DuPont FEP Film

FLUOROCARBON FILM

Information Bulletin

Description

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

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

FEP Is Unique Among Plastics

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

DuPont FEP Film Is Offered

- In thicknesses from 12.5–500 µm (0.5–20 mil)
- In custom slit widths up to 1.2–1.6 m (46–63 in) depending on thickness
- In various size rolls wound on 7.6 cm or 15.2 cm (3 in or 6 in) cores

DuPont FEP film affords the engineer/designer a wide range of opportunities to take advantage of these properties with minimal and convenient fabrication techniques. The ability of DuPont FEP film to be easily cut, thermoformed, heat sealed, and welded permits ready application as diaphragms, gaskets, protective linings, or thermoformed pouches or containers, wherever high temperature and/or chemical resistance is required.

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

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

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

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

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

DuPont FEP film offers unique properties in a convenient form requiring minimal fabrication. Consider it for your next project. For additional information, call (800) 283-2493.

DUPONT®

The miracles of science™

Types and Guages

Table 1 – Types and Guages of DuPont FEP Fluorocarbon Film									
Gauge	**50**	**100**	**175**	**200**	**300**	**500**	**750**	**1000**	**2000**
Thickness, mil	0.5	1	1.75	2	3	5	7.5	10	20
Thickness, µm	12.5	25	44	50	75	125	190	250	500
Approx. area factor, ft^2/lb	180	90	51	45	30	18	12	9	4.5
Approx. area factor, m^2/kg	36	18	10.3	9	6 4	2.5	2	1.2	0.6
Availability									
Type A - FEP, general-purpose	X	X	X	X	X	X	X	X	X
Type C - FEP, one side cementable	—	X	X	X	X	X	—	—	—
Type C-20 - FEP, both sides cementable	—	X	—	X	—	X	—	—	—

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

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

Mechanical and Thermal Properties

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

Tensile Properties

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

Dimensional Stability

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

Hygroscopic Expansion

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

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

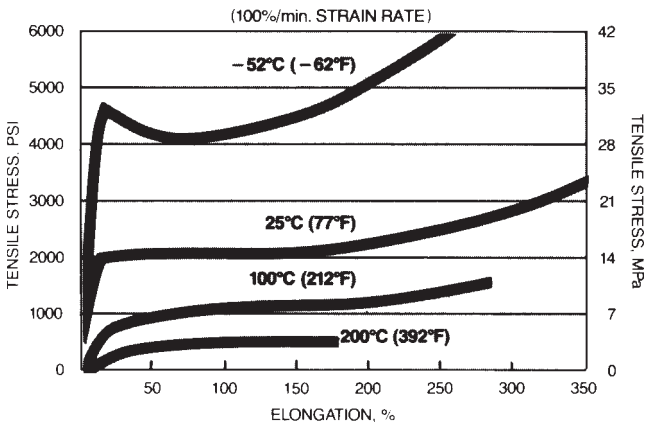


Figure 2: Tensile Properties of DuPont FEP Film vs. Temperature

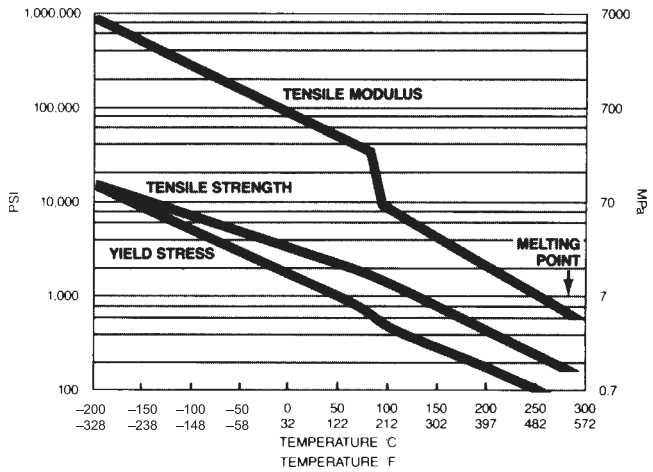
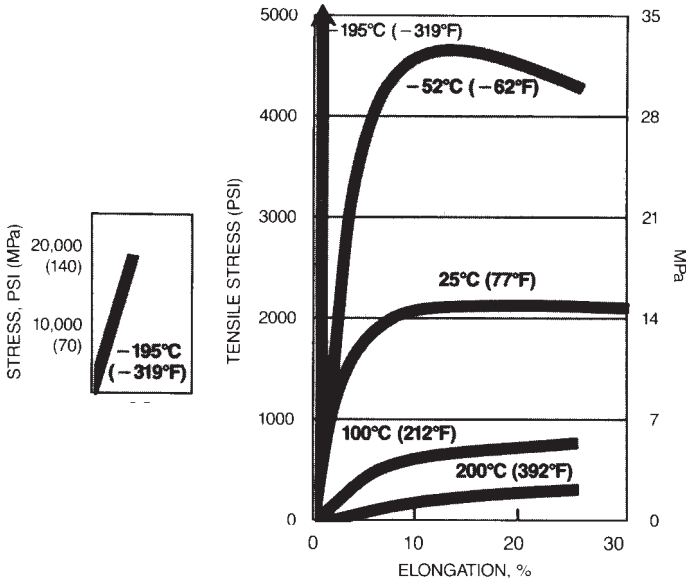


