Teflon™ FEP

Fluoropolymer Film

Information Bulletin

Description

Teflon™ FEP fluoropolymer film offers the outstanding properties of FEP fluoropolymer in a convenient, easy-to-use form.

It can be heat sealed, thermoformed, welded, metallized, and laminated to many other materials or serve as a hot-melt adhesive.

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

Teflon™ 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

Teflon™ 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

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

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

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

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

Teflon™ FEP film offers unique properties in a convenient form requiring minimal fabrication.

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

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

Chemours™

Table 1. Types and Gauges of Teflon™ FEP Fluoropolymer 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	3.8	2.5	1.9	0.95
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 Teflon™ film is clearly identified as to resin type, film thickness, and film type.
FEP: Resin type 500: Film thickness, 500 gauge, 5 mil C: Film type, cementable one side

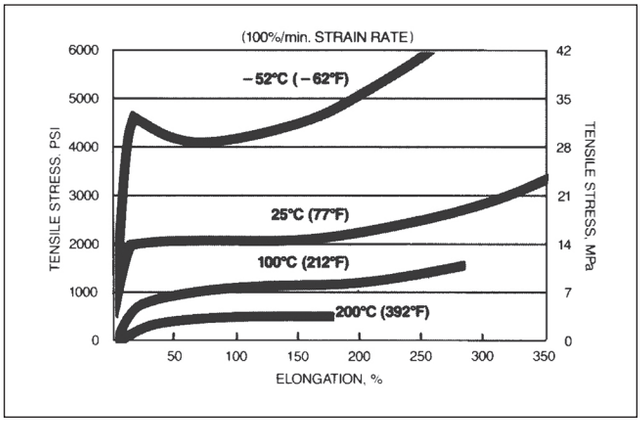
Mechanical and Thermal Properties

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

Tensile Properties

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

Figure 1: Tensile Stress vs. Elongation of Teflon™ FEP Film



Dimensional Stability

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

Hygroscopic Expansion

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

Figure 2: Tensile Properties of Teflon™ FEP Film vs. Temperature

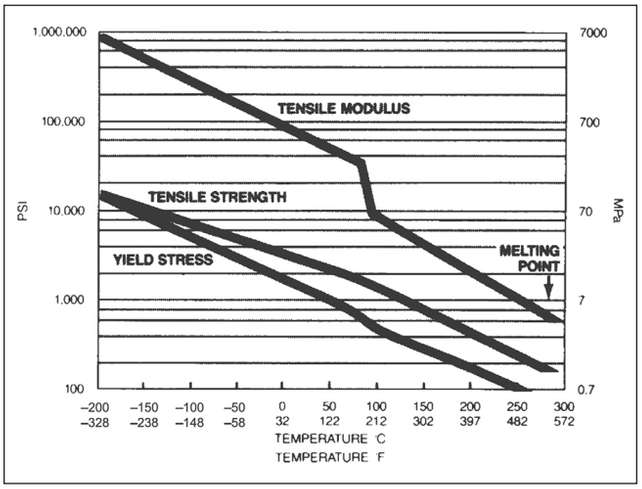
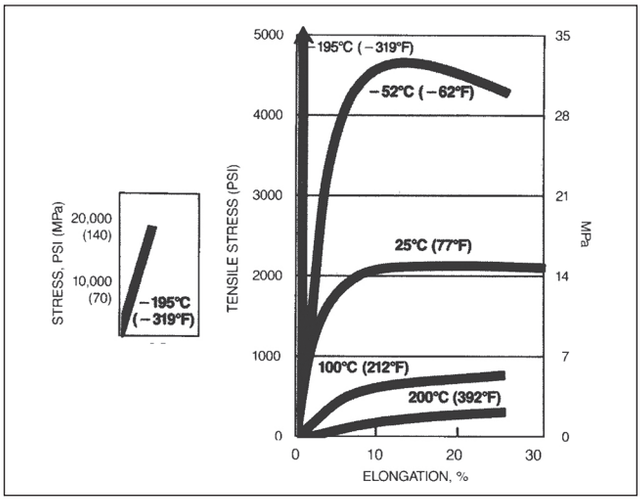


