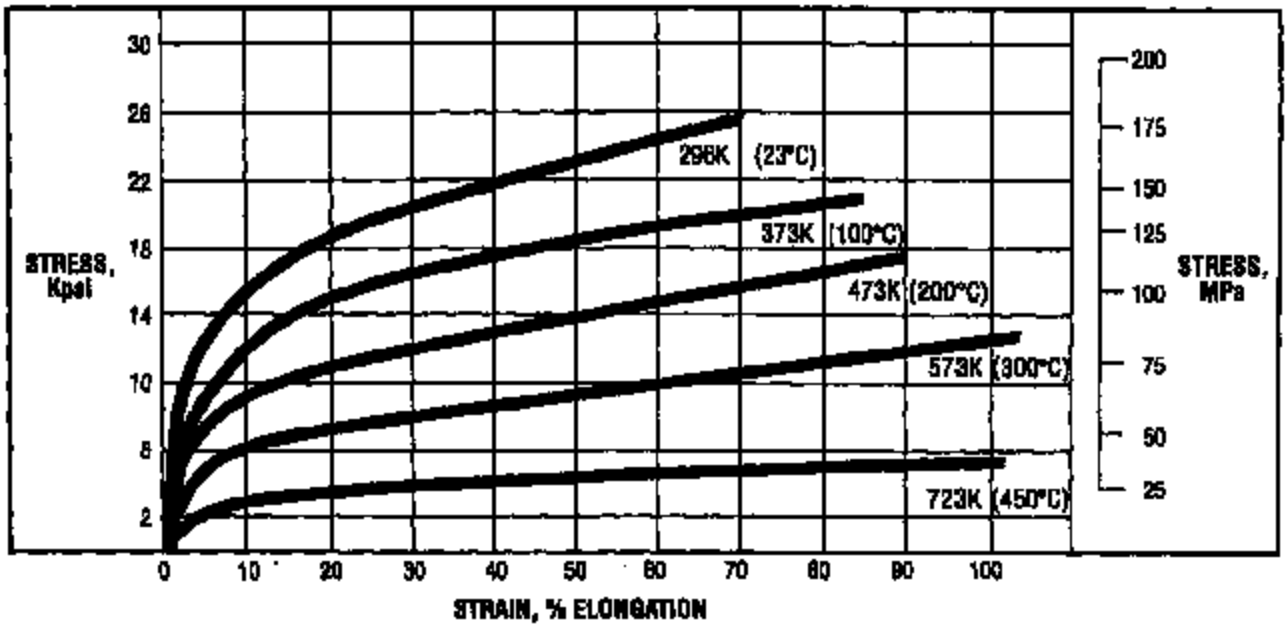
*Since a number of combinations of polyimide film and fluorocarbon coating add up to the same total gauge, it is necessary to distinguish among them. A three digit system is used in which the middle digit represents the nominal thickness of the base KAPTON film in mils. The first and third digits represent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

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))

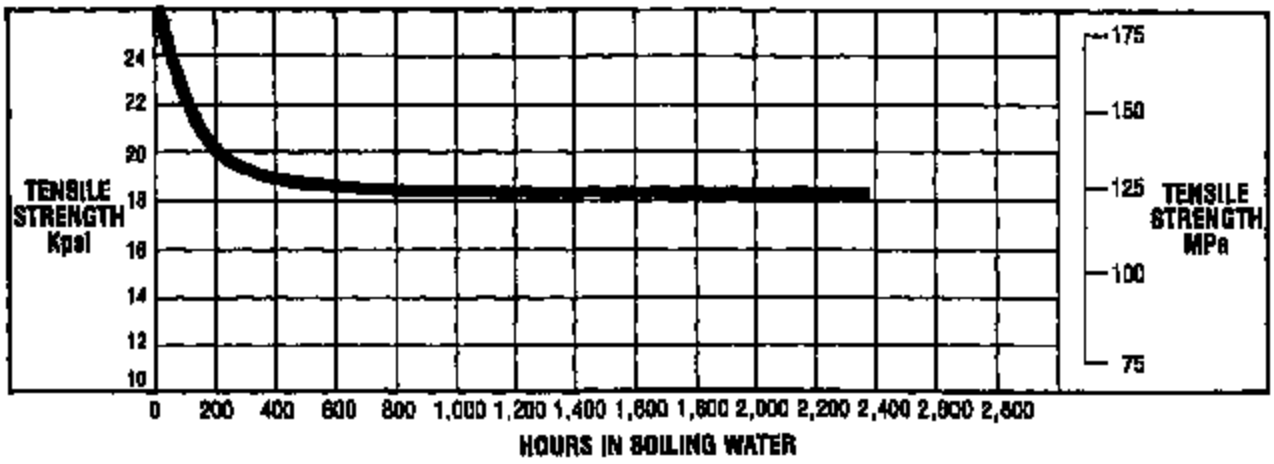


HYDROLYTIC STABILITY

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.

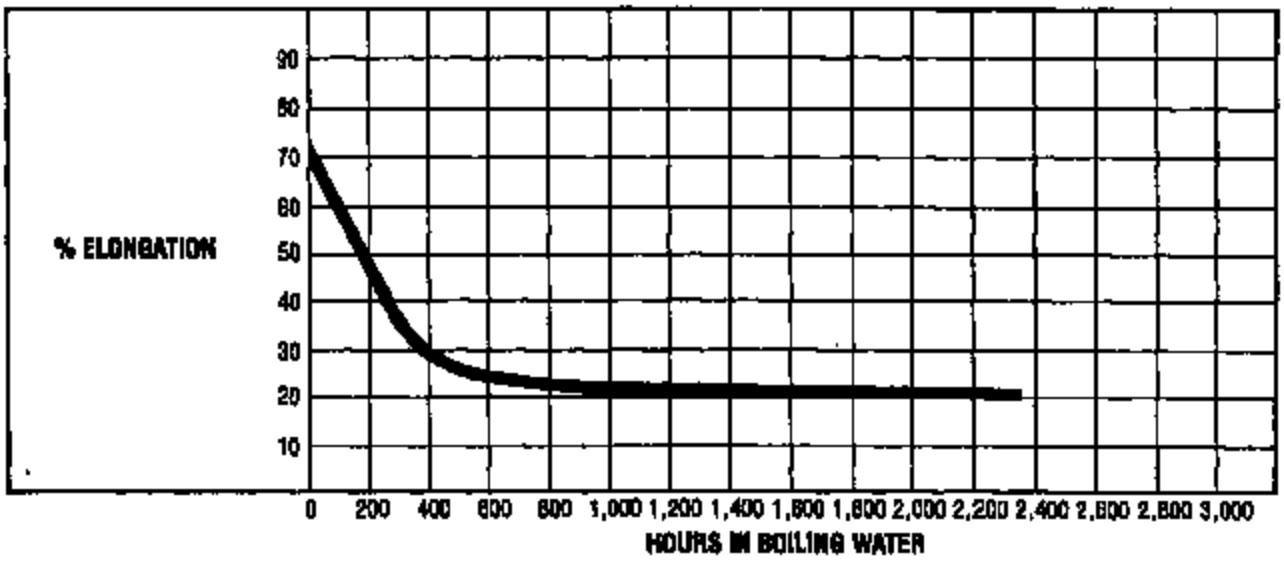
TENSILE STRENGTH AFTER EXPOSURE TO 373K (100°C) WATER

(Type H Film 25 μm (1 mil))



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

(Type H Film 25 μm (1 mil))

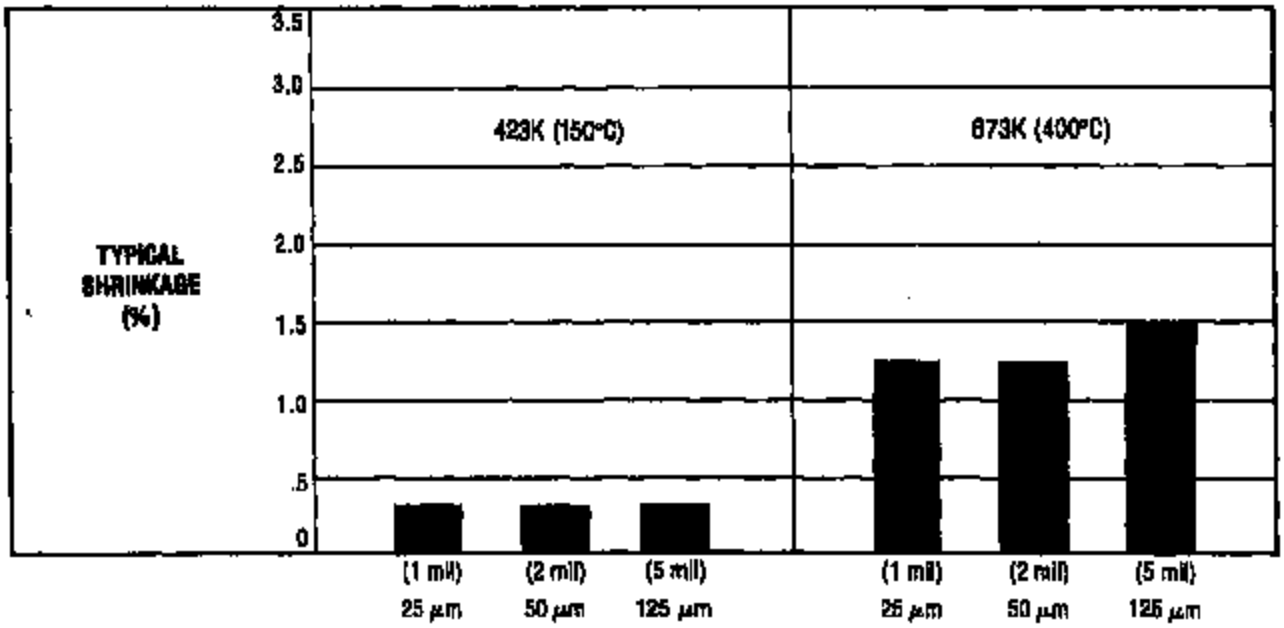


DIMENSIONAL STABILITY

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

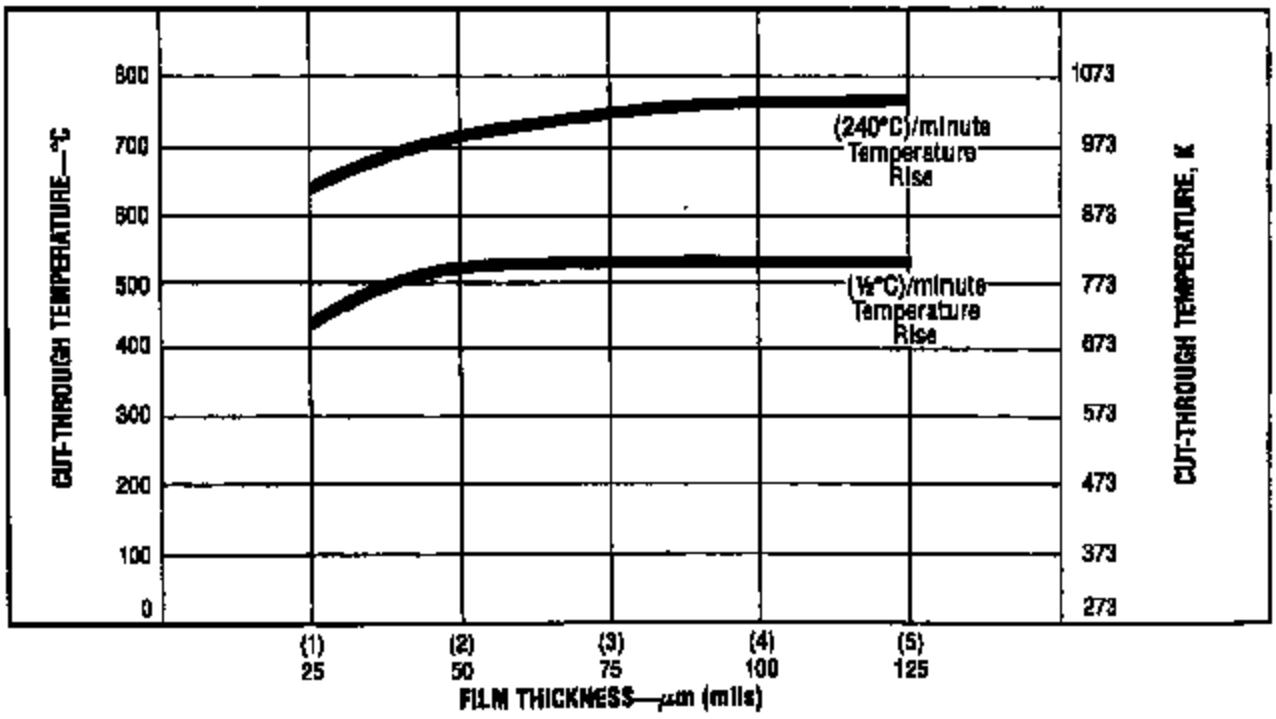
Temperature Range	"K" m/m-K x 10^{-6}
296-373K (23-100°C)	1.80
373-473K (100-200°C)	3.10
473-573K (200-300°C)	4.85
573-673K (300-400°C)	7.75
296-673K (23-400°C)	4.55

CUT-THROUGH AND COLD FLOW

Most organic films exhibit a tendency to flow or thin out under high compressive stresses, especially at elevated temperatures. KAPTON® polyimide film possesses an extremely high resistance to such stresses. Test procedures described in ASTM D-676-61 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.

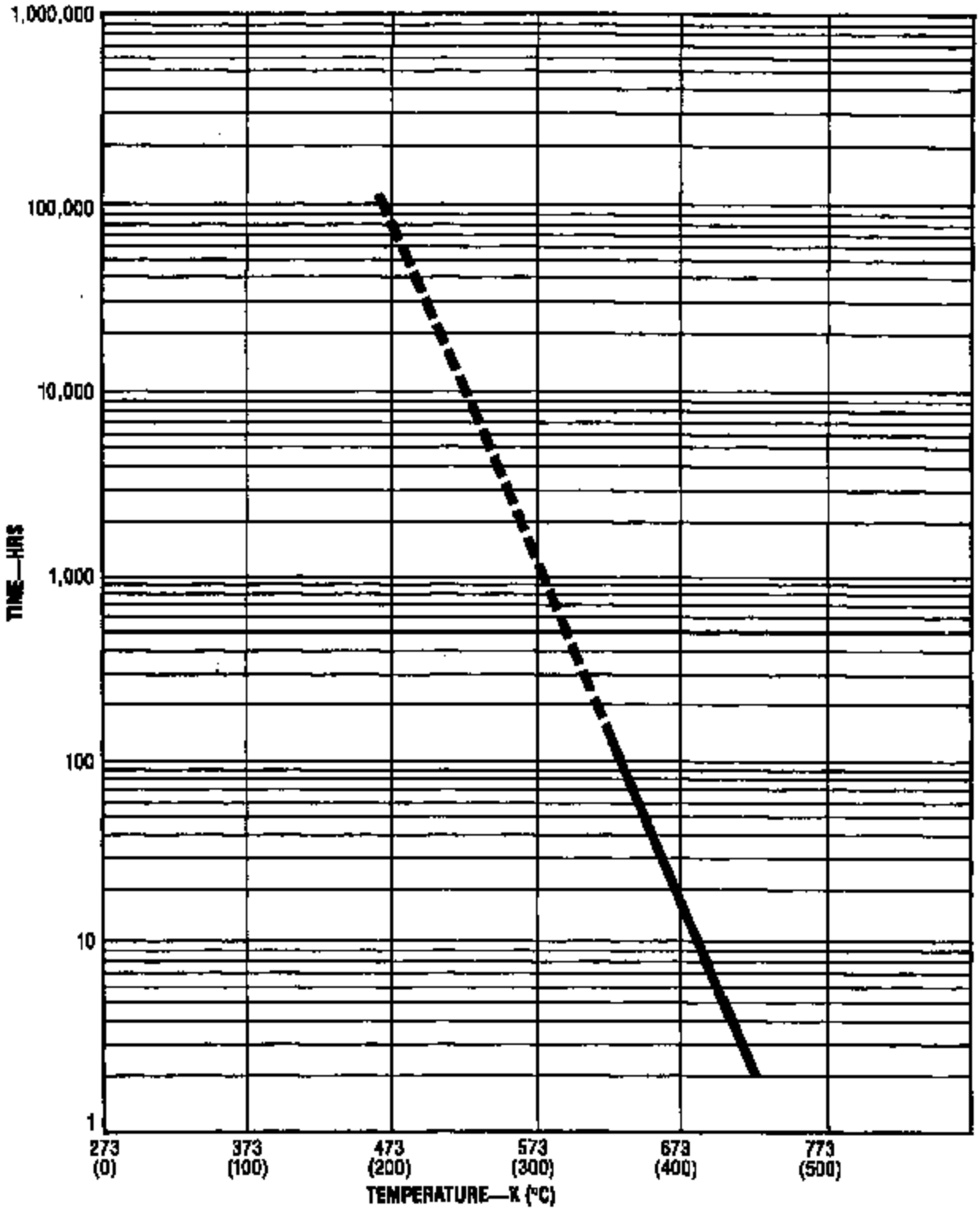
CUT-THROUGH TEMPERATURE VS. RATE OF TEMPERATURE RISE AND GAUGE

(Type H Film)



RESISTANCE TO CUT-THROUGH VS. TEMPERATURE

(Type H Film—25 μm (1 mil))



actual ——————

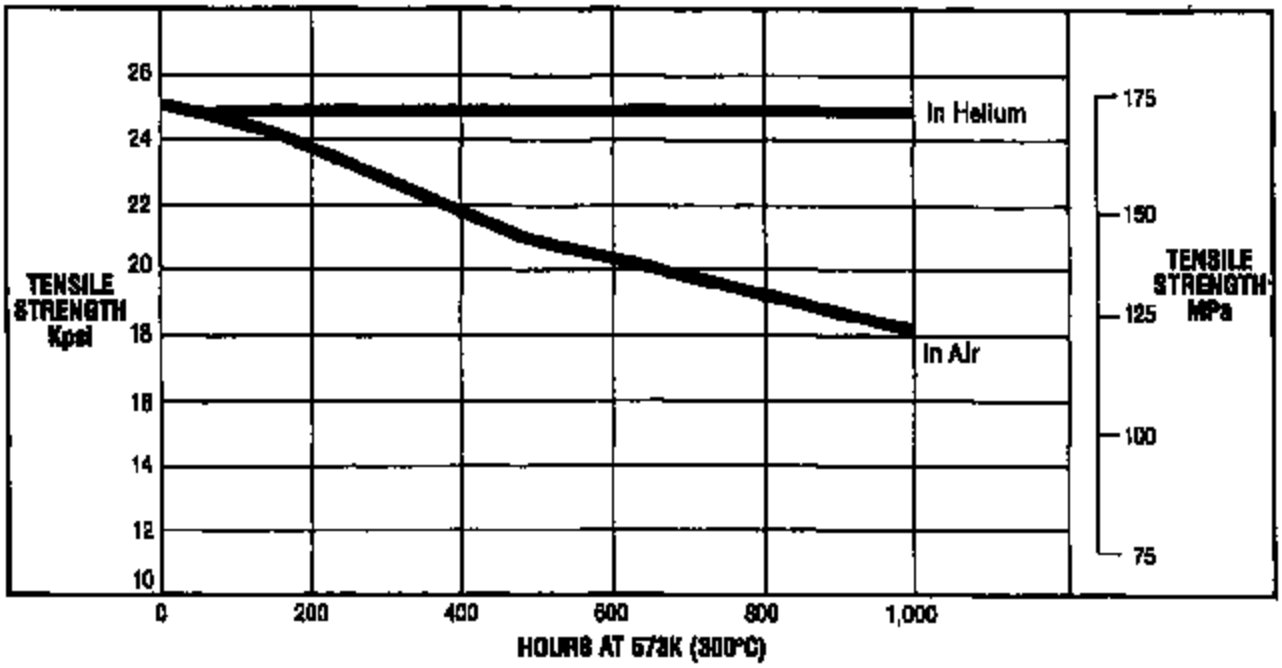
extrapolated — — — —

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.

