EVERFLON™ PFA

Properties Handbook

Polyfluoroalkoxy

EVERFLON ACADEMIC

Introduction

Everflon™ PFA is a copolymer of tetrafluoroethylene ($C2F4$) and perfluoroalkoxyethylene. As the diagram below shows, in the basic structure of Everflon™ PFA, all of the carbon atoms are strongly bonded to fluorine atoms.

As a result, over a wide range of temperatures, Everflon™ PFA has excellent chemical,electrical, mechanical, and surface properties. Moreover, compared with Everflon™ PTFE, it is fluid when molten and so is amenable to injection, extrusion, blow, transfer, and other melt processing methods.

This technical brochure is provided to assist users as they develop various applications that exploit the properties of Everflon™ PFA; the document gives comprehensive coverage of the material properties of Everflon™ PFA and information about how to use the resin in molding processes

Commercially Available Everflon™ PFA Fluoropolymers

Everflon™ETFE Grade	Resin Characteristics	Applications
403/S	Low MFR resin for molding and extrusion applications	Tubing Pipe lining Films Injection-/blow-molded parts
410/S	Mid-range MFR resin for molding and extrusion applica-tions	Thin wall wire insulation Intricate/small injection- molded parts
420/S	High MFR resin for Injection and extrusion applications	Tubing Wire and cable Injection- molded parts
430/S	Ultra-high MFR resin for injection and extrusion application	Thin wall wire insulation Intricate-/small injection- molded parts
GC403	Low MFR resin with high-stress crack resistance for molding and extrusion applications	Tubing and piping Molded parts and linings Sheet lining for vessels and chemical delivery systems in high purity applications
GC410	Mid-range MFR resin for molding and extrusion applica-tions	Injection molded parts and tubing in high- purity applica-tions
GC420	High MFR resin for molding extrusion applications	Injection- molded parts in high- purity applications (i.e., fittings, valve bodies, filter housings)
GC430	Ultra-high MFR resin for injection and extrusion applica-tions	Thin wall wire insulation Intricate-/small injection- molded parts
C403	Low MFR static dissipative resin	Tubing, linings, and molded parts that require static dissipative performance
C410	Middle MFR static dissipative resin	Cables, tubing, linings, and molded parts that require static dissipative performance
C420	High MFR static dissipative resin	Cables, tubing, linings, and molded parts that require static dissipative performance
CC04	Color Concentrate with PFA virgin resin	Cables, tubing, linings, and molded parts with various colors requirement
JP04	Powder for specialty applications	Ideal for compounding and compression molding
GS04	Free-flowing, high-purity roto-molding and roto-lining powder	Hollow parts Complex geometries Lining

Characteristics of Everflon™ PFA

Excellent sustained mechanical strength

From –200 to +260C,Everflon™ PFA holds its mechanical strength over a wide range of temperature and, within this range, products maintain a stable form.

Excellent chemical resistance

Able to resist most solvents, Everflon™ PFA is a material that is highly stable when used with chemicals.

Excellent electrical characteristics

Displaying an very low dielectric constant and very low dielectric tangent, Everflon™ PFA is an outstanding material for electrical insulation and has been helping to raise the reliability in the electronics sector.

Excellent noncombustibility

Everflon™ PFA has an oxygen index value of more than 95% because of its incombustibility, it is finding widespread application in diverse fields.

Excellent surface characteristics

Along with low friction, non-stick properties, water and oil repellency and other excellent surface characteristics that can used with good effect, Everflon™ PFA also is highly reliable and displays low resistance to fluid flow.

Excellent weatherability

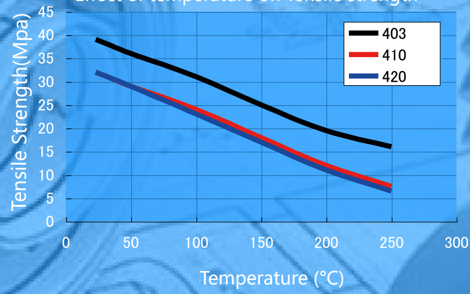
Everflon™ PFA stands up to direct sunlight, the rigors of the wind and weather, exhaust gas, and other trials without fall off in performance or deterioration: even after long exposure out of doors, its properties are not compromised.