Figure 3: Tensile Stress vs. Elongation of Teflon™ FEP Film



Residual Shrinkage

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

Thermal Expansion

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

Table 2. Typical Mechanical Properties of Teflon™ FEP Film*

Property	ASTM Method	SI Units	English Units
Tensile Strength (at Break)	D882	21 MPa	3000 psi
Elongation at Break	D882	300%	
Yield Point	D882	12 MPa	1700 psi
Elastic Modulus	D882	480 MPa	70,000 psi
Stress to Produce 5% Strain	D882	12 MPa	1700 psi
Folding Endurance (MIT)	D2176	10,000 cycles	
Tear Strength—Initial (Graves)	D1004	5.3 N	1.2 lbf
Tear Strength—Propagating (Elmendorf)	D1922	2.5 N	250 g
Bursting Strength**	D774	76 kPa	11 psi
Density	D1505 2150	kg/m^3	134 lb/ft^3
Coefficient of Friction Kinetic (Film-to-Steel)	D1894	0.3	0.3

*200 gauge, unless otherwise noted
**100 gauge film

Table 3.Typical Thermal Properties of Teflon™ FEP Film*

Property	ASTM Method	SI Units	English Units
Melt Point	D3418 (D TA)	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/(hr·ft^2·°F)
Coefficient of Linear Thermal Expansion	D696	9.4×10^{-5}	5.4×10^{-5}
Flammability Classification	ANSI/UL94	VTM-0	
Oxygen Index	D2863	95%	
Dimensional Stability	30 min at 150 °C (302 °F)	MD = 0.7% expansion TD = 2.2% shrinkage	

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

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

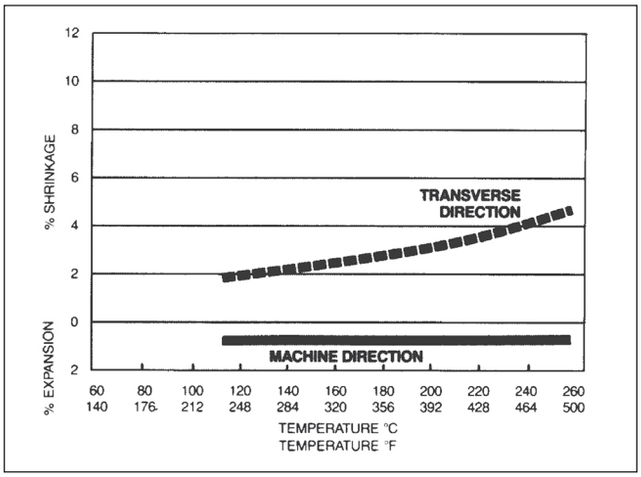
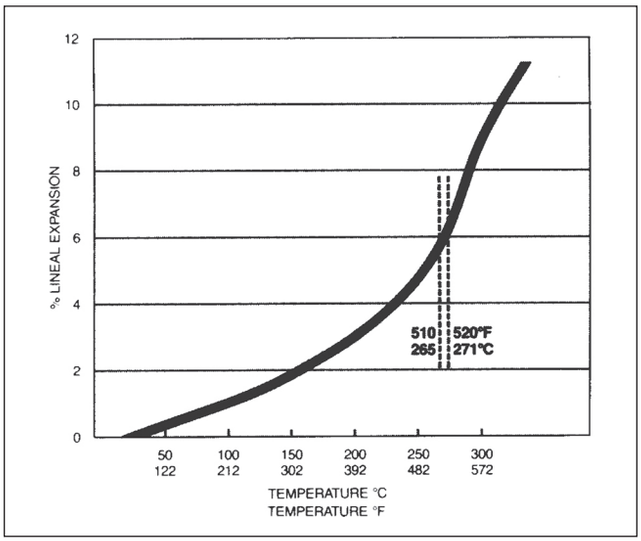


Figure 5: Thermal Expansion of Teflon™ FEP Film



Electrical Properties

Teflon™ FEP fluoropolymer 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 Teflon™ FEP film is a function of film thickness; thinner films exhibit greater dielectric strength.