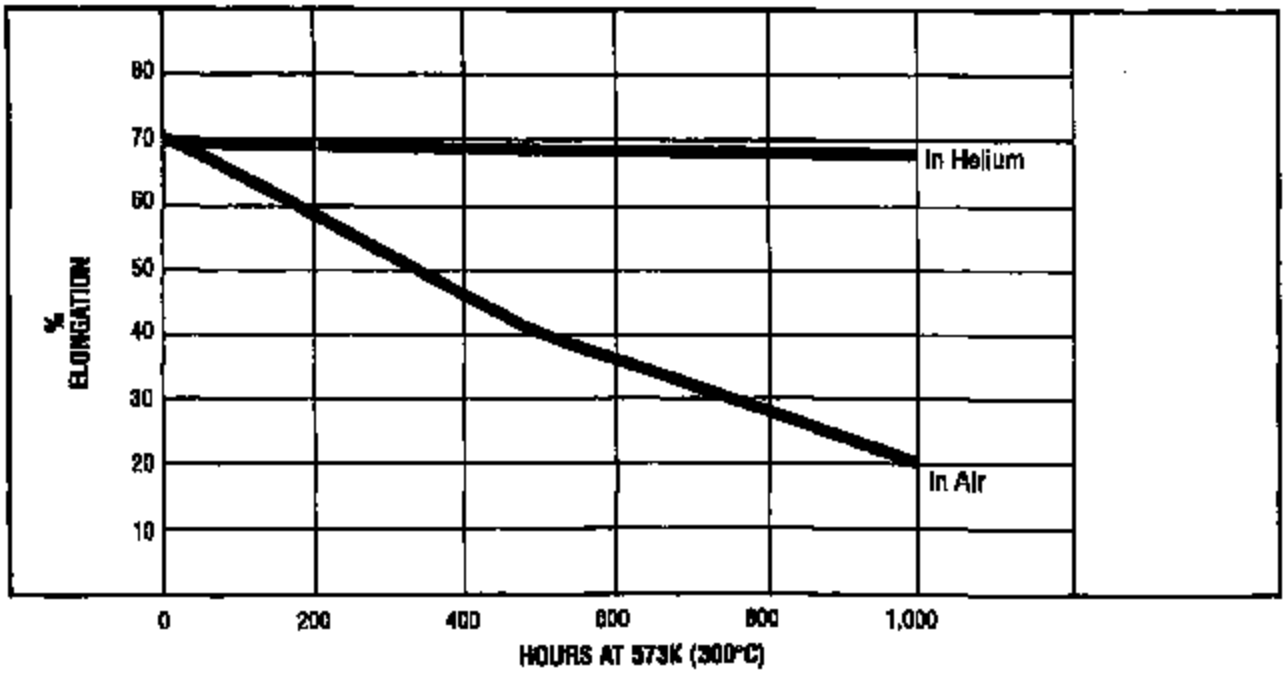
TENSILE STRENGTH VS. AGING AT 573K (300°C)

(Type H Film 25 μm (1 mil))



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

(Type H Film 25 μm (1 mil))



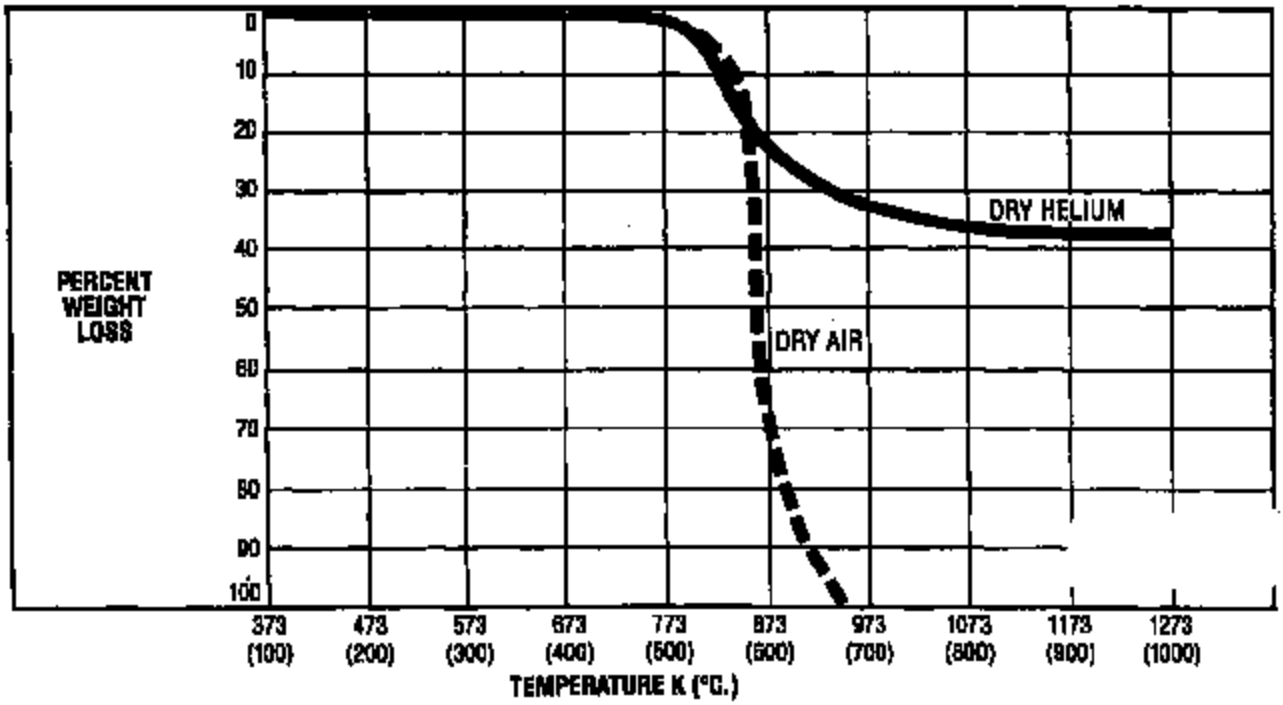
TIME REQUIRED FOR REDUCTION IN ULTIMATE ELONGATION FROM 70% to 1%

(Type H Film 25 μm (1 mil))

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

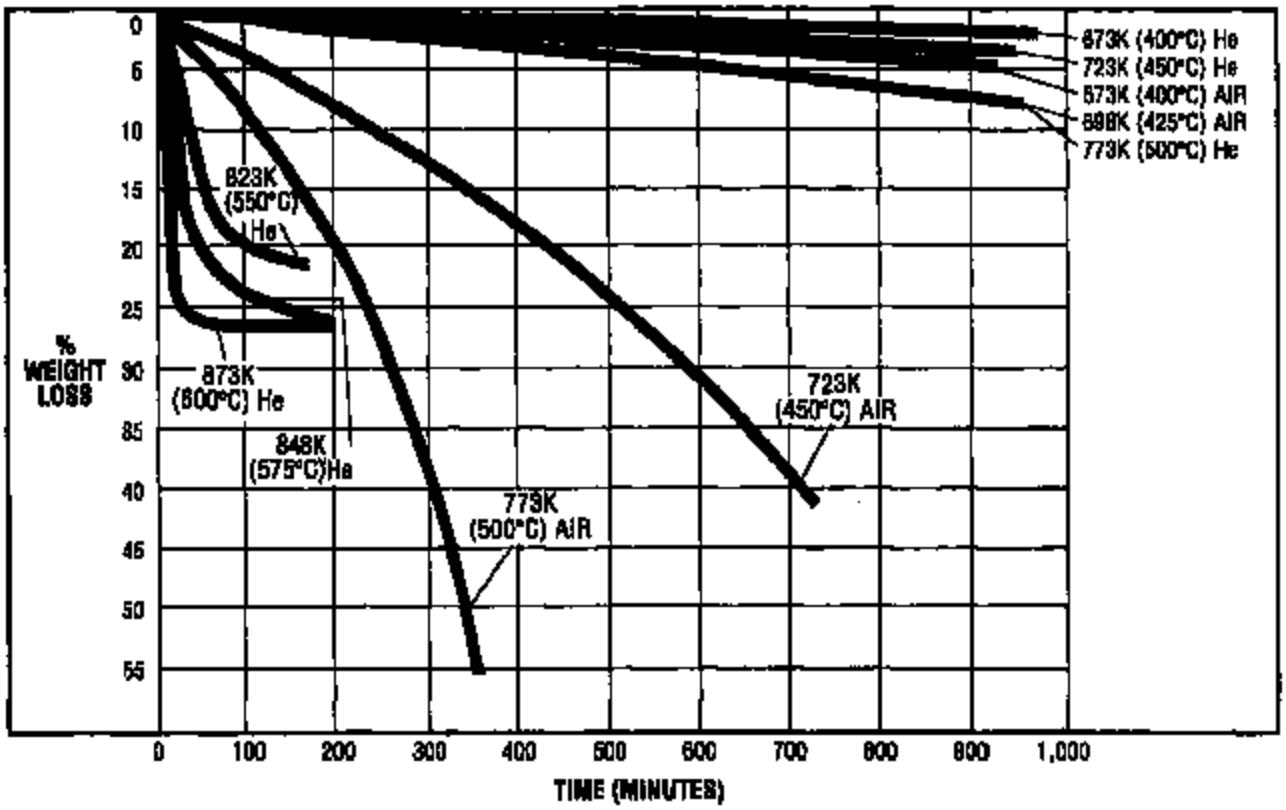
WEIGHT LOSS AT (3°C)/MINUTE TEMPERATURE RISE

(Type H Film 25 μm (1 mil))



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)	8×10^{17} ohm-m		
75 μm (3 mil)	5×10^{16} ohm-m		
125 μm (5 mil)	1×10^{16} ohm-m		

KAPTON® Type V Film

TYPICAL ELECTRICAL PROPERTIES

PROPERTY	TYPICAL VALUE	TEST CONDITION	TEST METHOD
Dielectric Strength			
50 μm (2 mil)	213 v/μm (5,400 v/mil)	60 hertz	ASTM D-149-81
75 μm (3 mil)	181 v/μm (4,600 v/mil)	¼" electrodes	
125 μm (5 mil)	142 v/μm (3,600 v/mil)		
Dielectric Constant			
50 μm (2 mil)	3.6	1 kilohertz	ASTM D-150-81
75 μm (3 mil)	3.7		
125 μm (5 mil)	3.7		
Dissipation Factor			
50 μm (2 mil)	.0025	1 kilohertz	ASTM D-150-81
75 μm (3 mil)	.0025		
125 μm (5 mil)	.0027		
Volume Resistivity			
50 μm (2 mil)	8×10^{17} ohm-m	125 volts	ASTM D-257-78
75 μm (3 mil)	5×10^{16} ohm-m		
125 μm (5 mil)	1×10^{16} ohm-m		

KAPTON® Type F Film

TYPICAL ELECTRICAL PROPERTIES

PROPERTY	120F616	150F019	250F029
Dielectric Strength Total volts volts/μm (volts/mil)	7,500 287 (6,800)	6,300 165 (4,200)	 157 (4,000)
Dielectric Constant	2.8	3.0	
Dissipation Factor	.0022	.0014	
Volume Resistivity ohm-m @ 296K (23°C) (ohm-cm.) ohm-m @ 473K (200°C) (ohm-cm.)	 1.5×10^{14} (1.5×10^{16}) 5×10^{11} (5×10^{13})	 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

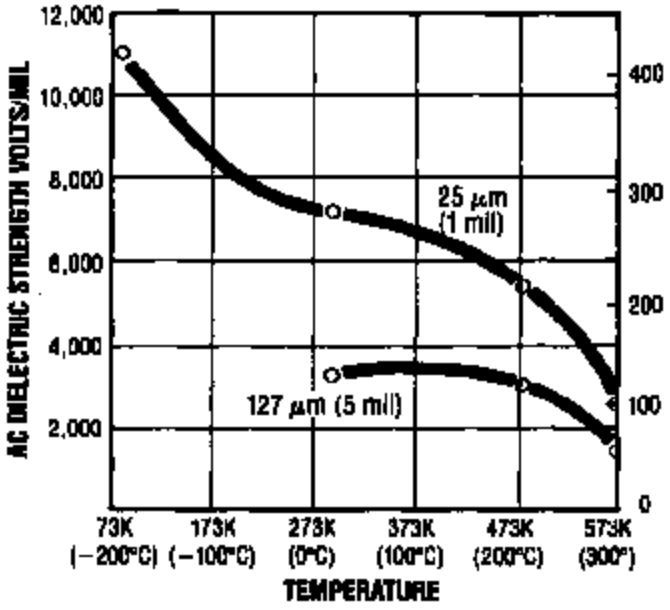
For calculations involving absolute water content, 50% RH in our study is equal to 1.3% water in the film and 100% RH is equal to 2.9% water, the maximum adsorption possible regardless of the driving force.

EFFECT OF TEMPERATURE

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

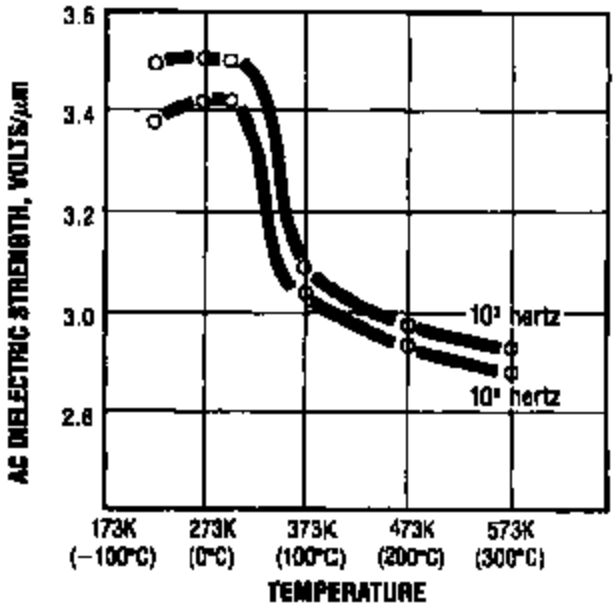
AC DIELECTRIC STRENGTH VS. TEMPERATURE

(Type H Film)



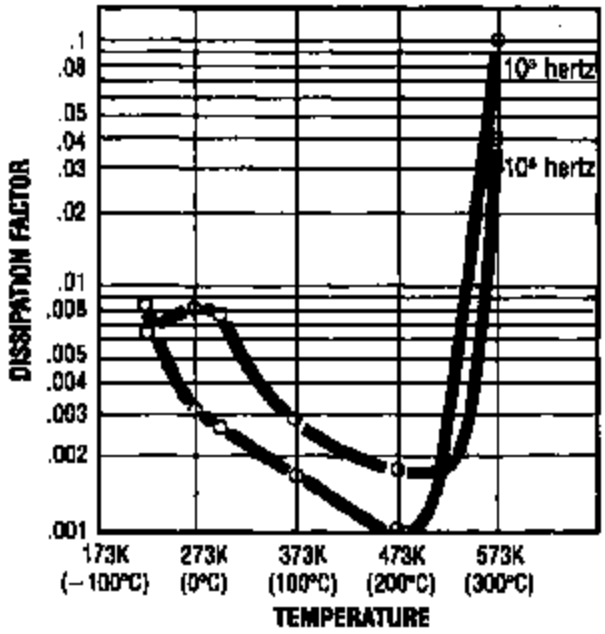
DIELECTRIC CONSTANT VS. TEMPERATURE

(Type H Film—25 μm (1 mil))



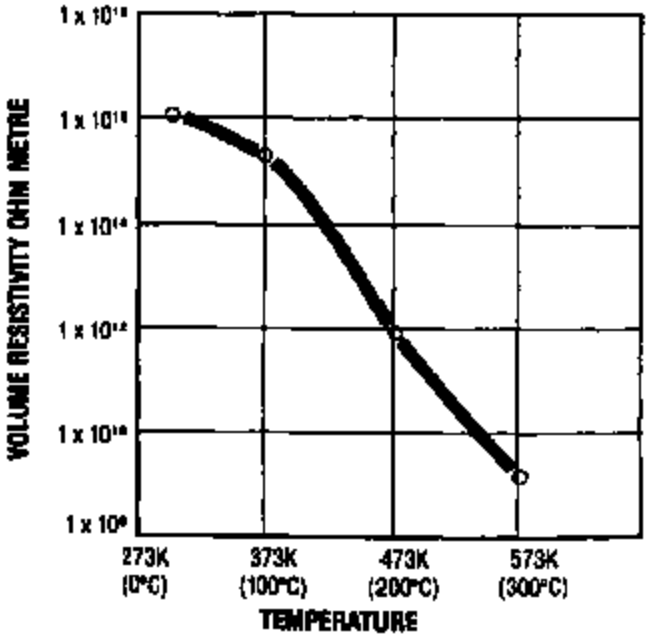
DISSIPATION FACTOR VS. TEMPERATURE

(Type H Film 25 μm (1 mil))



VOLUME RESISTIVITY VS. TEMPERATURE

(Type H Film 25 μm (1 mil))