Figure 3: Tensile Stress vs. Elongation of DuPont FEP Film



Residual Shrinkage

Stresses set up in the film during manufacturing or converting can cause shrinkage in unrestrained film when exposed to high temperatures. Exposure of film to an elevated temperature, and the attendant shrinkage, will relieve this stress, and no further shrinkage will occur at lower temperatures.

Thermal Expansion

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

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

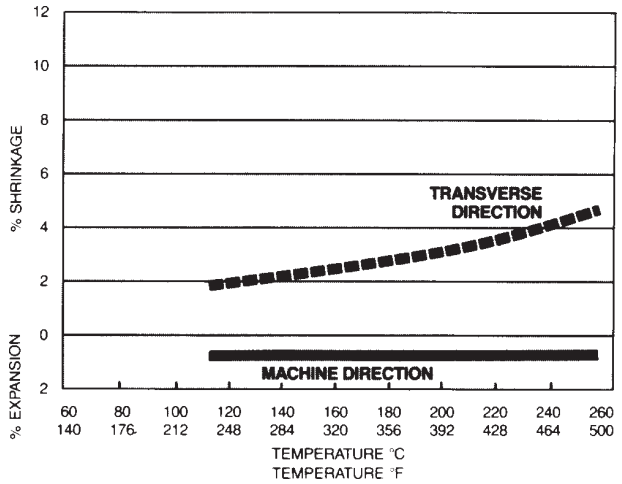


Table 2 - Typical Mechanical Properties of DuPont FEP Film*

Property	ASTM Method	SI Units	English Units
Tensile Strength (at Break)	ASTM D-882	21 MPa	3000 psi
Elongation at Break	ASTM D-882	300%	
Yield Point	ASTM D-882	12 MPa	1700 psi
Elastic Modulus	ASTM D-882	480 MPa	70,000 psi
Stress to produce 5% strain	ASTM D-882	12 MPa	1700 psi
Folding Endurance (MIT)	ASTM D-2176	10,000 cycles	
Initial Tear Strength–Initial (Graves)	ASTM D-1004	5.3 N	1.2 lbf
Propagating Tear Strength (Elmendorf)	ASTM D-1922	2.5 N	250 g
Bursting Strength**	ASTM D-774	76 kPa	11 psi
Density	ASTM D-1505	2150 kg/m^3	134 lb/ft^3
Coefficient of friction kinetic (film to steel)	ASTM D-1894	0.3	0.3