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

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

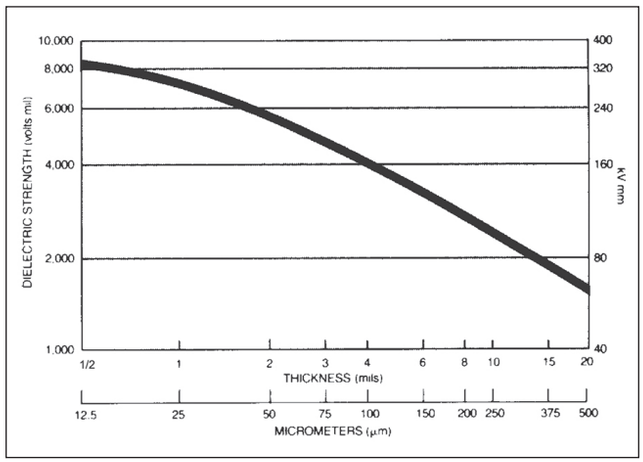


Table 4.Typical Electrical Properties of Teflon™ FEP Fluoropolymer Film, 25 μm (1 mil) Thickness

Property	ASTM Method	SI Units	English Units
Dielectric Strength, 6.4 mm (0.25 in) electrode in air 60 Hz	D149	260 kV/mm	6500 V/mil
Dielectric Constant	D150 (1 kHz)	2.0	
Dissipation Factor	D150 (1 kHz)	0.0002	
Volume Resistivity	D257	1 X 10^{18} ohm·m	1 X 10^{18} ohm·cm
Surface Resistivity	D257	1 X 10^{16} ohm (per square)	
Surface Arc Resistance	D495	>165 sec*	

*Samples melted in arc did not track

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

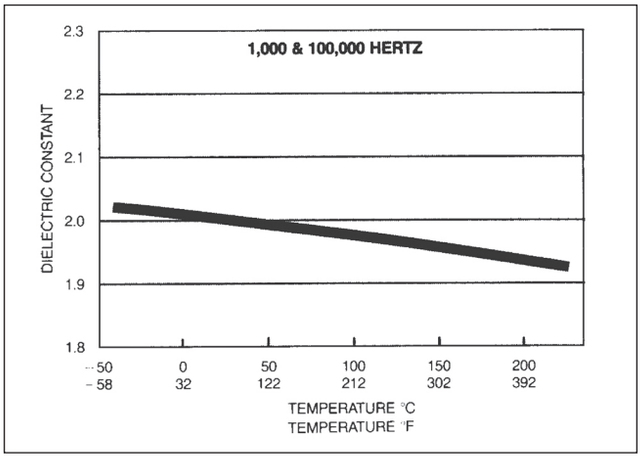


Figure 8: Dielectric Constant vs. Frequency

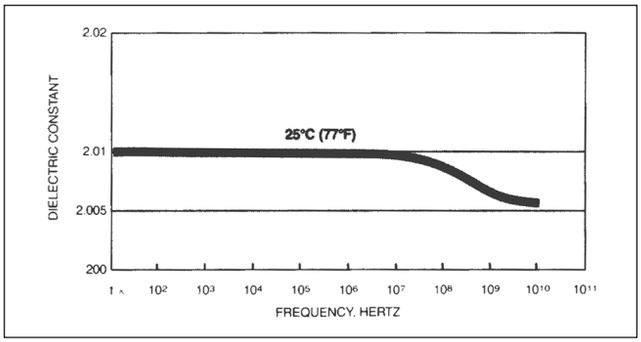


Figure 9: Dissipation Factor vs. Temperature of Teflon™ FEP Film

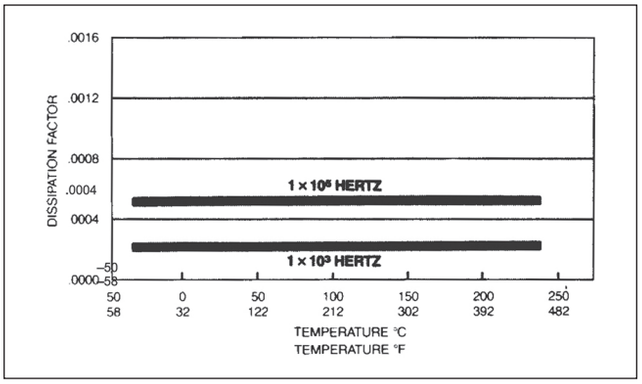
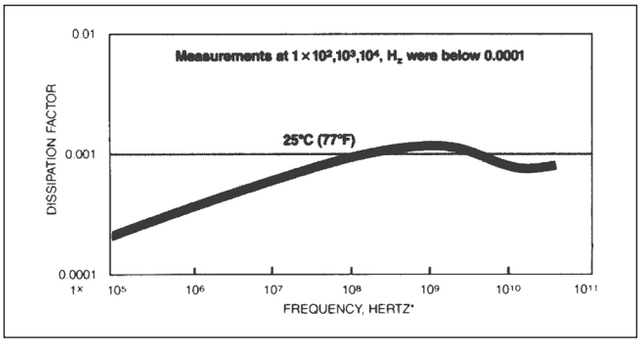