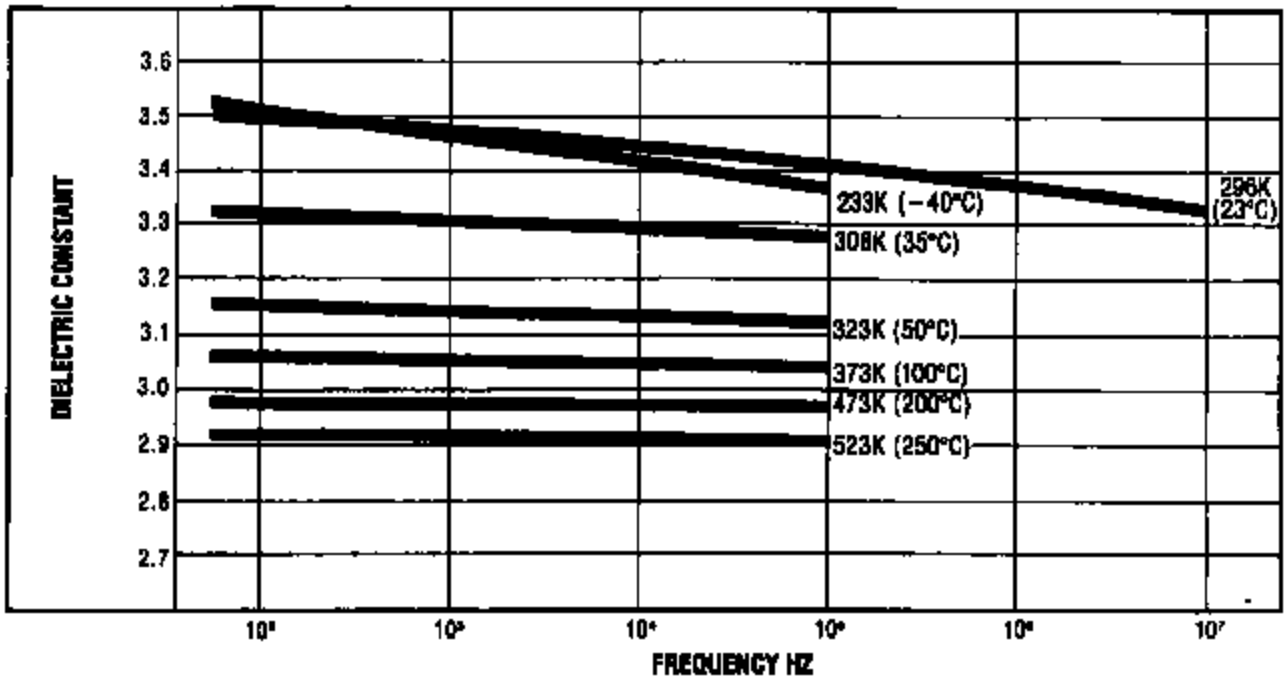


EFFECT OF FREQUENCY

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

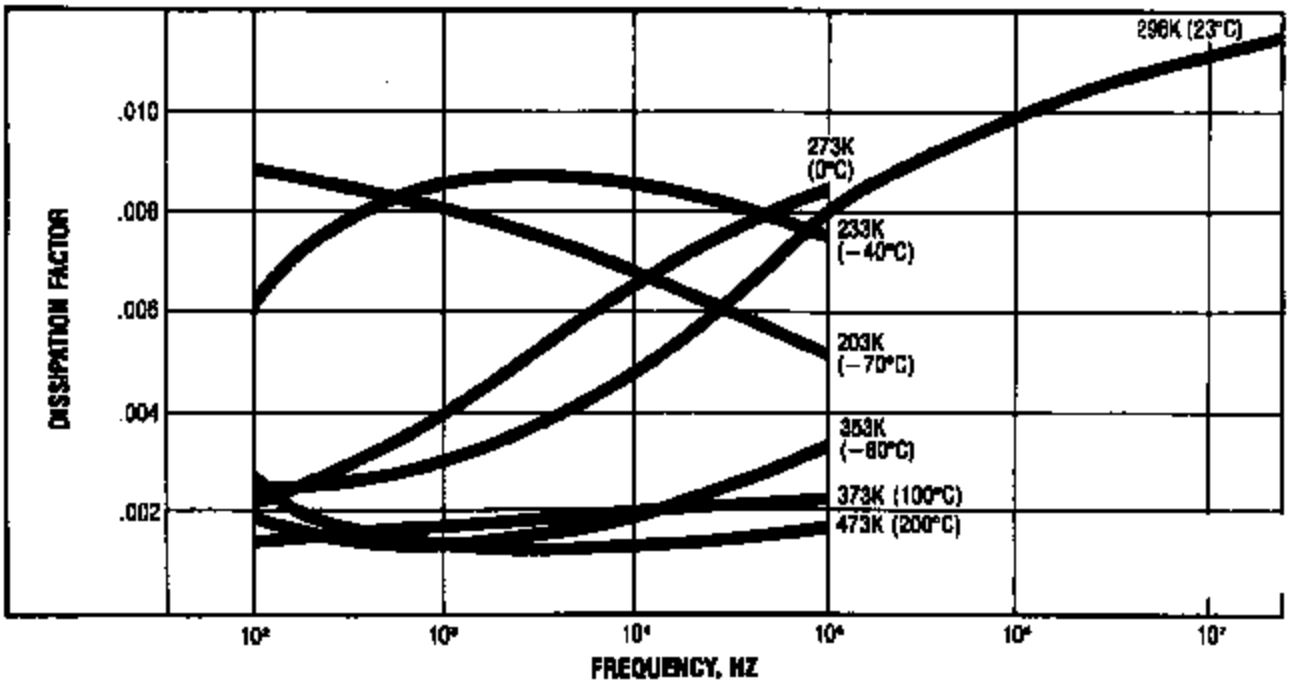
DIELECTRIC CONSTANT VS. FREQUENCY

(Type H Film 25 μm (1 mil))



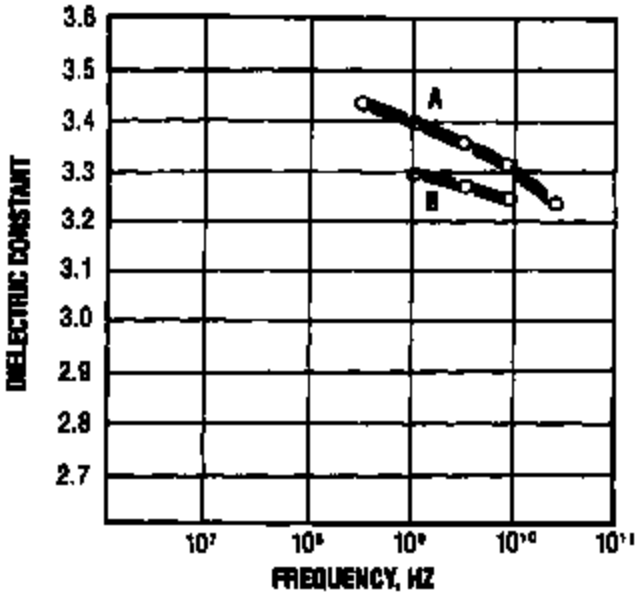
DISSIPATION FACTOR VS. FREQUENCY

(Type H Film 25 μm (1 mil))

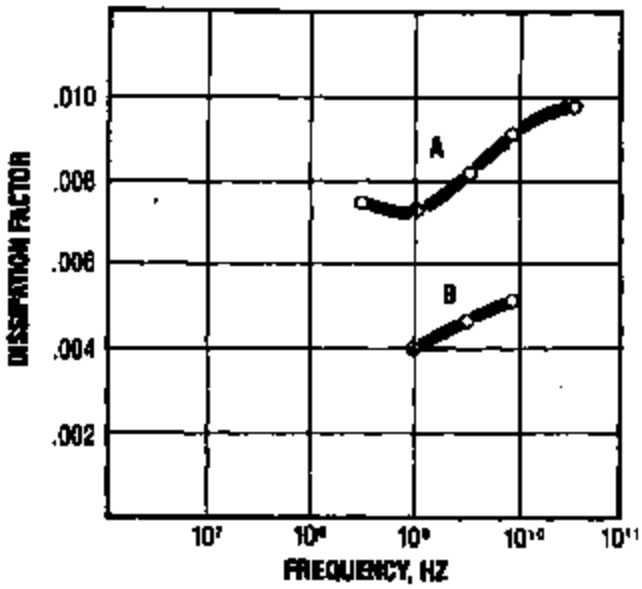


DIELECTRIC PROPERTIES IN GIGAHERTZ FREQUENCY RANGE

(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-495-61. The failure was due to true tracking rather than erosion, etc.

CORONA LIFE

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

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

CHEMICAL PROPERTIES

KAPTON® Type H Film

25 μm (1 mil)

CHEMICAL PROPERTIES

PROPERTY	TYPICAL VALUES (~25 μm (1 mil)) % Tensile Retained	% Elongation Retained	% Modulus Retained	TEST CONDITION/METHOD
				Days Immersed at Room Temperature
RESISTANCE TO:				
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 @ 479K (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

KAPTON® Type V Film

CHEMICAL PROPERTIES

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

KAPTON® Type F Film

CHEMICAL PROPERTIES

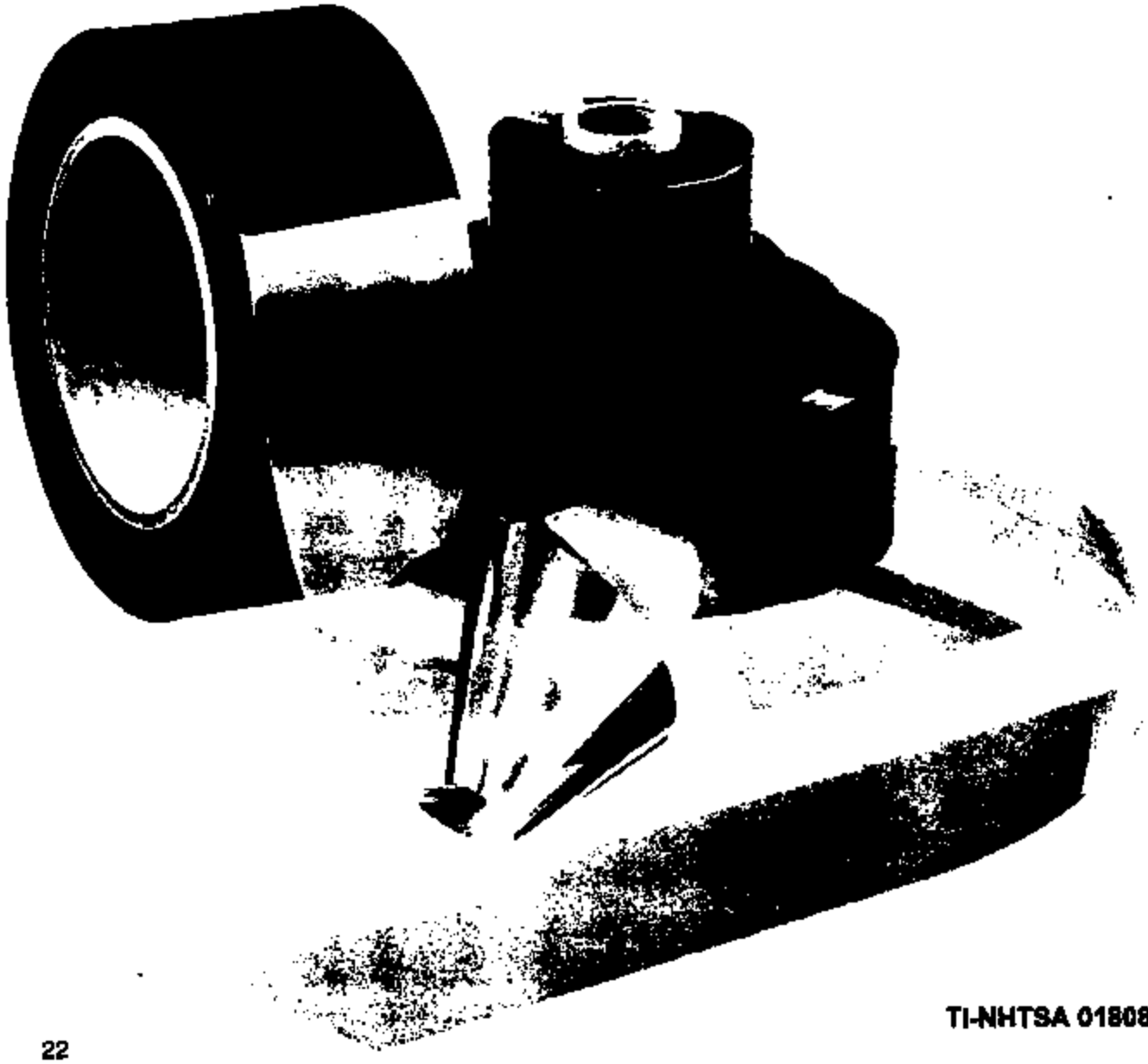
PROPERTY	120F516	150F019	490F022
Moisture Absorption @ 298K (25°C), 50% R.H. 98% R.H.	 1.3% 2.5%	 .8% 1.7%	 .4% 1.2%
Water Vapor Permeability g/m²·d (gm./(100 in²) (24 hrs.) g/m²·d·μm (g./(100 in²)(24 hrs./mil)	 13.7 (0.89) 0.44 (1.07)	 8.8 (0.57) 0.35 (0.85)	 3.6 (0.23) 0.14 (0.92)

NOMINAL CONSTRUCTION, Type F Film

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

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

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



TI-NHTSA 018082

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Kapton
POLYIMIDE FILM
DUPONT

Kapton®
POLYIMIDE FILM

Summary of Properties

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Kapton®
POLYIMIDE FILM

GENERAL INFORMATION

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

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

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

Applications for KAPTON polyimide film include a variety of electrical and electronic insulation applications: wire and cable tapes, formed coil insulation, substrates for flexible printed circuits, motor slot liners, magnet wire insulation, 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 HN, an all-purpose, all-polyimide film that has been used successfully in applications at temperatures as low as −269°C (−452°F) and as high as 400°C (752°F). Type HN film can be laminated, metallized, punched, formed, or adhesive coated. It is available as 0.3, 0.5, 0.75, 1, 2, 3, and 5 mil film.
- KAPTON TYPE VN, an all-purpose, all-polyimide film with all of the properties of Type HN, plus superior dimensional stability. Type VN is available in 0.5, 0.75, 1, 2, 3, and 5 mils.
- KAPTON Type FN, a Type HN film coated on one or both sides with TEFLON® FEP fluorocarbon resin to impart heat sealability, to provide a moisture barrier and to enhance chemical resistance. It is available in a variety of constructions.

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

*Reg. U.S. Pat. Off.

Kapton
POLYIMIDE FILM

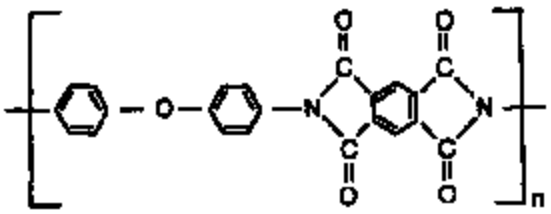
safe handling

Industrial Films Division

SAFETY IN HANDLING AND USE

Introduction

KAPTON polyimide film is a strong, tough, transparent amber-colored plastic film exhibiting excellent physical, chemical and electrical properties over an extremely wide temperature range. It has the structure:



KAPTON is produced in three forms, Type H, Type V, and Type F. Type H is the basic uncoated polyimide film. Type V is similar to Type H but has superior dimensional stability. Type F is coated on one or both sides with Teflon® FEP fluorocarbon resin which imparts heat sealability, provides a moisture barrier, and enhances chemical resistance.

KAPTON is used as insulation for wire and cable, formed coils, magnet wire and transformers, and motor slot liners, among other uses. It also is used as a substrate for flexible printed circuits.

This booklet provides guidelines for the safe handling of KAPTON during processing, use, and disposal.

Users of Type F KAPTON should also refer to DuPont bulletin "Teflon® Fluorocarbon Resins — Safety in Handling and Use."

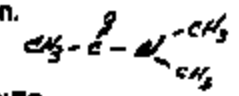
I. GENERAL PROPERTIES

KAPTON Type H and Type V, exhibits no melting point or softening point. A one-mil thick film has a zero-strength temperature of 815°C (1500°F). Zero-strength is measured as the maximum temperature at which the film will sustain a load of 138 KPa (20 psi) for 5 seconds.

KAPTON is insoluble in most common organic solvents after immersion for up to a year (Ref. 1). The hydrolytic stability of KAPTON Type H has been measured after 168 days exposure to boiling water. The film retained 65% of its tensile properties and 20% of its elongation. KAPTON is dissolved by strong acids (Ref. 2, 3) such as fuming nitric and concentrated sulfuric acid, particularly on heating, and is hydrolyzed by alkali and super-heated steam.

KAPTON Type F exhibits better chemical, hydrolytic, and oxidative resistance than Types H and V.

KAPTON may contain up to 1% by weight of dimethyl acetamide residual solvent. At elevated temperatures, some of the solvent may be released and must be removed by exhaust ventilation or diluted to safe levels. OSHA (29 CRF 1910.1000) has established the safe level for dimethyl acetamide as ten parts per million.



II. PYROLYSIS STUDIES

Studies (Ref. 4, 5) have shown the outstanding thermal stability of polyimide film. Its rate of degradation is dependent upon the availability of oxygen. In air at about 500°C (932°F) KAPTON decomposes and completely disappears after twelve hours. At 450°C in air, carbon monoxide may be formed in significant amounts. In a vacuum or inert atmosphere, 60 to 65% of the film remains after prolonged aging at 1000°C (1832°F). The residue retains its original shape but has lost its mechanical strength. The major off-gases are carbon dioxide and carbon monoxide. (See chart)

®Reg. U.S. Pat. & T.M. Off.

Kapton

POLYIMIDE FILM

ADHESION TO KAPTON®

KAPTON® polyimide film, made only by Du Pont, is available in three basic film types. Type H KAPTON is 100% polyimide film. Type F is coated on one or both sides with a TEFLON® FEP fluorocarbon adhesive and Type V is a plain polyimide film having superior dimensional stability properties. Typical property information for KAPTON is found in Bulletin E-72087, "Summary of Properties." Specifications are found in Bulletin E-67624, "Industry Specifications Bulletin FC-85-2." For flexible printed circuit applications the trade specification IPC-FC-231/Sheet 1, applies to KAPTON.

ADHESIVE SELECTION

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

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

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

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

Selection of an adhesive is usually dependent on the properties required of the adhesive and the demands of the application. Property considerations are the thermal rating, chemical resistance, flow 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

III. FLAMMABILITY

Lewis and Stabler (Ref. 6) report the flammability characteristics of polyimide film as "self-extinguishing." KAPTON has a 94 VTM-O rating, the highest given in the U.L. 94 verticle burning test for thin films. The oxygen index is 37% for 100 H film (ASTM 2863).

IV. HANDLING PRACTICES

Safe handling of Type H and V KAPTON polymide films at high temperatures requires adequate ventilation. If small quantities of KAPTON are involved, as is often the case, normal air circulation will be all that is needed in case of overheating. Whether or not existing ventilation is adequate at higher temperatures will depend on the combined factors of film quantity, temperature, and exposure time. For additional information on the Teflon® FEP coatings used on Type F KAPTON, refer to the booklet — "Teflon® Fluorocarbon Resins — Safety in Handling and Use."