Material properties of Everflon™ PFA

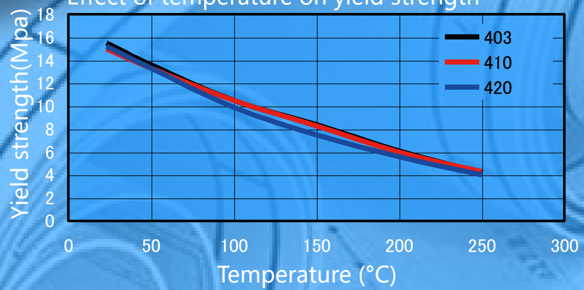
	Property	Unit	ASTM standard	403	410	420	430
Physical	Melting point	℃	--	305-315			
	MFR	g/10min		1-3	6-12	20-30	35-45
	Specific gravity	--	D792	2.12-2.17			
Mechanical	Tensile strength23 ℃ 250 ℃	MPa	D638	30 16	28 8	24 7	22
	Elongation 23 ℃ 250 ℃	%	D638	380	350	330	300
	Impact strength(Izod)	kg-cm/cm (J/M)	D256A	No Break			
	Hardness(Dorometer)	--	D1706	D60			
	Flexural modulus	10^3kg/cm^2 (GPa)	D790	5.5 0.54	6.3 0.62	6.5 0.64	6.5 0.64
	MIT (Flex life)	Times	D2176	500,000	20,000	10,000	10,000
Thermal	Thermal conductivity	10-4cal/cm/sec ℃	C177	6.0			
	Specific heat	cal/℃.g		0.25			
	Coefficient of linear thermal expansion	10^5℃	D696	14		15	15
	Ball pressure temp.	℃		230	230	--	
	Max service temp. (continuous)	℃		260			
Electrical	Volume resistivity	Ω-cm	D257	$>10^{17}$			
	Surface resistivity	Ω	D257	$>10^{17}$			
	Dielectric constant	60Hz 10^3Hz 10^6Hz 10^9Hz	D150	< 2.1			
	Dielectric tangent	60Hz 10^3Hz 10^6Hz	D150	< 0.0003			
	Ark resistance	S	D495	>300			
Others	Water absorption	%	D570	< 0.03			
	Flammability	--	UL94	V-0			
	Oxygen index	--	D2863	>95			

Mechanical Properties

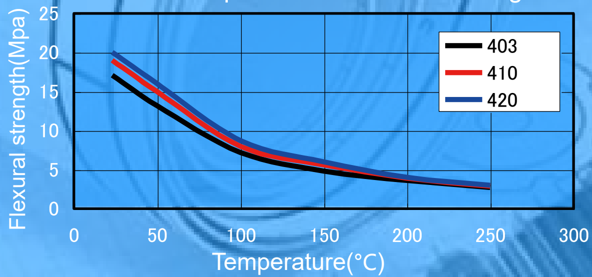
Effect of temperature on Tensile strength



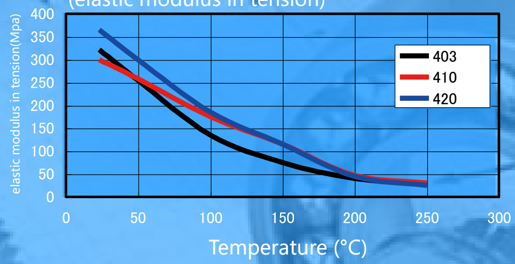
Effect of temperature on yield strength



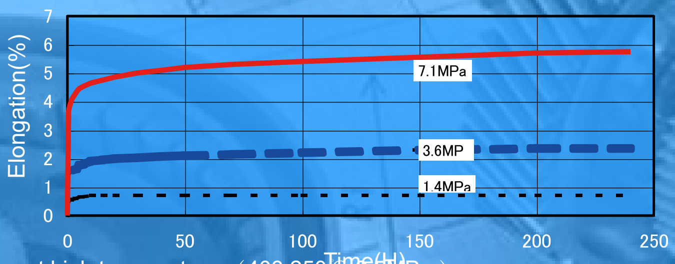
Effect of temperature on flexural strength



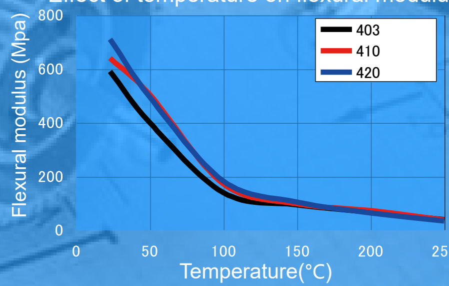
Effect of temperature on Young's Modulus (elastic modulus in tension)



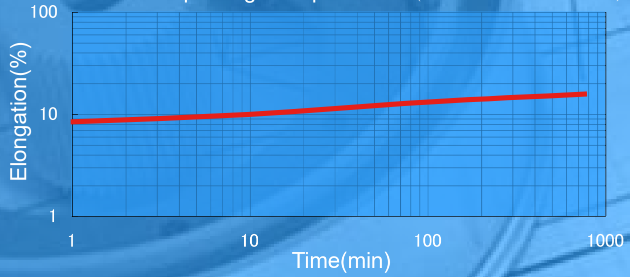
Effect of loading on tensile creep (403 room temp.)