Figure 10: Dissipation Factor vs. Frequency of Teflon™ FEP Film



Dissipation Factor

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

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

Volume Resistivity

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

Insulation Resistance

Even at 200 °C (392 °F), the insulation resistance of Teflon™ FEP film (65,000 Mohm·µF) is higher than most conventional dielectric materials at room temperature (see Figure 12).

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

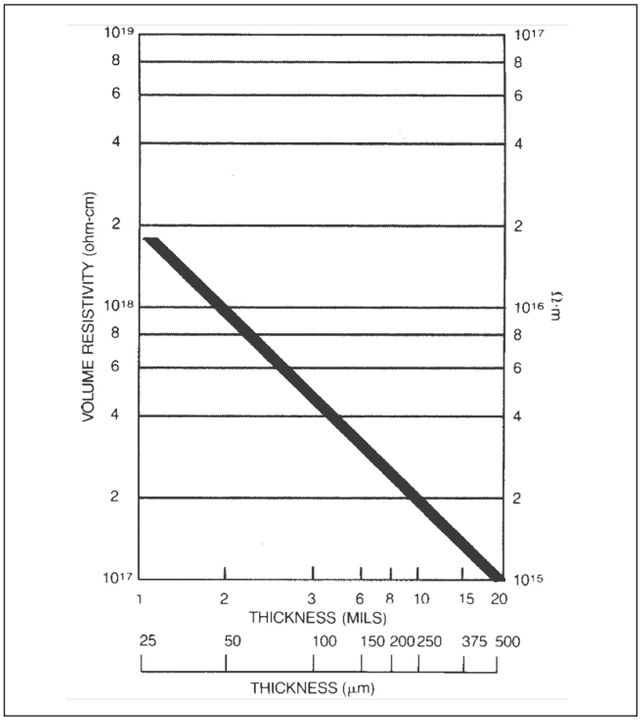
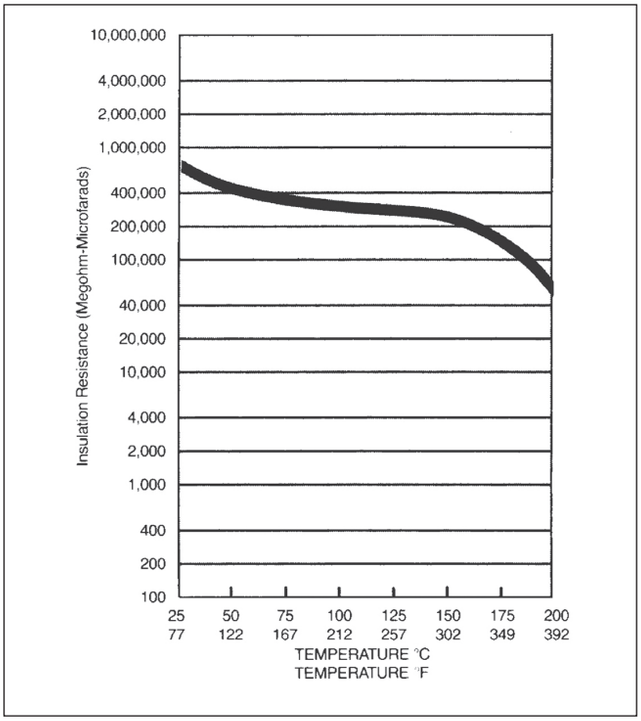


Figure 12: Insulation Resistance vs. Temperature (125 μm/0.5 mil Teflon™ FEP Film)



Chemical Properties

Teflon™ FEP fluoropolymer 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 ($R\text{-}NH_2$) may attack the film in a manner similar to molten alkali metals. Special testing is required when such extreme reducing or oxidizing conditions are evident. With these exceptions noted, Teflon™ FEP fluoropolymer films exhibit a very broad range of chemical and thermal serviceability.

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

Physical Properties

Absorption

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

Teflon™ FEP fluoropolymer 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 film. Moisture absorption is typically less than 0.01% at ambient temperature and pressure.