A. Soldering and Hot Wire Stripping

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

Ventilation practices should follow the same common sense rules applicable to any soldering procedure. Normal ventilation provided for worker comfort usually provides adequate safety. During hot-wire stripping, it is recommended that exhaust ducts be used at the workbench.

There have been no reports of ill effects during soldering or hot-wire stripping of wire and cable insulated with KAPTON.

B. Welding and Flame Cutting

Direct application of welding arcs and torches can quickly destroy most plastics, including all types of KAPTON film. For practical reasons, therefore, it is best to remove all such parts from equipment to be welded. Where removal is not possible, such as in welding or cutting coated parts, mechanical ventilation should be provided.

Because KAPTON is rated for use at very high temperatures, parts made from it may survive at locations close to the point of direct flame contact. Thus some in-place welding operations can be done. Since the quantity of film heated is usually relatively small (less than one pound), ventilation requirements seldom exceed those for normal welding work. Because of the possibility of inadvertent overheating, however, the use of a small fan or elephant-trunk exhaust is advisable.

C. Scrap Disposal

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

D. Fire Hazards

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

In the event of fire, personnel entering the area should use a fresh air supply or a respirator. This type of equipment is standard in fighting many types of fire. All types of chemical extinguishers may be used to fight fires involving KAPTON. Large quantities of water also may be used to cool and extinguish a fire.

E. Static Electricity

The processing of KAPTON polyimide film can cause the generation of a strong static charge. Unless this charge is bled off as it forms through the use of ionizing radiation or metal tinsel, it can build to many thousands of volts and discharge to people or to metal equipment. In dust or solvent laden air, a flash fire or explosion could result. Precautions for static charges should also be taken when removing plastic films used as protective packaging for KAPTON.

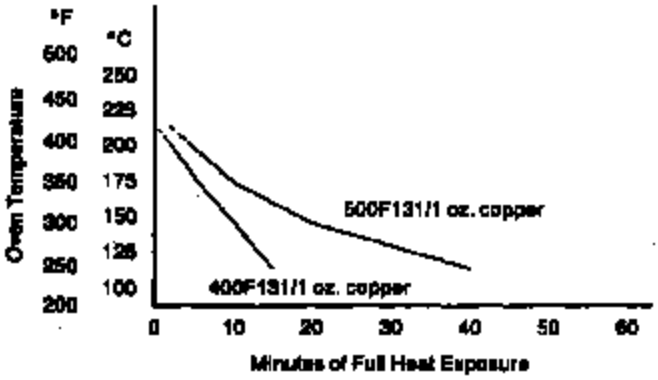
REFERENCES

1. J. T. Milek, "Polyimide Plastics: A State-of-the-Art-Report," Electronic Properties Information Center, S-8, October 1, 1965, Air Force Systems Command, Contract AF33 (615)-2460, Project 7381: Task 738103.

2. C. E. Broog, A. L. Endrey, S. V. Abrams, C. E. Berr, W. M. Edwards, and K. L. Oliver, J. Poly. Sci., Part A, 3(4), 1373-90 (1965).

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

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



SOLDERING AND PRESS CONDITIONS FOR TYPE H LAMINATES

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

EFFECTS OF HUMIDITY ON PEEL STRENGTH

Humidity can have a large effect on peel strength with certain adhesive systems, and RH ought to be controlled in peel strength measurements. A summary of our investigation into this phenomenon is given in Table III. Results show that those adhesives having functional groups capable of absorbing water vapor will promote high peel strengths at high RH and low peel strengths at low RH. Between an RH of 10% and an RH of 70%, the effect can be as large as 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.

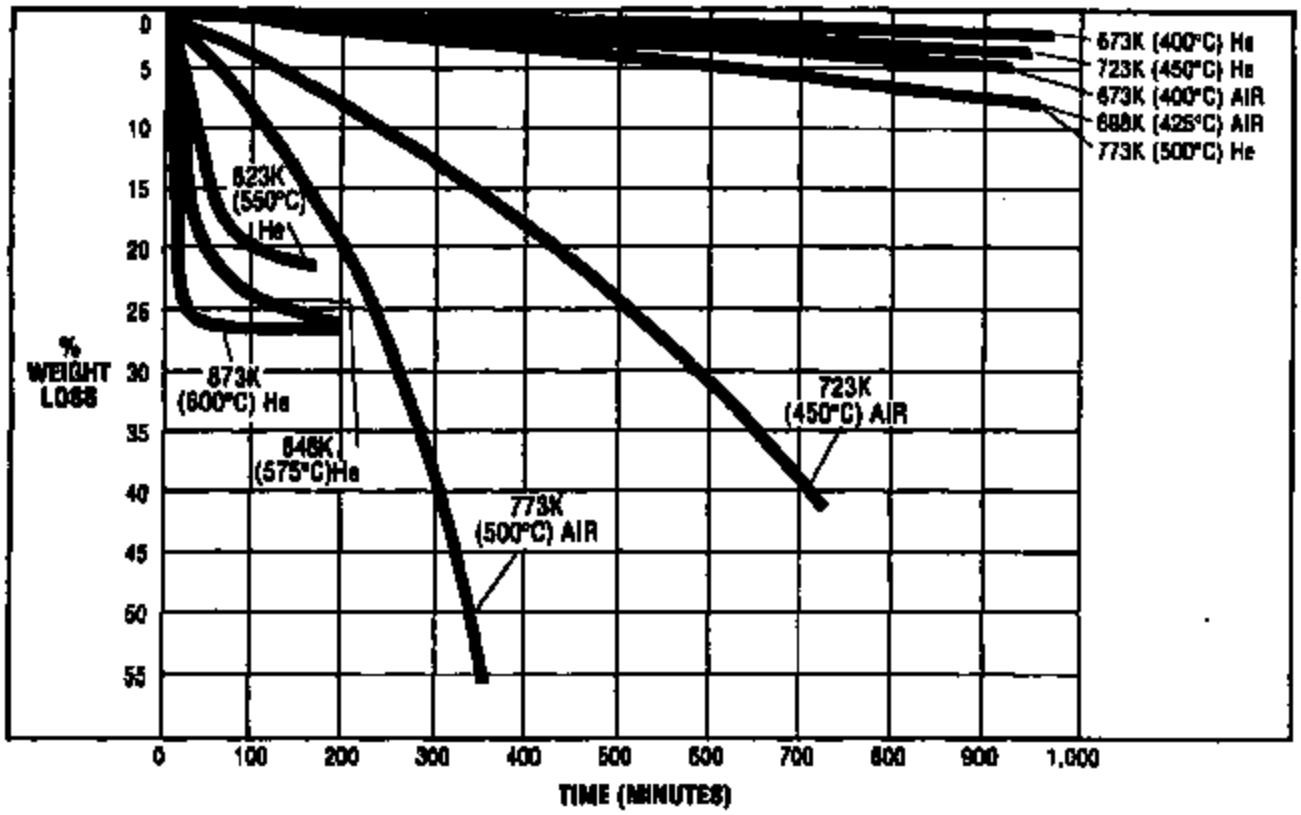
EFFECT OF THERMAL TREATMENT ON PEEL STRENGTH

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.

ISOTHERMAL WEIGHT LOSS

(Type H Film 25 μm (1 mil))



3. N. A. Andreva, M. I. Bessonov, L. A. Laius, and A. P. Rudakov, "Polyimides — A New Class of Thermally Stable Polymers," Progress in Matls. Sci. Series, Vol. VII, Technomic Publ. Co., Stamford, Conn., 1970, p. 79-85.

4. 1968 Listing of Plastic Materials, etc., P. 10, March 1968, National Sanitation Foundation.

5. General Electric Co. Res. Lab., Research of Dielectric Materials, Rept. #ML-TDR-64-57, May 1964, DDC AD-602 436, NASA N64-26308.

6. R. F. Stabler and L. L. Lewis, "KAPTON Polyimide Film — A New Insulation for Aerospace Wire and Cable," Paper presented at Soc. of Aerospace Materials and Process Engineers Meeting, San Francisco, May 26, 1965.

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Kapton® POLYIMIDE FILM . . . only from Du Pont

INDUSTRIAL FILMS DIVISION

DU PONT POLYMER PRODUCTS DEPARTMENT

In U.S.A.
Du Pont Company
Polymer Products Department
Industrial Films Division
Wilmington, DE 19898

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TI-NHTSA 018094

E-72084 1-85

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Kapton®
Polymide Film

DuPont
Electronics

High Performance Films

KAPTON® Polyimide Film
Technical Bulletin

Suppliers of Adhesives to the Electronics Industry

L[illegible]t
El[illegible]ctronics

High Performance Substrates and Materials

September 1989

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Vigor Co., New York, NY	(212) 807-3845
◐ Whittaker (Dayton Chemicals Div.) West Alexandria, OH	(513) 839-4612

This list is believed to be complete as of the date of publication. There may be others not known to us, who manufacture similar products based on KAPTON polyimide film.

DUPONT

KAPTON® Polyimide Film
Technical Bulletin

Suppliers of Adhesives to the Electronics Industry

DuPont Electronics

High Performance Substrates and Materials

September 1989

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Du Pont Electronics

TI-NHTSA 018100

DU PONT

MATERIAL SAFETY DATA SHEET

IDENTIFICATION

NAME
HFC-134a

FORMULA
CH_2FCF_3

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

ADDRESS
Wilmington, DE 19898

CHEMICAL FAMILY
Halogenated Hydrocarbon

TSCA INVENTORY STATUS
Reported/Included

PRODUCT INFORMATION PHONE
(800) 441-9450

MEDICAL EMERGENCY PHONE
(800) 441-3637

TRANSPORTATION PHONE
CHEMTREC (800) 424-9300

PHYSICAL DATA

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

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

VAPOR DENSITY (AIR = 1)
3.18

FORM
Liquefied Gas

COLOR
Colorless

PERCENT VOLATILE BY VOLUME
100

VAPOR PRESSURE
96 psig @ 25°C (77°F)

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

APPEARANCE
Clear

ODOR
Slight Ethereal

HAZARDOUS COMPONENTS

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

HAZARDOUS REACTIVITY

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

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

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

POLYMERIZATION
Will not occur.

FIRE AND EXPLOSION DATA

FLASH POINT
Will not burn. METHOD TOC

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

AUTOIGNITION TEMPERATURE
Not determined.

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

EXTINGUISHING MEDIA
As appropriate for combustibles in area.

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

HEALTH HAZARD INFORMATION

PRINCIPAL HEALTH HAZARDS

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

Inhalation 4 Hour ALC: 567,000 ppm in rats

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

Acute Toxicity in Animals

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

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

Subchronic Toxicity in Animals

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

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

CARCINOGENICITY

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

EXPOSURE LIMITS

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

SAFETY PRECAUTIONS

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

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

HEALTH HAZARD INFORMATION (con't)

FIRST AID

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

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

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

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

NOTE TO PHYSICIANS

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

PROTECTION INFORMATION

GENERALLY APPLICABLE CONTROL MEASURES

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

PERSONAL PROTECTIVE EQUIPMENT

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

DISPOSAL INFORMATION

SPILL, LEAK OR RELEASE

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

WASTE DISPOSAL

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

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

Gordon,

this paper outlines some of the problems we experienced
- blisters
- cracking (embrittlement)
- delamination

we would like to add a drying procedure to the print to eliminate these problems
lets discuss

Bill
4/9/86

We use 5 mil H-film with a nylon-epoxy adhesive

REPORT NO. CR-66-36

EFFECTS OF MOISTURE ON MANUFACTURING AND PROCESSING

FLEXIBLE PRINTED CIRCUITS MADE WITH "KAPTON"* POLYIMIDE FILM

*Du Pont registered trademark

EFFECTS OF MOISTURE ON MANUFACTURING AND PROCESSING FLEXIBLE PRINTED CIRCUITS MADE WITH "KAPTON"* POLYIMIDE FILM

INTRODUCTION

"Kapton" polyimide film, because of its thermal and dimensional stability, toughness, high dielectric strength in thin gauges, and flame resistance, offers an outstanding combination of properties as a base sheet for flexible printed circuits. These circuits are usually prepared by laminating "Kapton" to copper foil, printing the desired pattern of conductors on the copper with an etch resistant coating, etching away the unwanted copper, and then laminating another sheet of film over the circuit to protect it.

In making and processing copper laminates and printed circuits, it must be remembered that, under normal plant conditions, "Kapton" contains small amounts of moisture absorbed from the atmosphere. This moisture does not have a major effect on film properties, but it must be eliminated during high temperature manufacturing and processing steps to avoid blisters and delamination in laminates and circuits.

EFFECT OF MOISTURE ON FILM PROPERTIES

The amount of moisture absorbed in "Kapton" Type H depends upon the relative humidity as shown in Figure 1.

*Du Pont registered trademark

Moisture Content vs. Relative Humidity
Typical Values 23°C

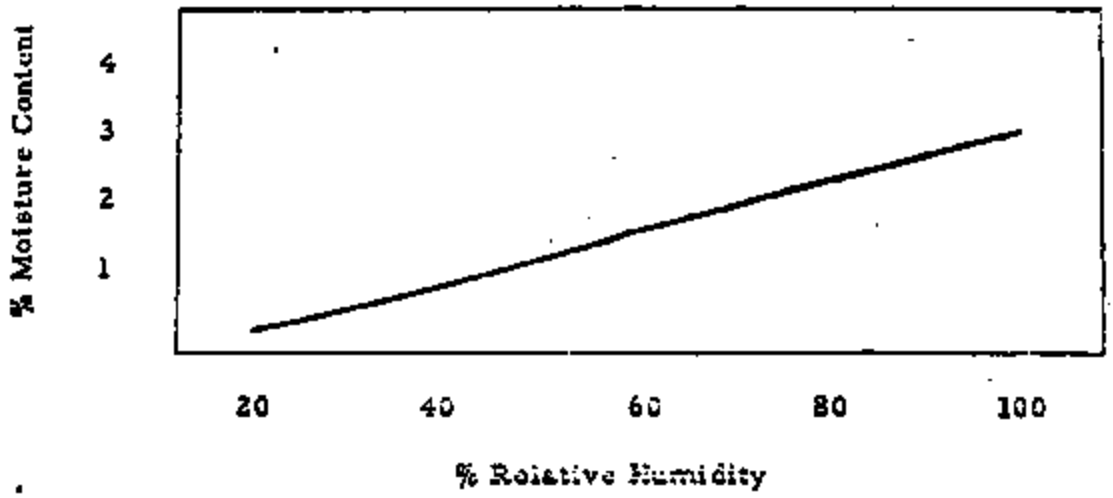


Figure 1

The effect of this moisture on the physical and electrical properties of "Kapton" polyimide film is shown in Table I.

Table I

Physical and Electrical Properties vs. Relative Humidity
(Typical Values - 1 mil "Kapton" Type H)

% Relative Humidity	Tensile Strength	AC Dielectric Strength	Dielectric Constant	Dissipation Factor
0	25000 psi	7600 v/mil	3.0	.0018
30	25000 psi	7300 v/mil	3.3	.0021
50	25000 psi	7000 v/mil	3.5	.0025
80	25000 psi	6500 v/mil	3.7	.0037
100	25000 psi	6200 v/mil	3.9	.0047

LAMINATING CONDITIONS

"Kapton" polyimide film may be laminated to copper foil for printed circuits with a variety of adhesives types including polyimides, epoxies, silicones, polyesters, phenolics, and "Teflon"* FEP-fluorocarbon resins (supplied by Du Pont as a composite with "Kapton" and designated "Kapton" Type F). During lamination to copper and any subsequent high temperature processing steps, moisture must be dried from "Kapton" to avoid blisters and delamination of the film from the copper. Under severe high temperature laminating conditions, embrittlement of the "Kapton" can also occur.

The rate at which moisture is absorbed or dried from "Kapton" depends on the temperature, relative humidity, film thickness, and adhesive coating. Sheets of uncoated "Kapton" Type H conditioned at 23°C, 100% RH and then placed in a 23°C, 0% RH dry box lost moisture at a rate as shown in Table II.

Table II

Rate of Drying "Kapton" Type H at 23°C

Film Thickness	Time for 1/2 of Moisture to Leave Film
1 mil	3 minutes
2 mil	10 minutes
3 mil	21 minutes
5 mil	54 minutes

*Du Pont registered trademark

Additional tests have been conducted at the Chestnut Run Laboratory with 3 mil "Kapton" coated one or two sides with 1 mil "Teflon" FEP to determine necessary drying conditions prior to press lamination to treated copper at 600°F. The minimum time needed to dry sheets of one and two-side coated film to give blister free laminates is shown in Table III. Two-side coated film requires longer to dry since the "Teflon" FEP acts as a barrier to moisture.

Table III

Drying Conditions for "Kapton" Type F
Prior to Lamination to Copper

Drying Temperature	400F031 3 mil H/1 mil FEP	500F131 1 mil FEP/3 mil H/1 mil FEP
250°F	5 minutes	45 minutes
300°F		30 minutes
350°F	1 minute	20 minutes
400°F		10 minutes

Films should be laminated as soon as possible after drying since reabsorption of moisture by "Kapton" polyimide film is fairly rapid. For example, sheets of dried one-side coated "Kapton" can be left in a 70% RH atmosphere for up to only about 10 minutes before enough moisture is reabsorbed to cause blisters during lamination. Two-side coated film reabsorbs enough moisture to cause blistered laminates after 30-60 minutes.

It may be feasible to dry full rolls of "Kapton" polyimide film prior to processing. Limited test data indicates 250°F for one or two days may be satisfactory to dry film in roll form.

It has also been found that the amount of blistering in laminates to copper depends on the time taken to bring film up to laminating temperature, the release sheet used, the copper treatment, and whether or not the laminate is cooled under pressure. In some cases laminating techniques have produced blister free copper laminates and printed circuits without predrying the film. In these cases, predrying is not needed unless problems are encountered with blistering.

PROCESSING CONDITIONS

Because of its outstanding thermal stability, copper laminates and printed circuits made with "Kapton"® polyimide film can be hand or dip soldered without adversely affecting the properties of the film. For dip soldering, circuit must be predried to prevent blistering due to absorbed moisture. Hand soldering does not normally require any film predrying.

Given in Table IV are minimum times required to dry laminates of "Kapton" to copper prior to dip soldering to prevent blistering.