Table 3 - Typical Thermal Properties of DuPont FEP Film*

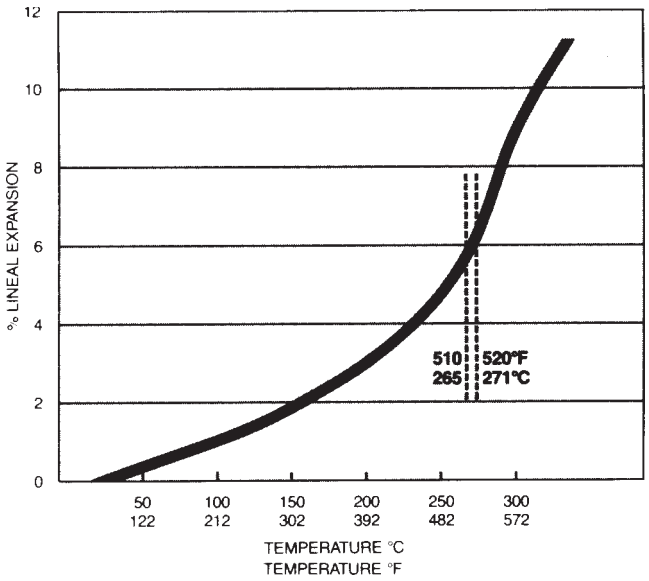
Property	ASTM Method	SI Units	English Units
Melt Point	ASTM D-3418 (DTA)	260–280°C	500–536°F
Maximum continuous service temperature		205°C	400°F
Zero Strength Temperature ***		255°C	490°F
Coefficient of Thermal Conductivity		0.195 W/m×K	1.35 BTU×in/h×ft^2×°F
Coefficient of linear thermal expansion	D-696	9.4 x 10^{-5}	5.4 x 10^{-5}
Flammability Classification	ANSI/UL 94	VTM-0	
Oxygen Index	ASTM D-2863	95%	
Dimensional Stability	30 min at 150°C (302°F)	MD = 0.7% expansion TD = 2.2% shrinkage	

*200 gauge unless otherwise noted

**100 gauge film

***Temperature at which film supports a load of 0.14 MPa (20 psi) for 5 sec

Figure 5: Thermal Expansion of DuPont FEP Film



Electrical Properties

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

Dielectric Strength

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

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

At a constant frequency, the dielectric constant of DuPont FEP film decreases with rise in temperature due to thermal expansion (see Figure 7). At a constant temperature, the dielectric constant falls slightly with an increase in frequency above 10^7 Hz (see Figure 8).

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

Property	Test Method	SI Units	English Units
Dielectric Strength, [6.4 mm (0.25 in) electrode in air 60 Hz]	ASTM D-149	260 kV/mm	6500 V/mil
Dielectric Constant	ASTM D-150 (1kHz)	2.0	
Dissipation Factor	ASTM D-150 (1kHz)	0.0002	
Volume Resistivity	ASTM D-257	1 X 10^{18} ohm.m	1 X 10^{18} ohm.cm
Surface Resistivity	ASTM D-257	1 X 10^{16} ohm (per square)	
Surface Arc Resistance	ASTM D-495	>165 sec*	

*Samples melted in arc did not track

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

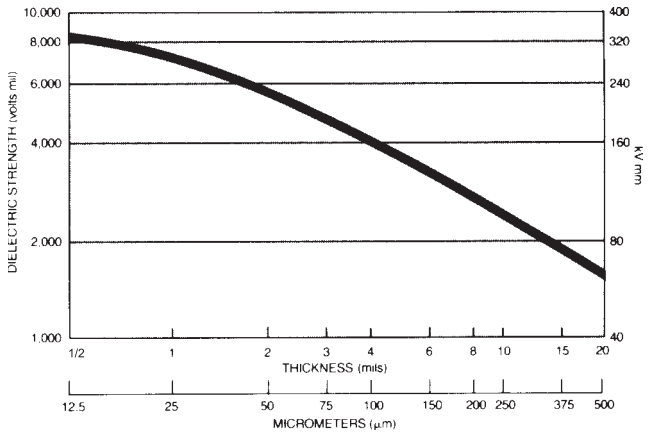


Figure 7: Dielectric Constant vs. Temperature of DuPont FEP Film at 1 kHz and 100 kHz