Table 5. Typical Chemicals With Which Teflon™ FEP Film Is Non-Reactive*

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

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

**Some halogenated solvents may cause moderate swelling.

Permeability

Many gases and vapors permeate Teflon™ 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 Teflon™ FEP fluoropolymer film, while Table 7 lists rates of vapor permeability for some representative substances.

Note that the pressure for each material is its vapor pressure at the indicated temperature.

Table 6. Typical Gas Permeability Rates of Teflon™ FEP Fluoropolymer Film, 25 µm (1 mil) Thickness

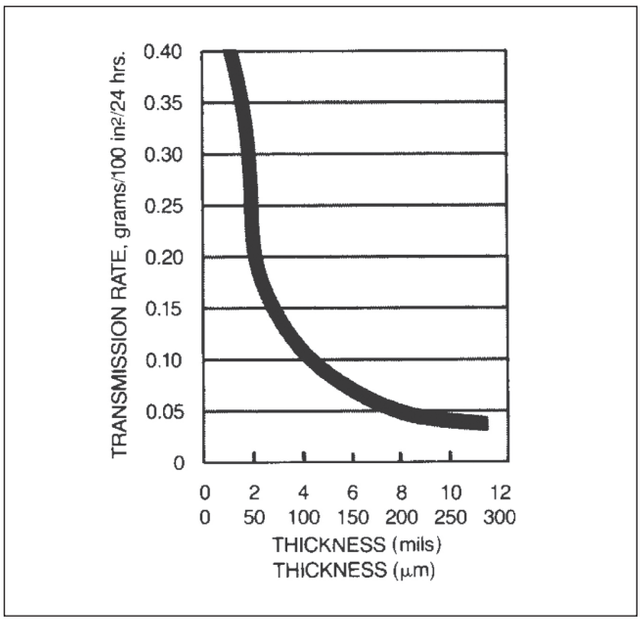
Gas	Permeability Rate, $cm^3/(m^2 \cdot 24\ hr \cdot atm)$*
Carbon Dioxide	25.9×10^3
Hydrogen	34.1×10^3
Nitrogen	5.0×10^3
Oxygen	11.6×10^3

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

Table 7. Typical Vapor Transmission Rates of Teflon™ FEP Fluoropolymer Film, 25 µm (1 mil) Thickness (Test Method: Modified ASTM E96)

Vapor	°C	°F	SI Units (g/m²·d)	English Units (g/100 in²·d)
Acetic Acid	35	95	6.3	0.41
Acetone	35	95	14.7	0.95
Benzene	35	95	9.9	0.64
Carbon Tetrachloride	35	95	4.8	0.31
Ethyl Acetate	35	95	11.7	0.76
Ethyl Alcohol	35	95	10.7	0.69
Freon™ F-12	23	73	372.0	24.0
Hexane	35	95	8.7	0.56
Hydrochloric Acid	25	77	<0.2	<0.01
Nitric Acid (Red Fuming)	25	77	160.0	10.5
Sodium Hydroxide, 50%	25	77	<0.2	<0.01
Sulfuric Acid, 98	25	77	2×10^{-4}	1×10^{-5}
Water	39.5	103	7.0	0.40

Figure 13: Water Vapor Transmission Rate of Teflon™ FEP Film at 40 °C (104 °F) per ASTM E96 (Modified)



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

Optical Properties

Teflon™ 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 Teflon™ FEP films of interest are:

Solar Transmission (ASTM E424)	96%
Refractive Index (ASTM D542)	1.341–1.347

Figure 14. Transmission Spectrum for Teflon™ FEP Film

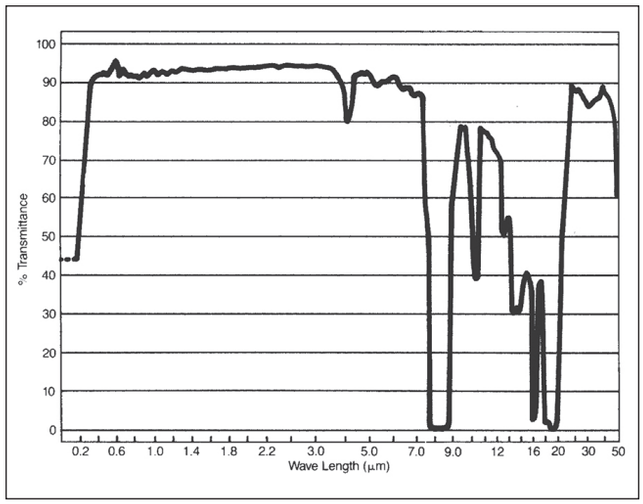


Figure 15. Transmittance at Normal Incidence of Solar Radiation through Teflon™ FEP Films for Various Thicknesses