Table IV

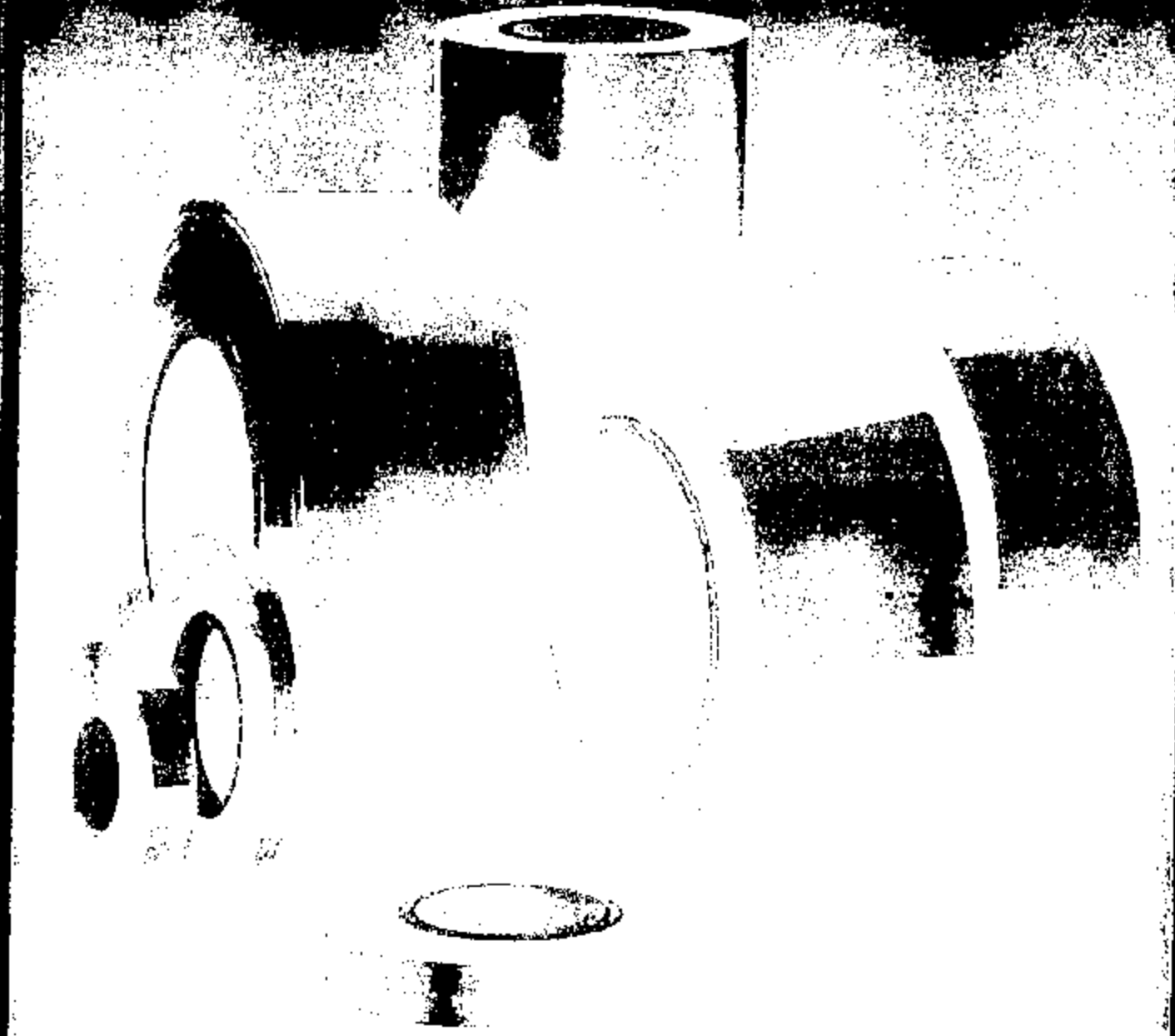
Drying Conditions for "Kapton" Type F
Prior to Dip Soldering

Drying Temperature	400F031 - Copper 3 mil H/1 mil FEP 1 oz. Copper	500F131 - Copper 1 mil FEP/3 mil H/ 1 mil FEP/1 oz. Copper
250°F	15 minutes	40 minutes
300°F	10 minutes	20 minutes
350°F	6 minutes	10 minutes
400°F	2 minutes	4 minutes

GCR/er
7/20/66

We believe this information is the best currently available on the subject. It is offered as a possible helpful suggestion in experimentation you may care to undertake along these lines. It is subject to revision as additional knowledge and experience are gained. Du Pont makes no guarantee of results and assumes no obligation or liability whatsoever in connection with this information. This is not a license to operate under, or intended to suggest infringement of, any existing patents.

SUMMARY OF PROPERTIES



DUPONT

TI-NHTSA 018114

CONTENTS

Kapton®
POLYIMIDE FILM

GENERAL INFORMATION

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

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

Du Pont makes three types of KAPTON:

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

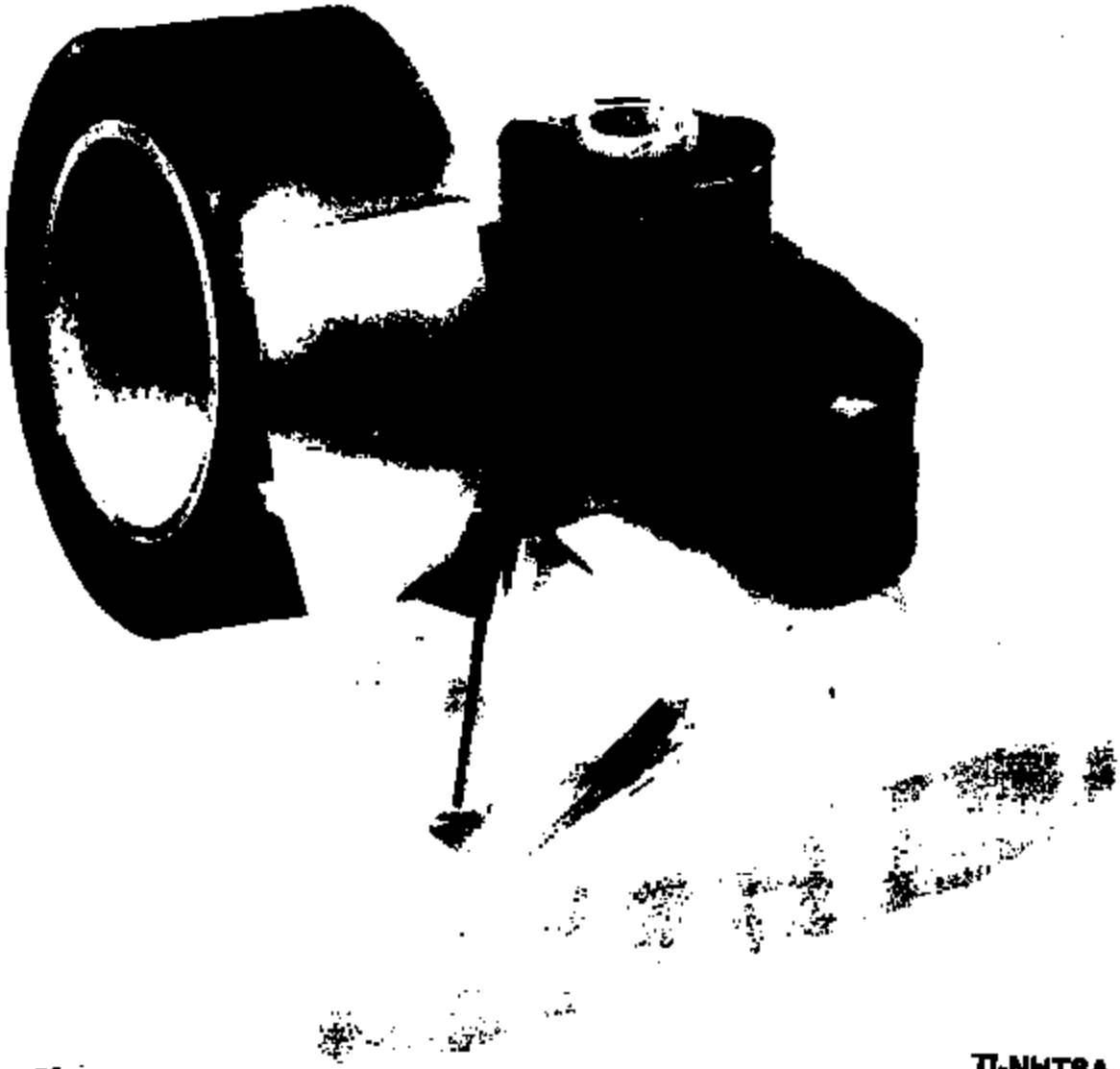
Note: This bulletin provides a summary of typical properties for all three KAPTON polyimide films Type H, Type V and Type F. Additional data should be obtained from your Du Pont Industrial Films Division representative for specification purposes.

*Reg. U.S. Pat. Off.

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

ORDER CODE	NOMINAL THICKNESS		"TEFLON" FEP		"KAPTON" TYPE H		"TEFLON" FEP	
	μm	mils	μm	mils	μm	mils	μm	mils
120F616	30	1.2	2.5	0.1	25	1	2.5	0.1
150F919	38	1.5	0	0	25	1	13	½
250F929	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
150F919	3.18-914	1/8-36	15.8	77
250F929	3.18-914	1/8-36	11.1	49



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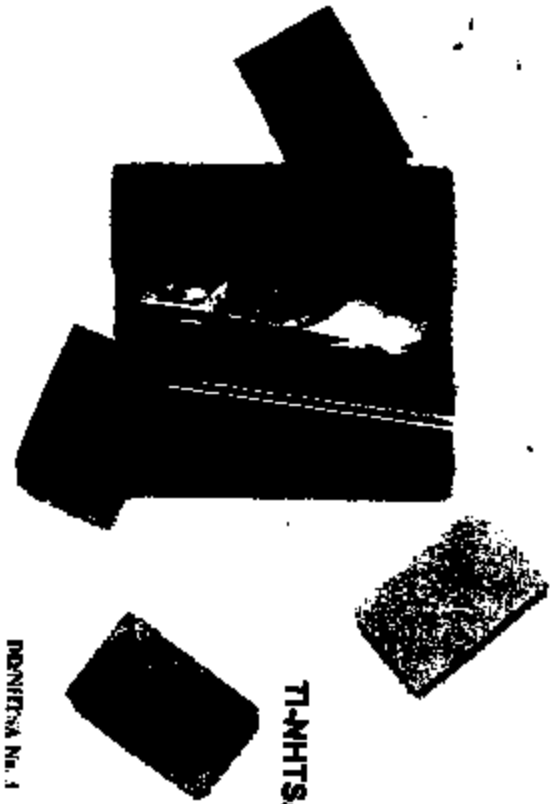
DuPont KAPTON®



TI-NHTSA 018118

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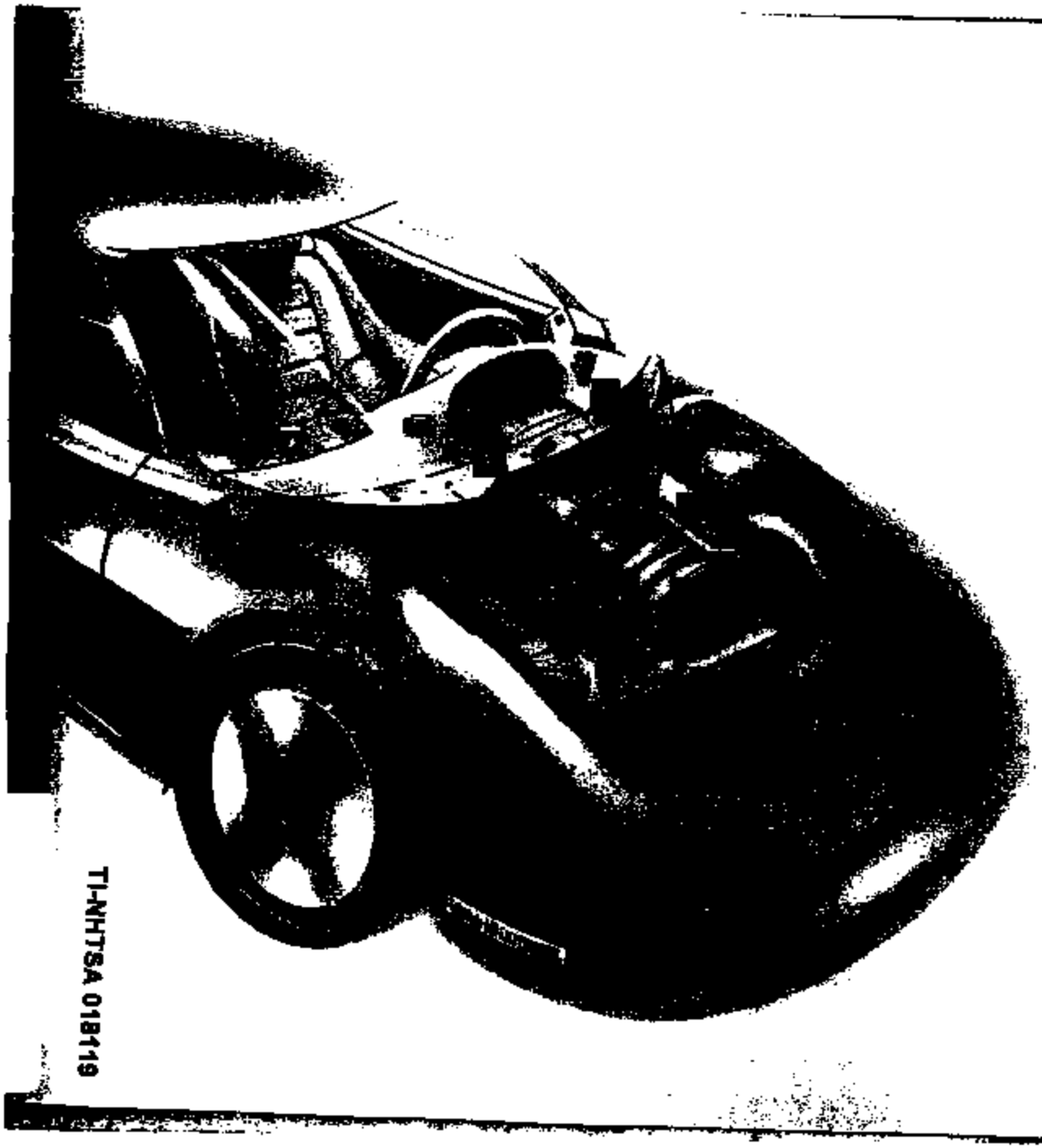
The thermal, physical, chemical resistance and electrical properties of KAPTON are exceptional. And, the benefits don't stop there. KAPTON can be easily fabricated by a wide variety of techniques, including die cutting, punching and thermoforming. It offers excellent adhesive bondability as well.

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

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

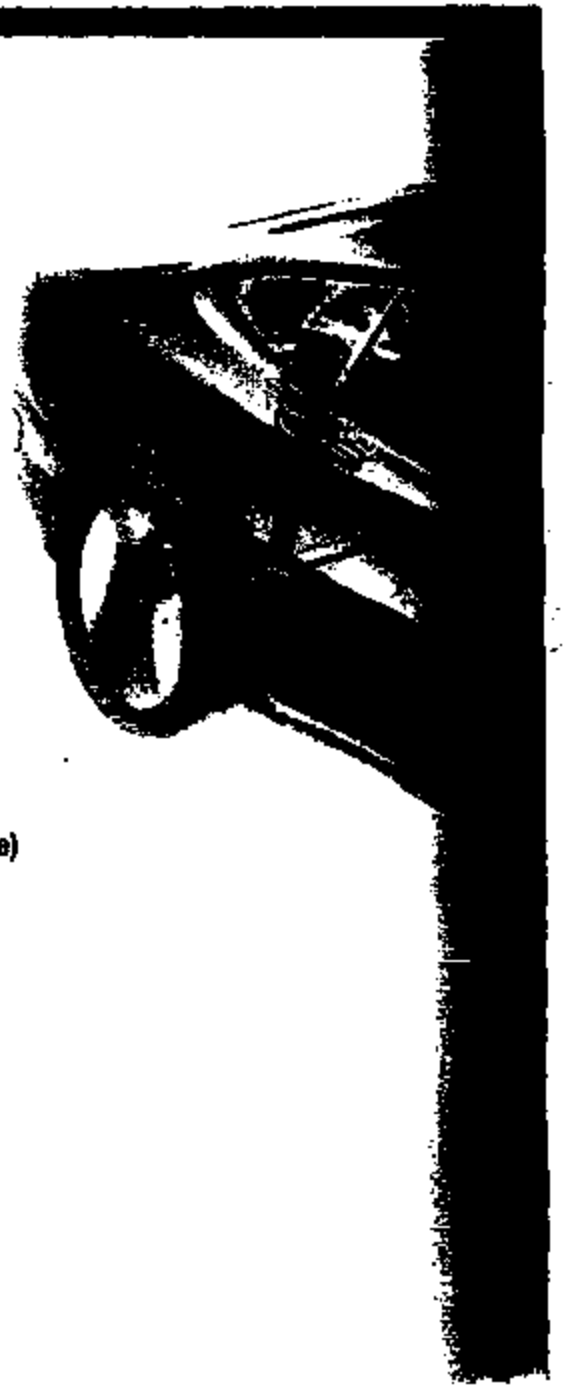


TI-NHTSA 018119

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

rent and Potential

of **KAPTON®**



- Alternator Heat Sink Insulator Pads
- Diaphragms
  - air bag
  - air conditioning system
  - fuel pressure regulator
  - oil pressure switch
  - power steering switch
  - pressure switch in brake systems (punched)
- Disposable Pin Carrier for PCB Interconnections
- Flexible Circuit for Dashboard
- Fuel Pulsation Dampener
- Fuse Plane
- Gasket (under the hood, punched)
- Miniature Pressure Transducer
- Radiator Plug
- Seals for Air Conditioning System

- Sensors
  - accelerator pedal
  - air conditioning system (pressure)
  - automatic windshield wipers (membrane)
  - brake pedal
  - brake system (pressure)
  - clutch slave cylinder
  - door buzzer
  - EGR
  - memory seat
  - shock height
  - temperature
  - throttle position
  - transmission

Typical

# of KAPTON®

Thermal Properties	
Useful Temperature Range, °C (°F)	-269 to 400 (-452 to 752)
UL®-94 Rating	V-0
UL Thermal Index (100,000 hours)	240°C (464°F)
Melting Point	None
Physical Properties	
Ultimate Tensile Strength at 23°C (73°F), MPa (psi)	231 (33,500)
Yield Point at 3% at 23°C (73°F), MPa (psi)	69 (10,000)
Stress to Produce 5% Elongation at 23°C (73°F), MPa (psi)	90 (13,000)
Ultimate Elongation at 23°C (73°F), %	72
Tensile Modulus at 23°C (73°F), GPa (psi)	2.5 (370,000)
Impact Strength at 23°C (73°F), N•cm (ft•lb)	78 (0.58)
Folding Endurance at 23°C (73°F) (MIT), cycles	285,000
Electrical Properties	
Dielectric Strength, kV/mm (V/mil)	300 (7,700)
Dielectric Constant at 1 kHz	3.4
Chemical Resistance	
	Most organic chemicals, solvents, fuels, lubricants

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

TI-NHTSA 018121

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

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

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

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

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

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

KAPTON Can Take the Heat Because today's and tomorrow's engines will run at increasingly elevated temperatures, high-temperature stability is a critical concern for any under-the-hood part. But temperature extremes are no problem for KAPTON, which carries a UL® Thermal Index

automotive, aerospace and electronics industries. These engineers have seen first-hand that KAPTON can take brutal punishment and keep on performing like few other materials.