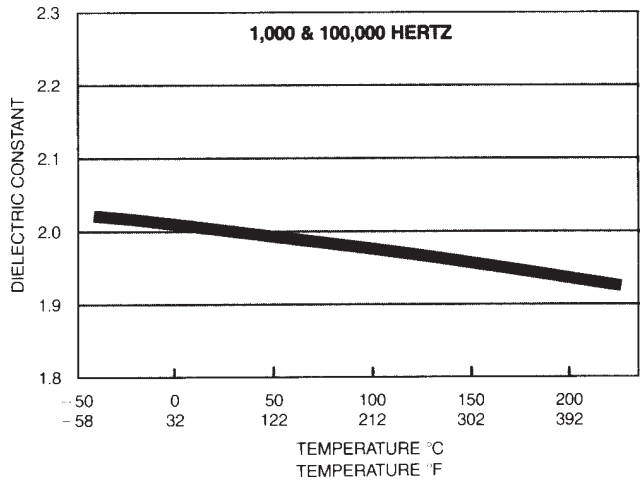
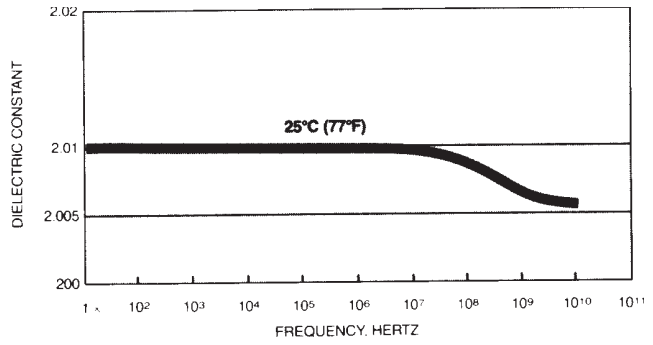


Figure 8: Dielectric Constant vs. Frequency



Dissipation Factor

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

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

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

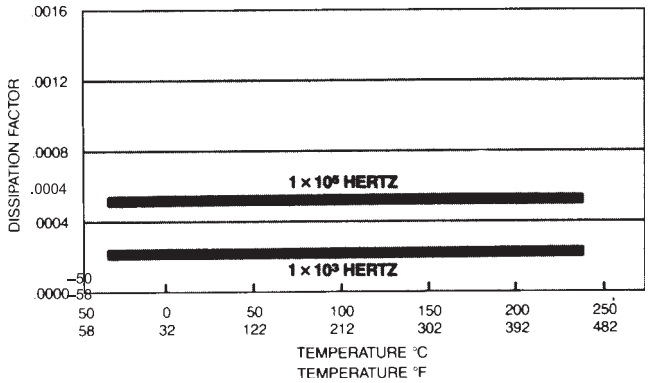
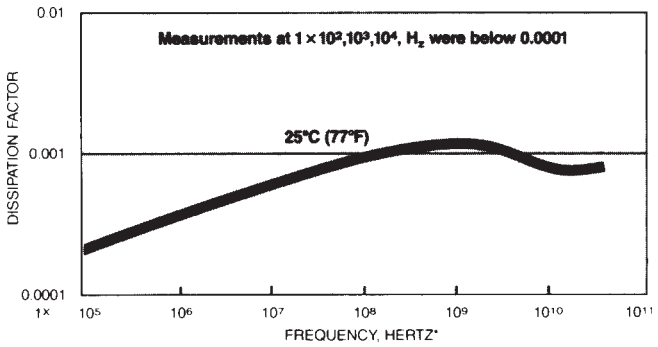


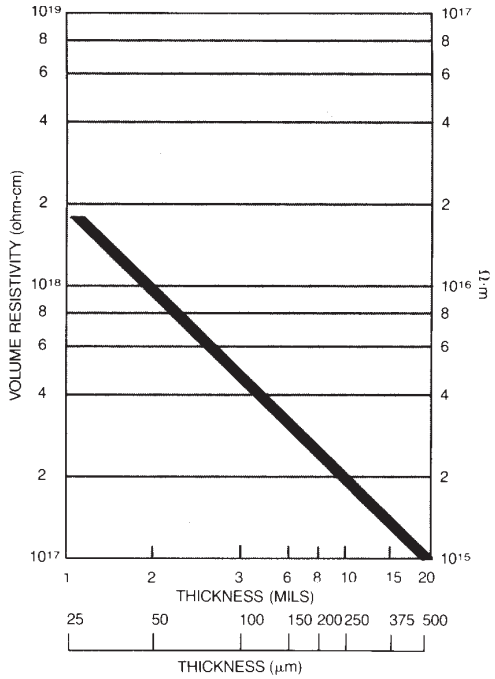
Figure 10: Dissipation Factor vs. Frequency of DuPont FEP Film