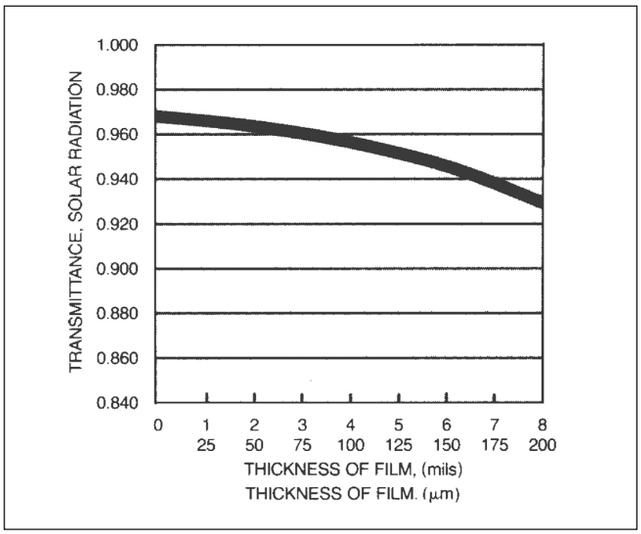
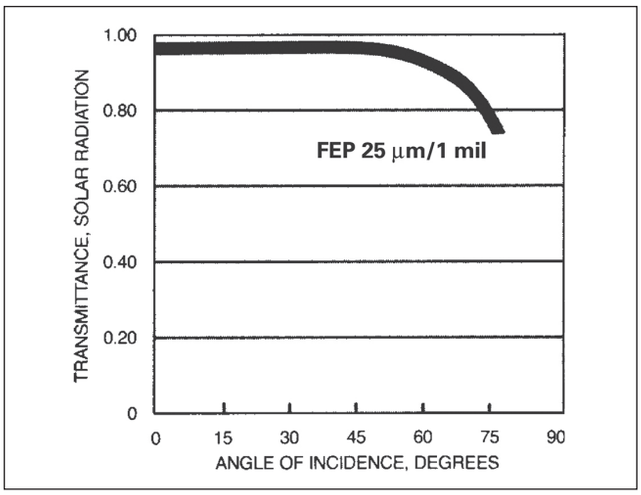


Figure 16. Transmittance of Solar Radiation through 25 μm (1 mil) Teflon™ FEP Film for Various Angles of Incidence



Miscellaneous Properties

Cryogenic Service

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

Mildew (Fungus) Resistance

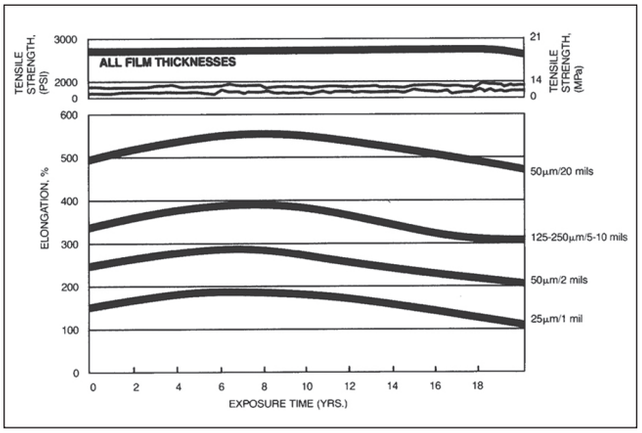
Teflon™ FEP has been shown to be completely resistant to mildew growth by testing both in humidity chamber exposure inoculated with a mixed spore suspension and a soil burial test for three months.

Weatherability

In contrast to most other clear thermoplastic films, Teflon™ 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 not the result of chemical additives.

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

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



Safety and Handling

Unheated Teflon™ FEP fluoropolymer is essentially inert. Animal tests indicate that Teflon™ 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 fluoropolymer resins.

Teflon™ 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 Plastics Industry Association.

For more information, visit teflon.com/industrial
For sales and technical support contacts, visit teflon.com/industrialglobalsupport

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