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

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

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

n Up Your

with DuPont KAPTON®

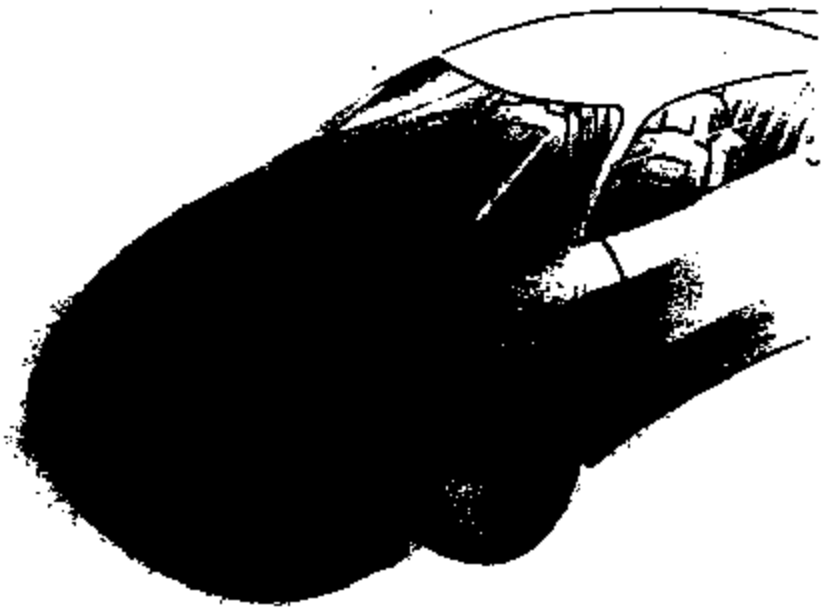
When you take a look into the future of the automotive industry, what do you see? Engines that will run hotter than ever before? Extended factory warranties? Stricter safety and emissions requirements? More and more challenges?

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

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

How to

with DuPont KAPTON®



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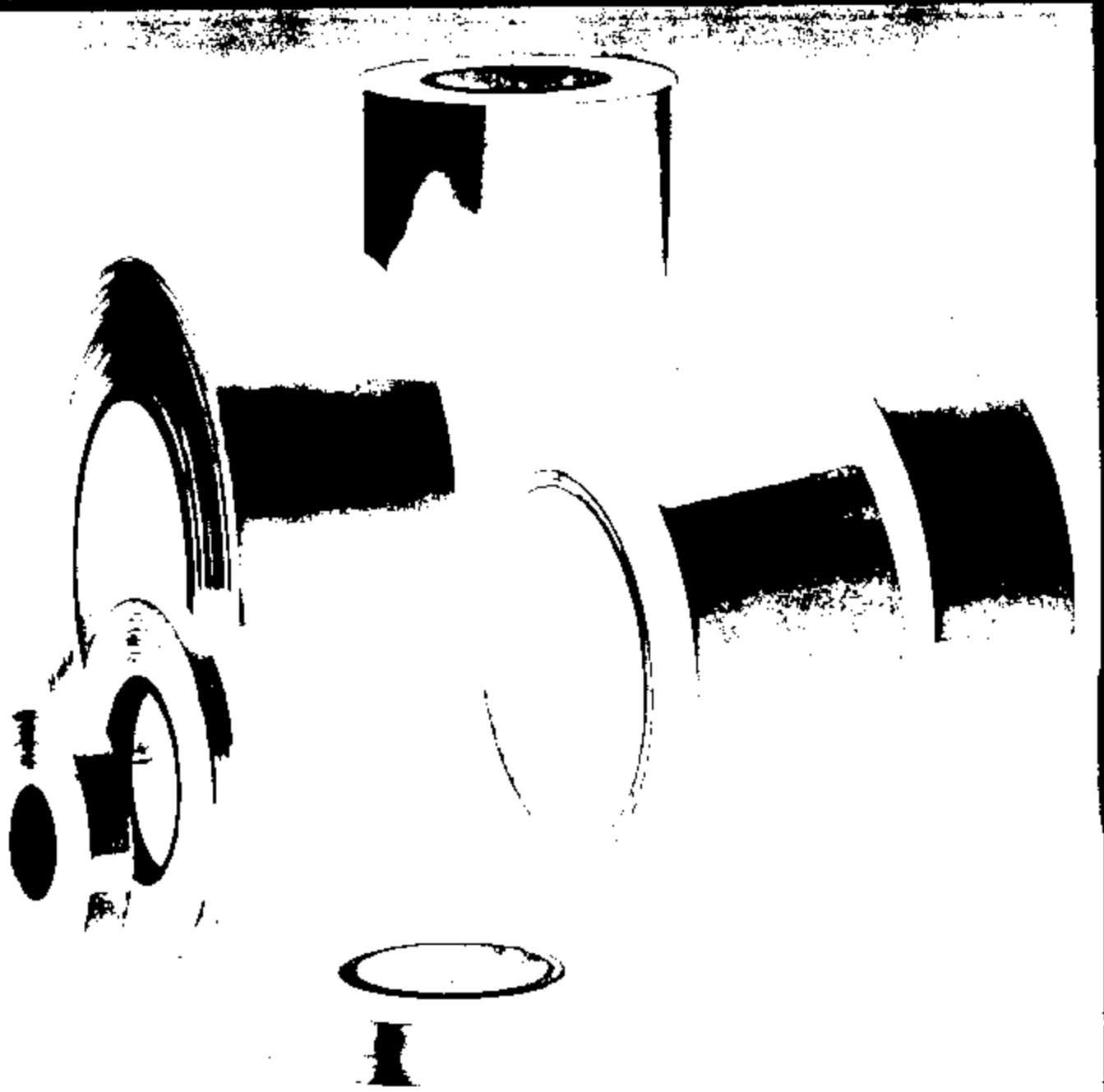
Kapton

POLYIMIDE FILM

SUMMARY OF PROPERTIES



DU PONT

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- 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.
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*Reg. U.S. Pat. Off.

PHYSICAL & THERMAL PROPERTIES

KAPTON® Type H Film

25 μm (1 mil)

PHYSICAL PROPERTIES

PHYSICAL PROPERTIES	TYPICAL VALUES 77K (−196°C)	296K (23°C)	473K (200°C)	TEST METHOD
Ultimate Tensile (MD) Strength, MPa (psi)	241 (35,000)	172 (25,000)	117 (17,000)	ASTM D-882-81
Yield Point (MD) at 3%, MPa (psi)		69 (10,000)	41 (6,000)	ASTM D-882-81
Stress to Produce (MD) 5% Elongation, MPa (psi)		90 (13,000)	59 (8,500)	ASTM D-882-81 ASTM D-882-81
Ultimate Elongation (MD)%	2	75	90	ASTM D-882-81
Tensile Modulus, GPa (MD) (psi)	3.5 (510,000)	3.0 (430,000)	1.86 (280,000)	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 $\left(\frac{\text{(cal)(cm)}}{\text{(cm²)(sec)(°C)}}\right)$	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-36		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)	38 (5,500)	
Ultimate Elongation (MD)			
296K (23°C)%	65	75	60
473K (200°C)%	95	85	
Tensile Modulus, MD GPa (psi)			
296K (23°C)	2.86 (415,000)	2.21 (320,000)	
473K (200°C)	1.48 (215,000)	1.19 (173,000)	
Impact Strength at 296K (23°C)			
g-m (Kg-cm/μm)	70 (7)	70 (7)	
g-m/μ (Kg-cm/mil)	2.3 (6.0)	1.8 (4.6)	
Tear Strength—Propagating (Elmendorf)			
g		20	
g/μm (g/mil)	0.39 (10)	0.53 (13.5)	0.47 (12)
Tear Strength—Initial (Graves)			
g		650	
g/μm (g/mil)	19 (750)	17 (435)	
Weight % Polyimide	80	57	73
Weight % FEP	20	43	27
Density			
$Kg/m^3 \times 10^{-3}$	1.53	1.67	1.57

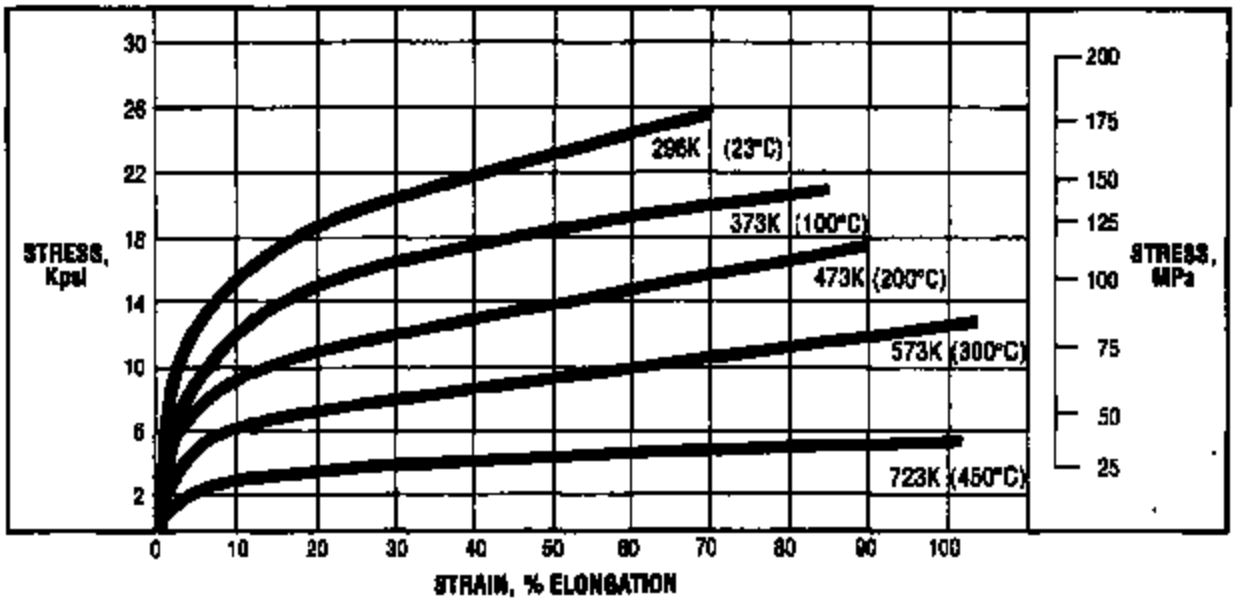
*Since a number of combinations of polyimide film and fluorocarbon coating add up to the same total gauge, it is necessary to distinguish among them. A three digit system is used in which the middle digit represents the nominal thickness of the base KAPTON film in mils. The first and third digits represent the nominal thickness of the coating of TEFLON FEP fluorocarbon resin in mils. The symbol 5 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))

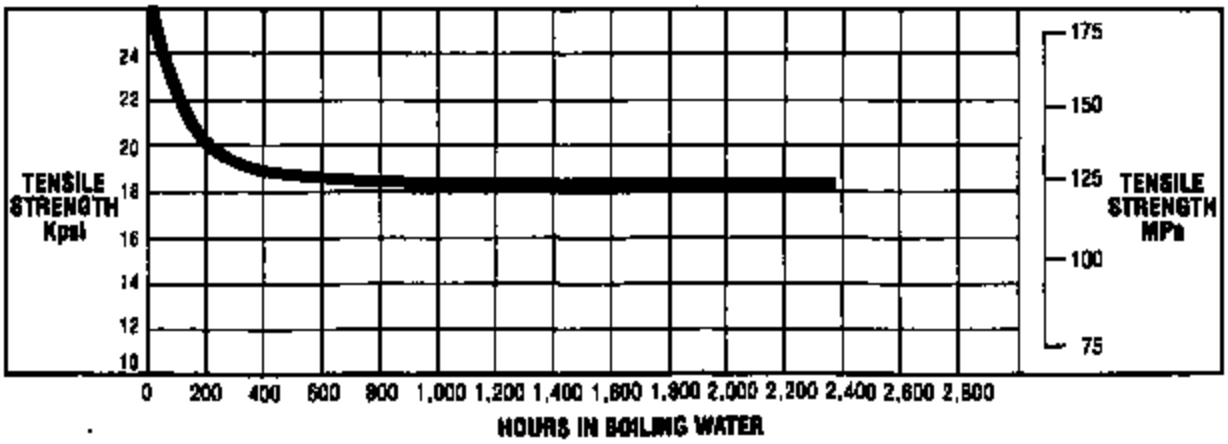


HYDROLYTIC STABILITY

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.

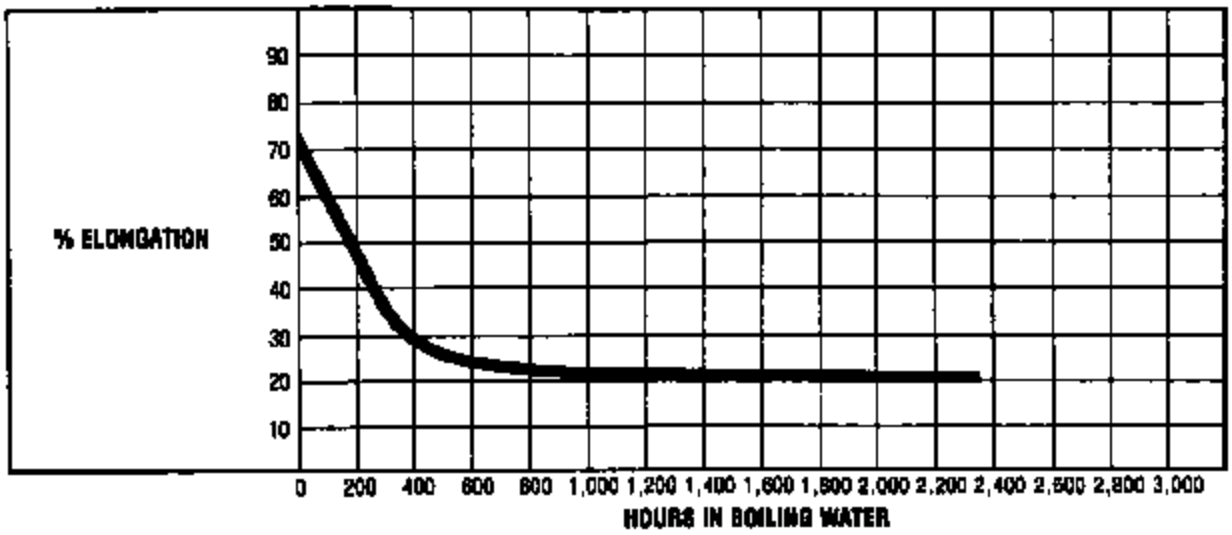
TENSILE STRENGTH AFTER EXPOSURE TO 573K (100°C) WATER

(Type H Film 25 μm (1 mil))



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

(Type H Film 25 μm (1 mil))

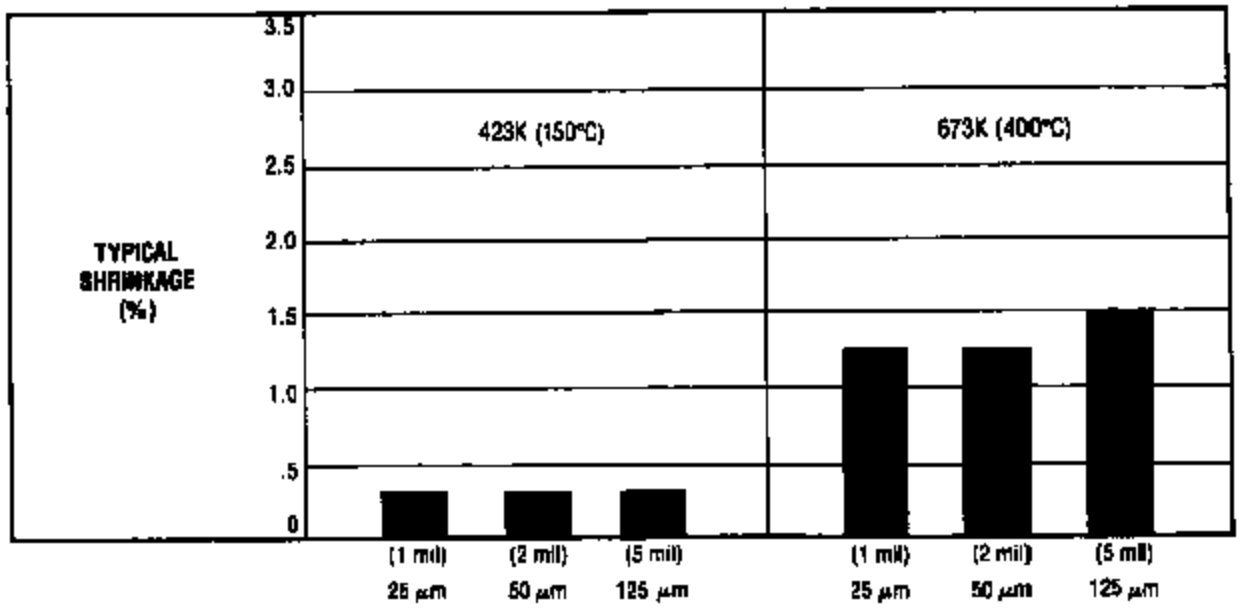


DIMENSIONAL STABILITY

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 8 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

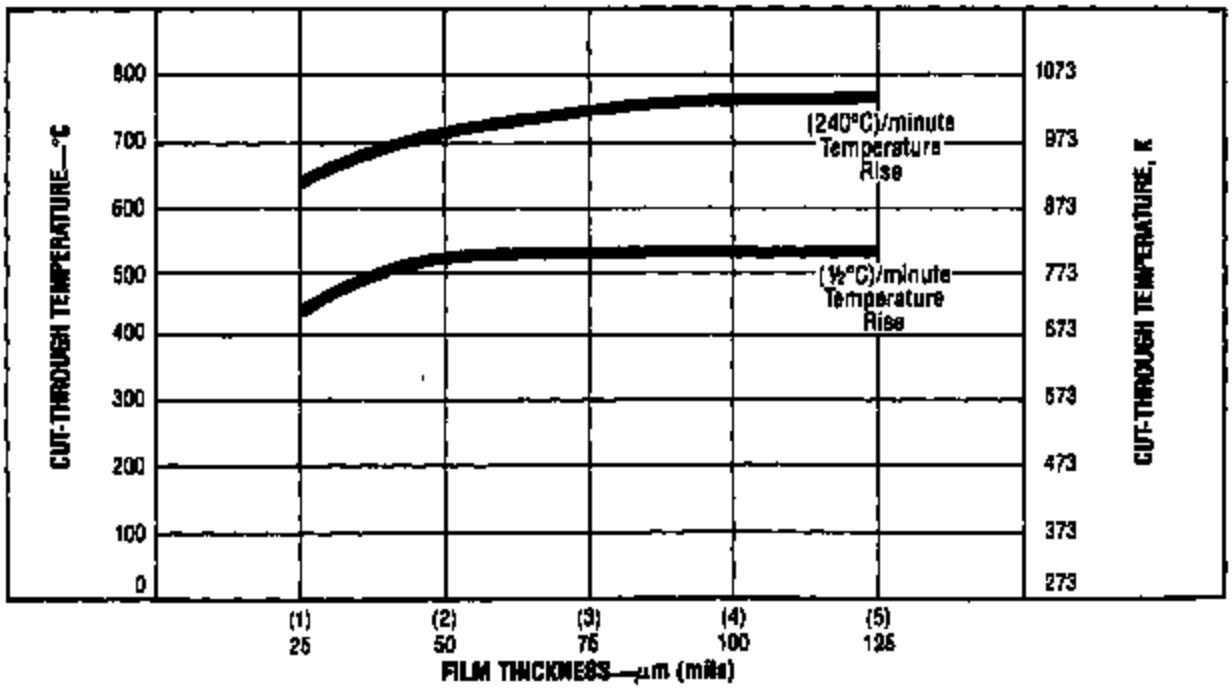
Temperature Range	"K" m/m-K x 10^{-6}
296-373K (23-100°C)	1.80
373-473K (100-200°C)	3.10
473-573K (200-300°C)	4.85
573-673K (300-400°C)	7.75
296-673K (23-400°C)	4.55

CUT-THROUGH AND COLD FLOW

Most organic films exhibit a tendency to flow or thin out under high compressive stresses, especially at elevated temperatures. KAPTON® polyimide film possesses an extremely high resistance to such stresses. Test procedures described in ASTM D-876-61 have been adapted to flat films to provide the data below. Stresses range from an infinitely high point load to 89 MPa (12,000 psi) at cut-through for a 25 μm (1 mil) film.