Volume Resistivity

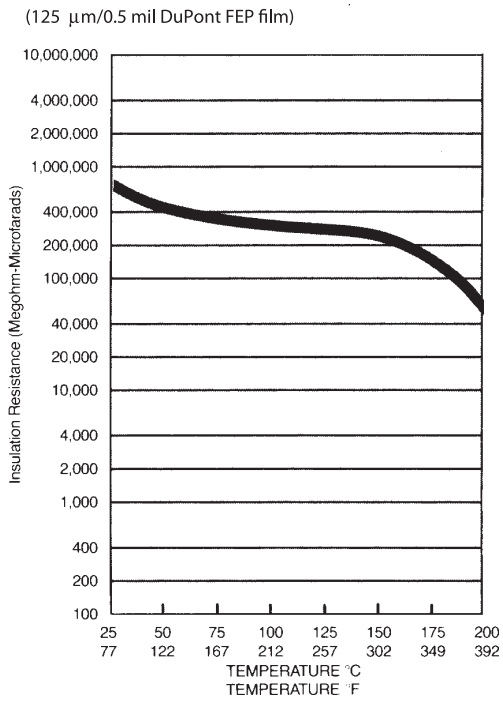
Volume resistivity of DuPont FEP film decreases slightly as the film thickness increases (see Figure 11).

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



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

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



Chemical Properties

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

In circumstances where end-use temperatures are close to the upper service limit of 205°C (400°F), 80% sodium hydroxide, metal hydrides, aluminum chloride, ammonia, and certain amines (R-NH2) may attack the film in a manner similar to molten alkali metals. Special testing is required when such extreme reducing or oxidizing conditions are evident. With these exceptions noted, DuPont FEP fluorocarbon films exhibit a very broad range of chemical and thermal serviceability.

Due to the many complex aspects of performance in severe environments, final selection should be based on functional evaluations or experience under actual end-use conditions. The chemical substances listed in Table 5 are representative of those with which DuPont FEP film has been found to be nonreactive.

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

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

* 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.

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

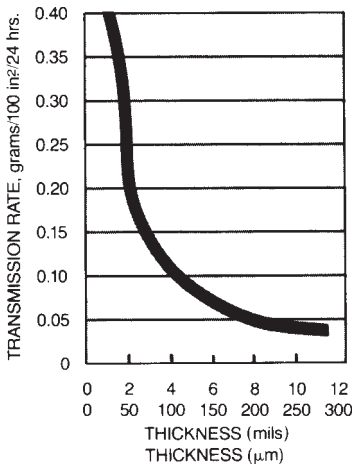
Many gases and vapors permeate FEP films at a much lower rate than for other thermoplastics (see Figure 13). In general, permeation increases with temperature, pressure, and surface contact area and decreases with increased film thickness. Table 6 lists rates at which various gases are transmitted through 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

Gas	Permeability Rate* $cm^3/(m^2.24\ h.atm)$
Carbon Dioxide	25.9×10^3
Hydrogen	34.1×10^3
Nitrogen	5.0×10^3
Oxygen	11.6×10^3

*To convert to $cm^3/(100\ in 2.24\ h.atm)$, multiply by 0.0645.

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



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

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

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

Optical Properties

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

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

Figure 14: Transmission Spectrum for DuPont FEP Film

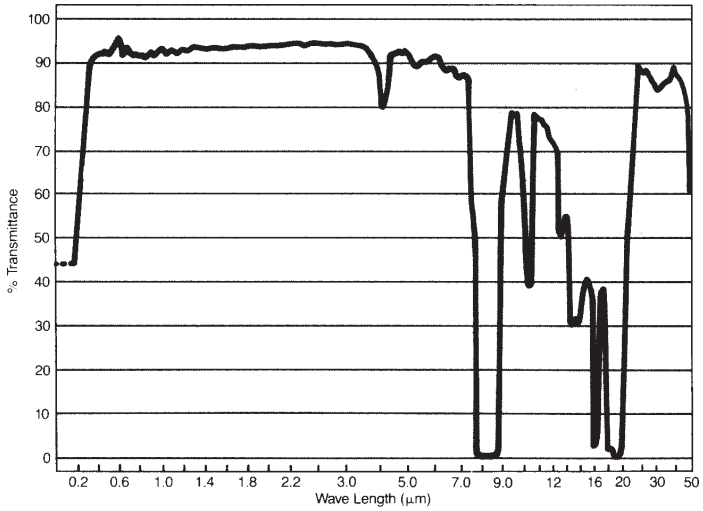


Figure 15: Transmittance at Normal Incidence of Solar Radiation through DuPont FEP Films for Various Thicknesses