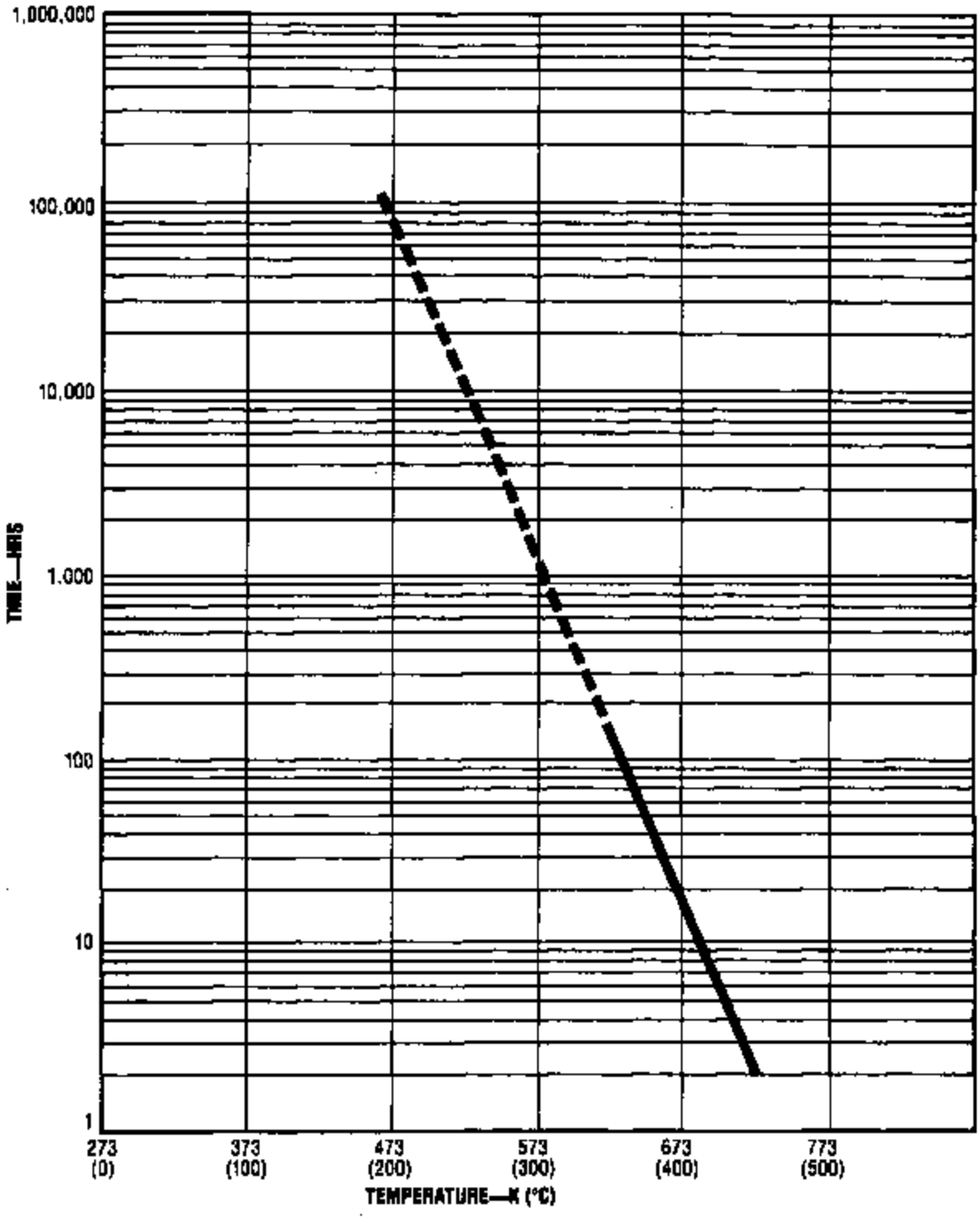
CUT-THROUGH TEMPERATURE VS. RATE OF TEMPERATURE RISE AND GAUGE

(Type H Film)



RESISTANCE TO CUT-THROUGH VS. TEMPERATURE

(Type H Film—25 μm (1 mil))



actual ——————

extrapolated — — — —

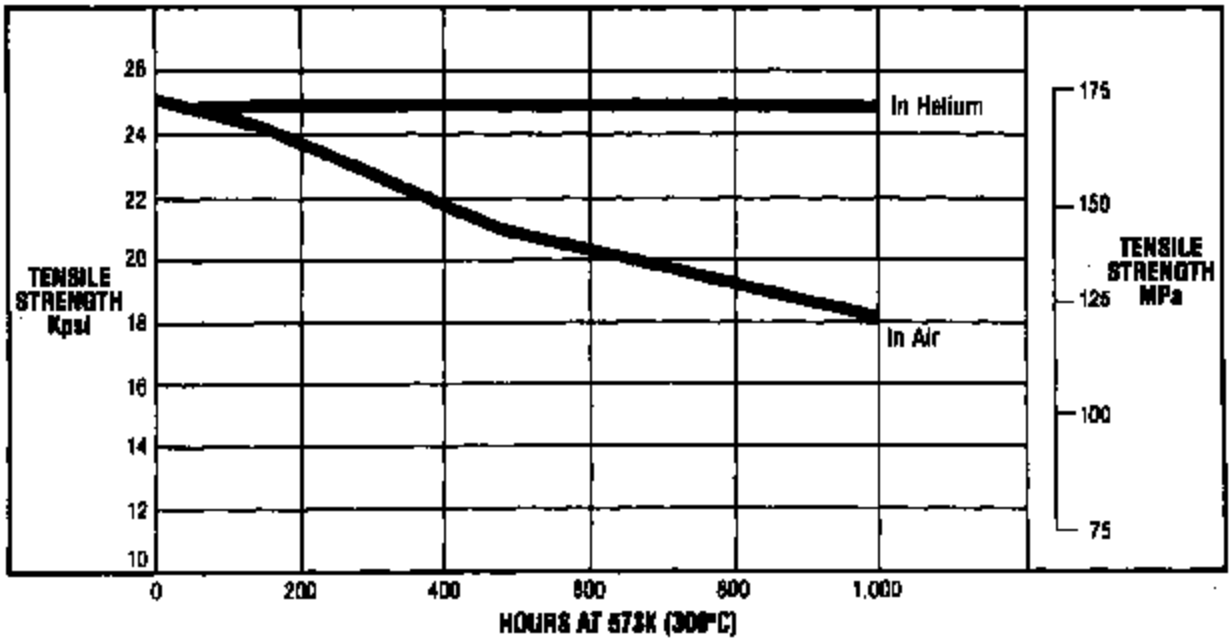
TI-NHTSA 018136

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.

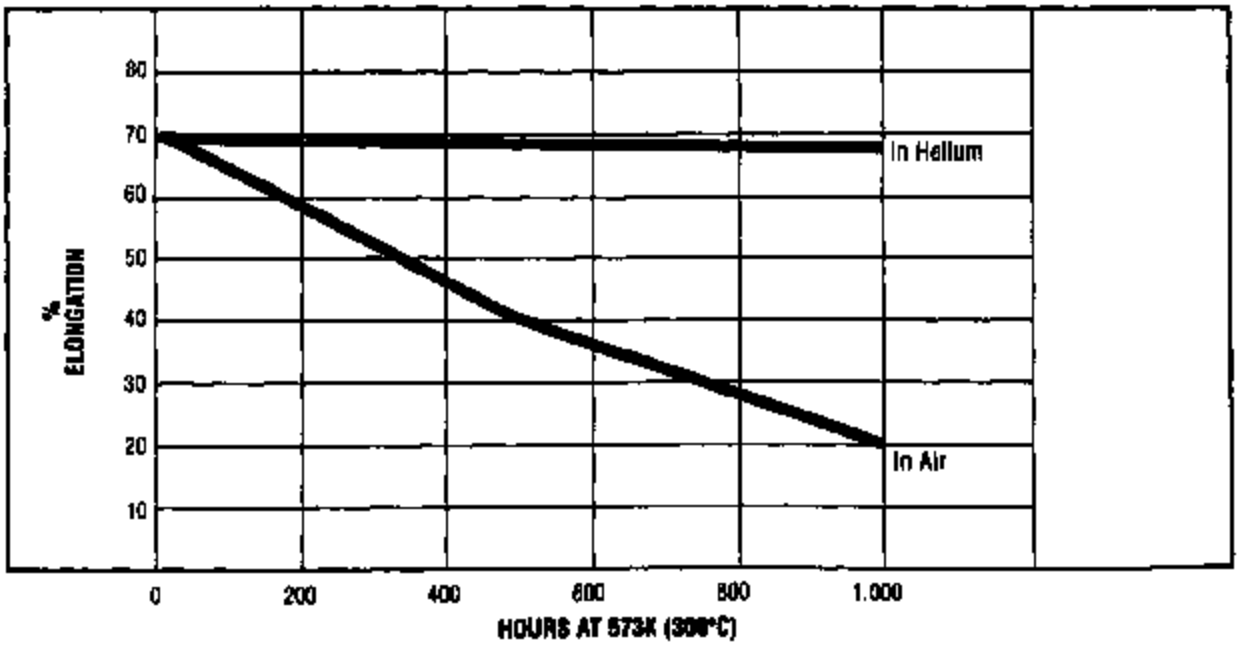
TENSILE STRENGTH VS. AGING AT 573K (300°C)

(Type H Film 25 μm (1 mil))



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

(Type H Film 25 μm (1 mil))



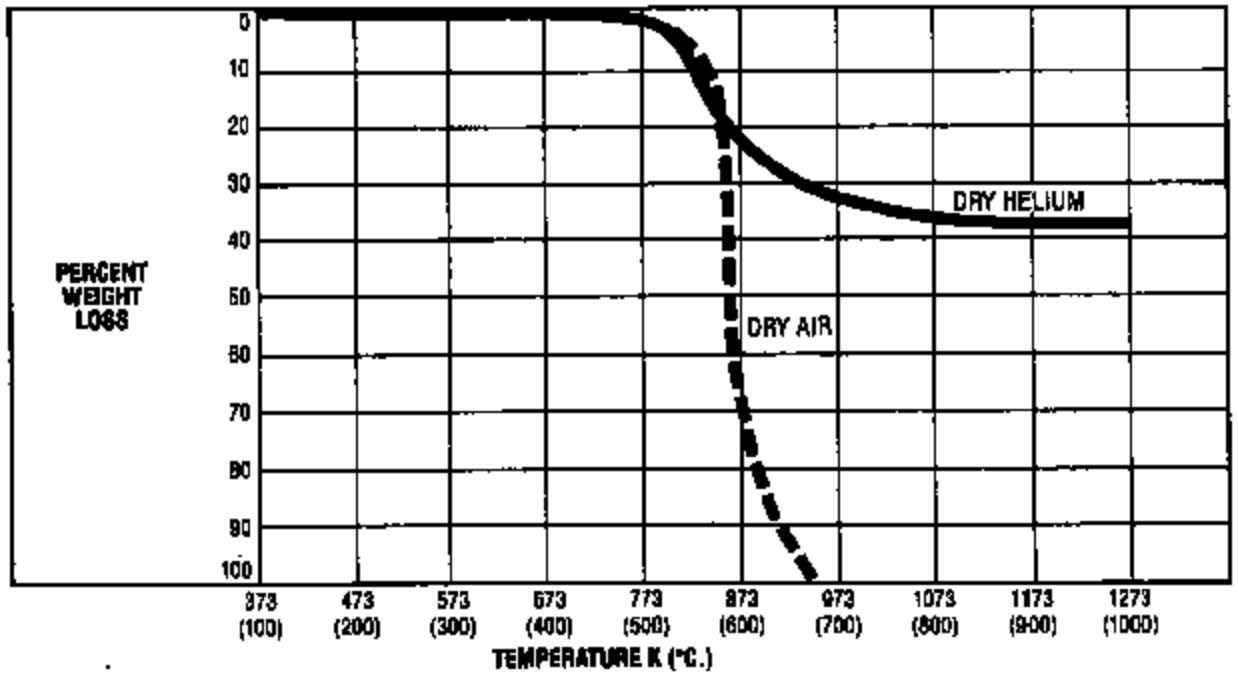
TIME REQUIRED FOR REDUCTION IN ULTIMATE ELONGATION FROM 70% to 1%

(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)	5 years	—

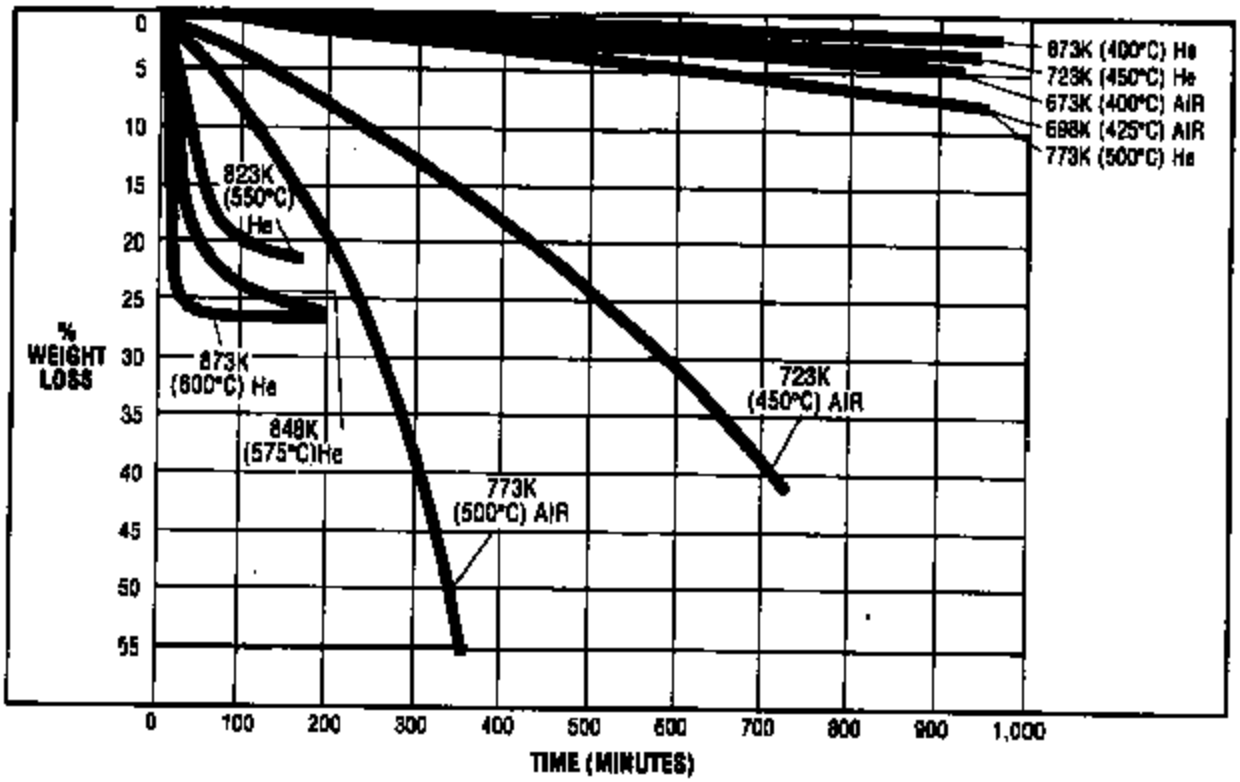
WEIGHT LOSS AT (3°C)/MINUTE TEMPERATURE RISE

(Type H Film 25 μm (1 mil))



ISOTHERMAL WEIGHT LOSS

(Type H Film 25 μm (1 mil))



ELECTRICAL 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)	8×10^{17} ohm-m		
75 μm (3 mil)	5×10^{17} ohm-m		
125 μm (5 mil)	1×10^{17} ohm-m		

KAPTON® Type V Film

TYPICAL ELECTRICAL PROPERTIES

PROPERTY	TYPICAL VALUE	TEST CONDITION	TEST METHOD
Dielectric Strength			
50 μm (2 mil)	213 v/μm (5,400 v/mil)	60 hertz	ASTM D-149-81
75 μm (3 mil)	181 v/μm (4,600 v/mil)	¼" electrodes	
125 μm (5 mil)	142 v/μm (3,600 v/mil)		
Dielectric Constant			
50 μm (2 mil)	3.6	1 kilohertz	ASTM D-150-81
75 μm (3 mil)	3.7		
125 μm (5 mil)	3.7		
Dissipation Factor			
50 μm (2 mil)	.0025	1 kilohertz	ASTM D-150-81
75 μm (3 mil)	.0025		
125 μm (5 mil)	.0027		
Volume Resistivity			
50 μm (2 mil)	8×10^{17} ohm-m	125 volts	ASTM D-257-78
75 μm (3 mil)	5×10^{17} ohm-m		
125 μm (5 mil)	1×10^{17} ohm-m		

KAPTON® Type F Film

TYPICAL ELECTRICAL PROPERTIES

PROPERTY	120F616	150F019	250F029
Dielectric Strength Total volts volts/μm (volts/mil)	 7,500 267 (6,800)	 6,300 165 (4,200)	 157 (4,000)
Dielectric Constant	2.6	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^{15} (10^{17}) 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

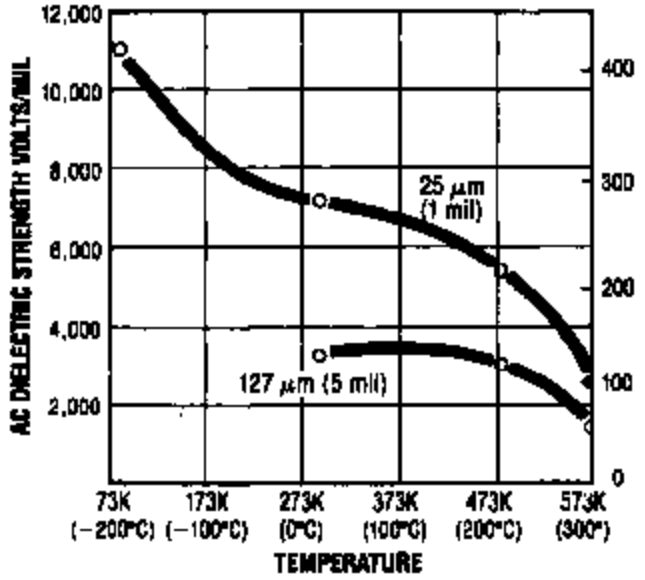
For calculations involving absolute water content, 50% RH in our study is equal to 1.3% water in the film and 100% RH is equal to 2.9% water, the maximum adsorption possible regardless of the driving force.