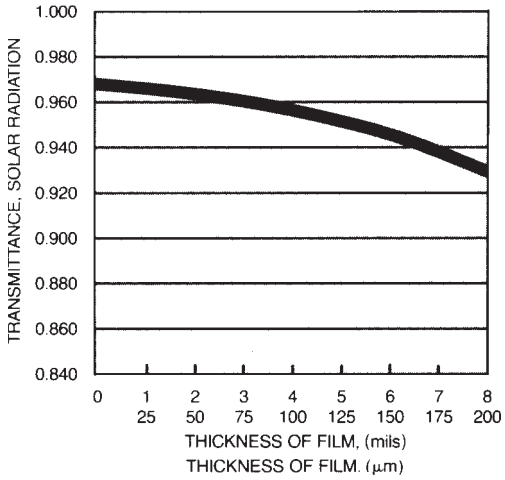
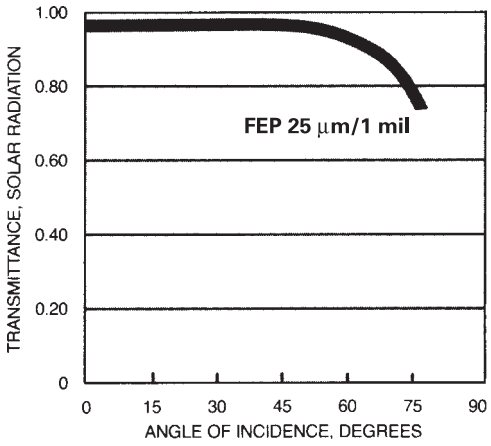


Figure 16: Transmittance of Solar Radiation through 25 μm (1 mil) DuPont FEP Film for Various Angles of Incidence



Miscellaneous Properties

Cryogenic Service

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

Mildew (Fungus) Resistance

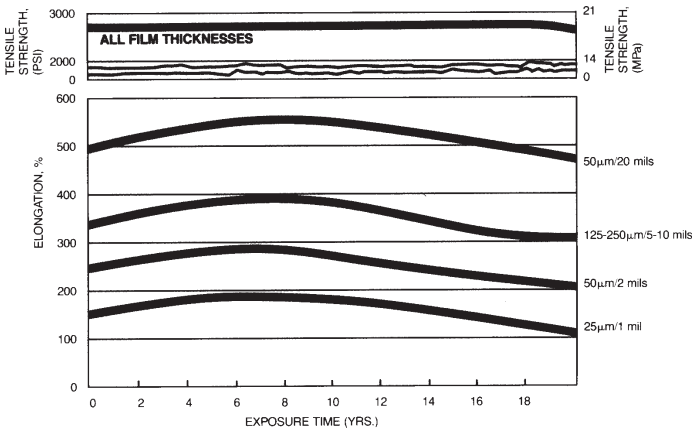
FEP has been shown to be completely resistant to mildew growth by testing both in humidity chamber exposure inoculated with a mixed spore suspension and a soil burial test for three months.

Weatherability

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

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

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



Safety and Handling

Unheated FEP fluorocarbon is essentially inert. Animal tests indicate that FEP is non-irritating and non-sensitizing to the skin. Dust generated by cutting, grinding, or machining the unheated film should be avoided, as with any other nuisance dusts that are regulated by OSHA at 15 mg/m^3 in air (29 CFR 1910:1000).

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

DuPont FEP film can be processed and used at elevated temperatures without hazard if proper ventilation is used. Ventilation should be provided at processing temperatures of 275°C (525°F) or above. Additional details on safety in handling and use are available in the "Guide to the Safe Handling of Fluoropolymer Resins" latest edition, published by the Fluoropolymers Division of the Society of Plastics Industry (SPI).

Other related literature available from DuPont:

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

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H55007-3 (09/10)