EFFECT OF TEMPERATURE

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

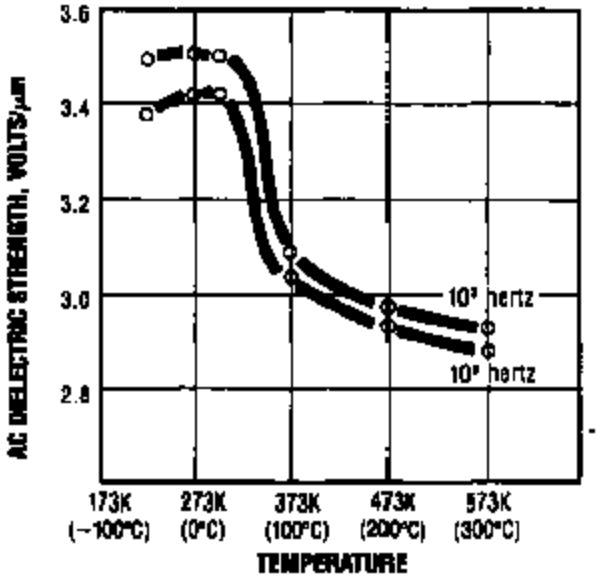
AC DIELECTRIC STRENGTH VS. TEMPERATURE

(Type H Film)



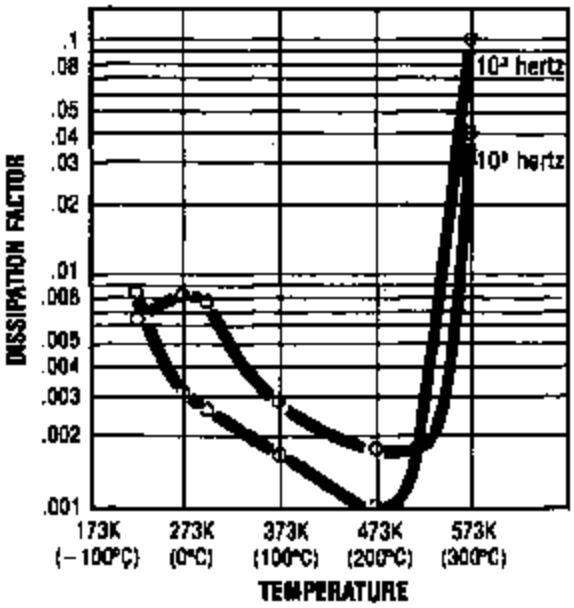
DIELECTRIC CONSTANT VS. TEMPERATURE

(Type H Film—25 μm (1 mil))



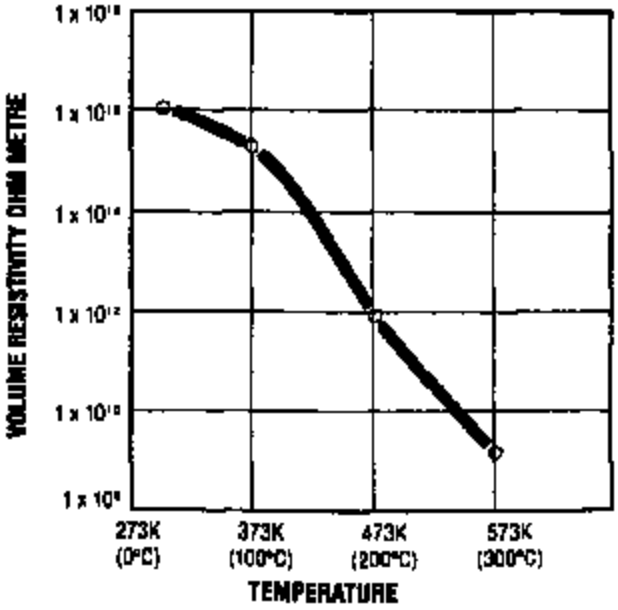
DISSIPATION FACTOR VS. TEMPERATURE

(Type H Film 25 μm (1 mil))



VOLUME RESISTIVITY VS. TEMPERATURE

(Type H Film 25 μm (1 mil))

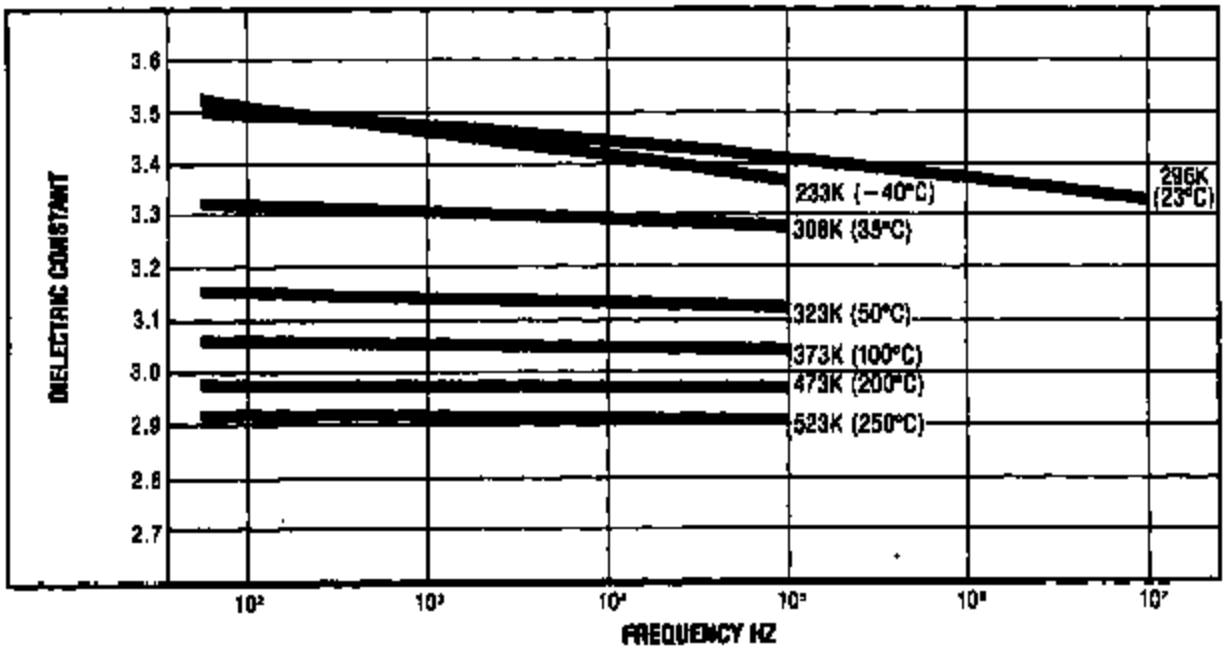


EFFECT OF FREQUENCY

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

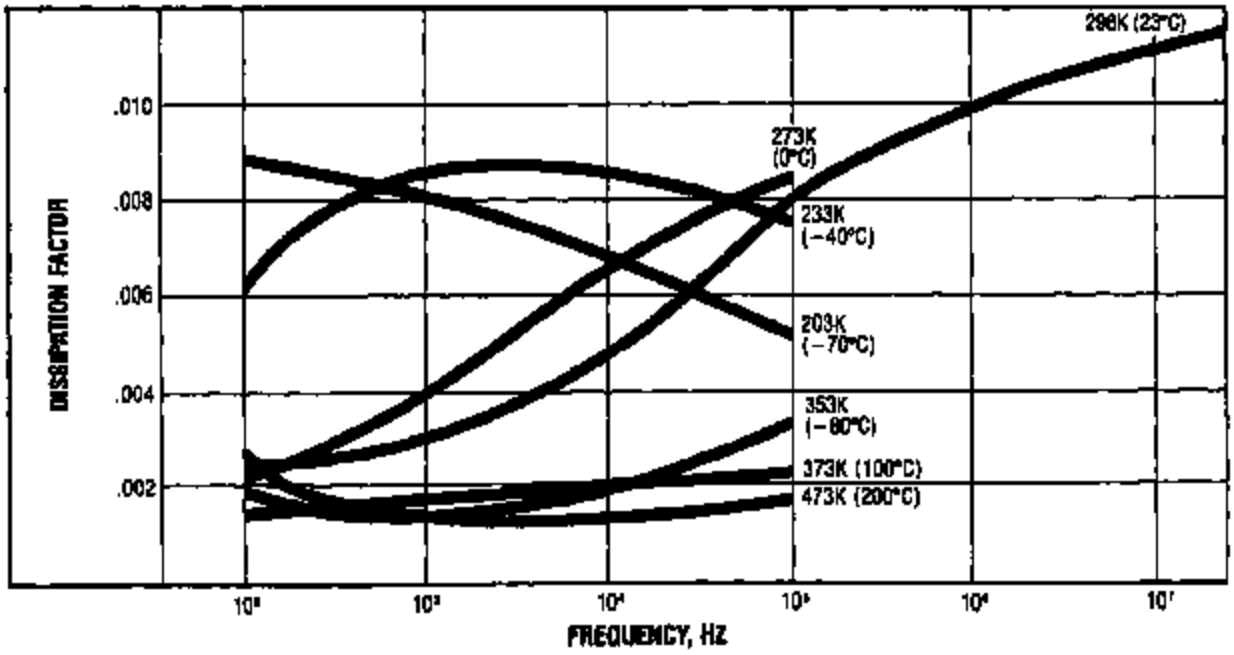
DIELECTRIC CONSTANT VS. FREQUENCY

(Type H Film 25 μm (1 mil))



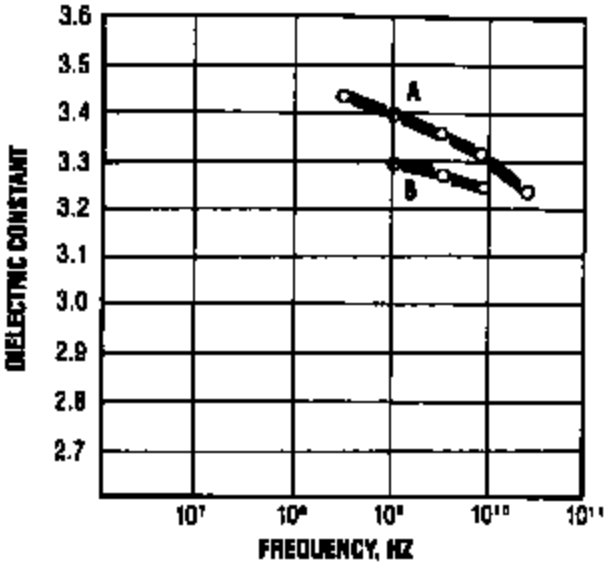
DISSIPATION FACTOR VS. FREQUENCY

(Type H Film 25 μm (1 mil))

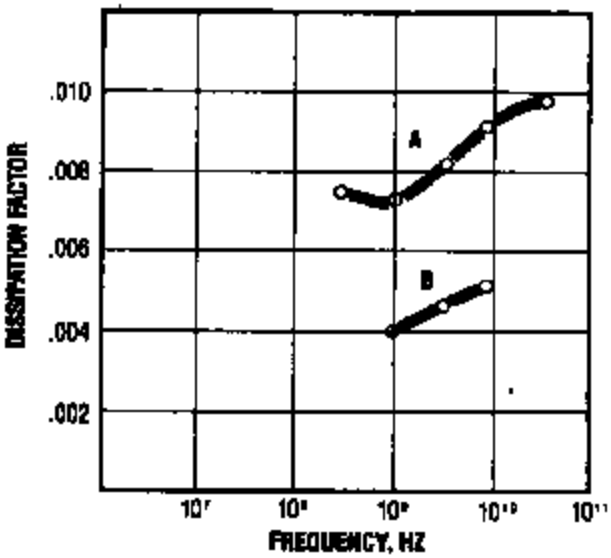


DIELECTRIC PROPERTIES IN GIGAHERTZ FREQUENCY RANGE

(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-495-61. The failure was due to true tracking rather than erosion, etc.

CORONA LIFE

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

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

CHEMICAL PROPERTIES

KAPTON® Type H Film

25 μm (1 mil)

CHEMICAL PROPERTIES

PROPERTY	TYPICAL VALUES (~25 μm (1 mil)) % Tensile Retained	% Elongation Retained	% Modulus Retained	TEST CONDITION/METHOD
RESISTANCE TO:				Days Immersed at Room Temperature
Benzene	100	62	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	30 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

KAPTON® Type V Film

CHEMICAL PROPERTIES

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

KAPTON® Type F Film

CHEMICAL PROPERTIES

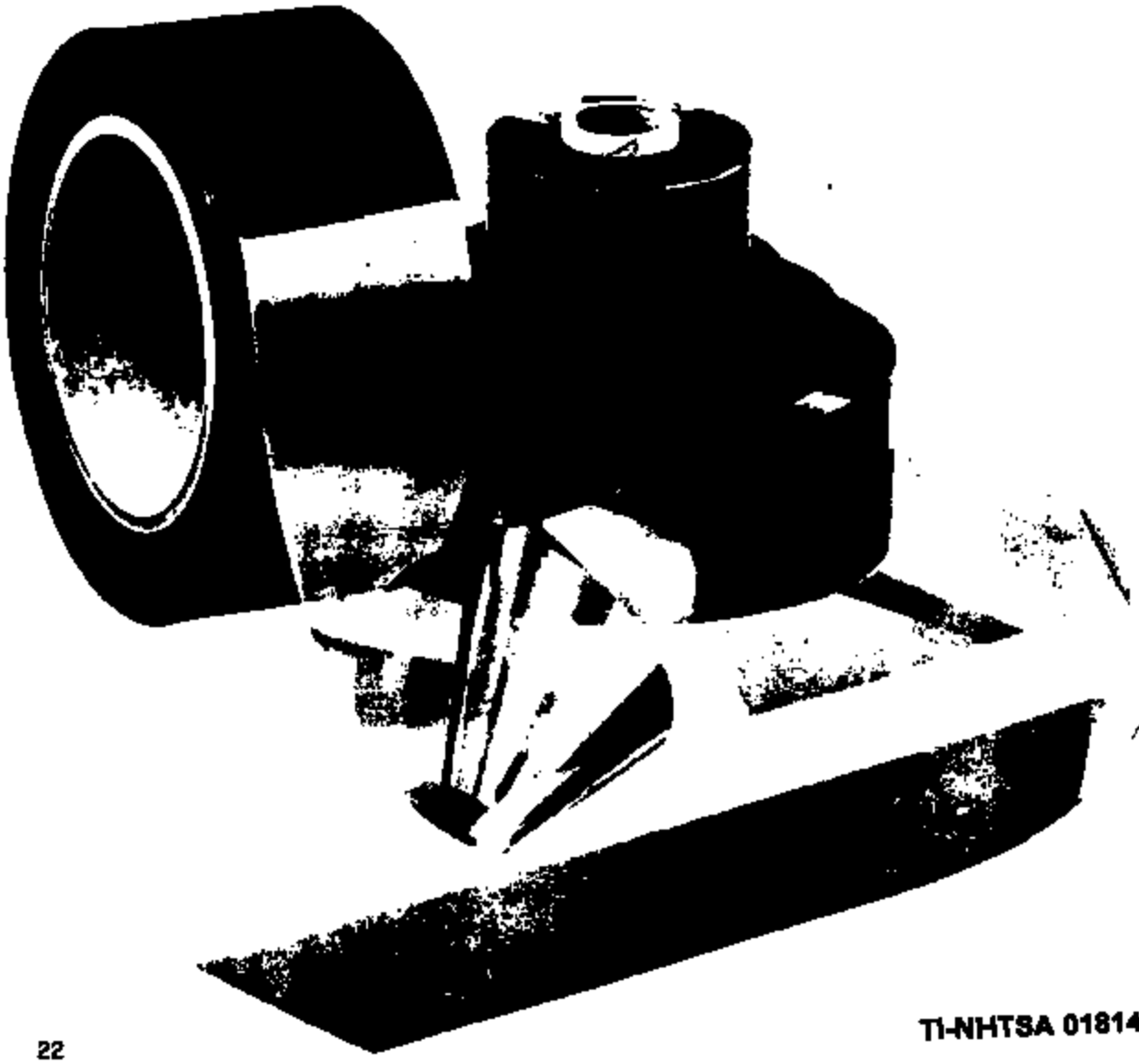
PROPERTY	120FD16	150FD19	400FD22
Moisture Absorption @ 296K (25°C), 50% R.H. 98% R.H.	 1.3% 2.5%	 .8% 1.7%	 .4% 1.2%
Water Vapor Permeability g/m²·d (gm./(100 in²) (24 hrs.) g/m²·d·µm (g./(100 in²)(24 hrs./mil)	 13.7 (0.89) 0.44 (1.07)	 8.8 (0.57) 0.35 (0.85)	 3.6 (0.23) 0.14 (0.92)

NOMINAL CONSTRUCTION, Type F Film

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

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

ORDER CODE	STANDARD WIDTHS		AREA FACTOR	
	mm	Inches	m^2/Kg	FT^2/LB.
120F616	3.18-914	1/8-36	21.3	104
150F019	3.18-914	1/8-36	15.8	77
250F029	3.18-914	1/8-36	11.1	49



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