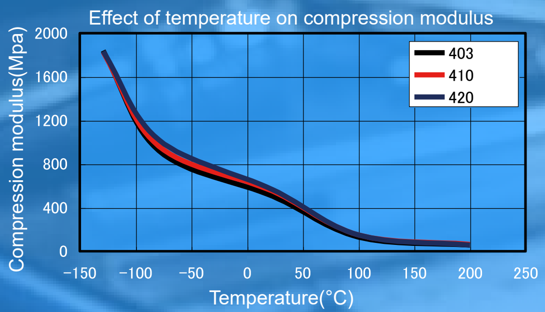


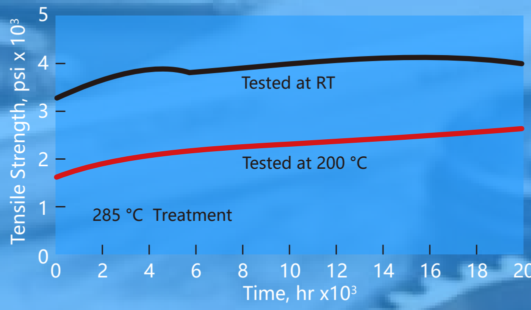
Effect of temperature on flexural modulus

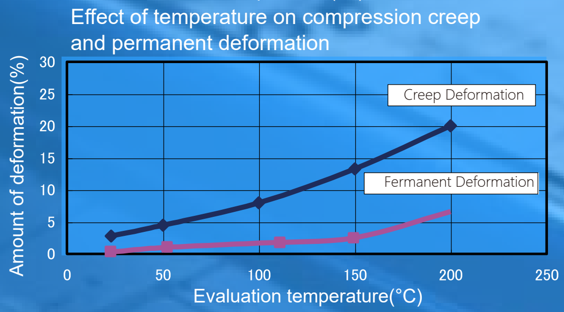


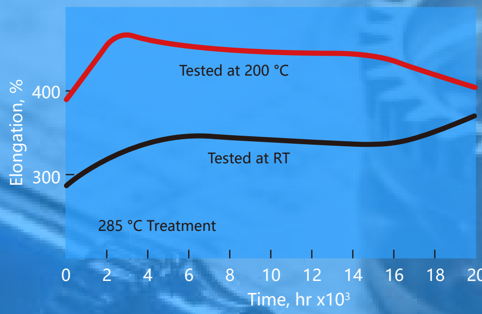
Tensile creep at high temperature （403 250℃ 2.5MPa ）

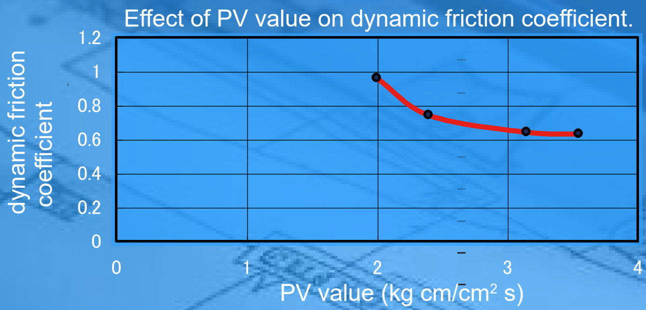


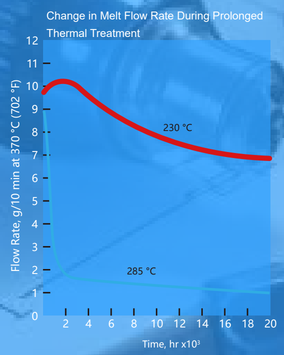

Effect of temperature on compression modulus
Compression modulus(Mpa)
2000
1600
1200
800
400
0
−150 −100 −50 0 50 100 150 200 250
Temperature(°C)
403
410
420

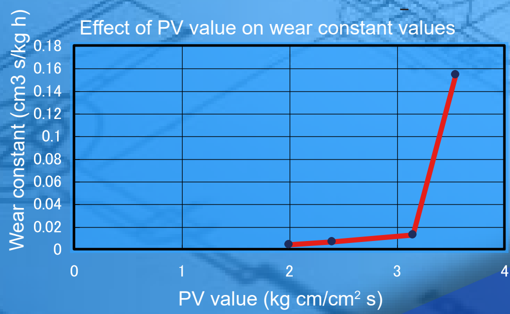

Tensile Strength, psi x 10³
5
4
3
2
1
0
Tested at RT
Tested at 200 °C
285 °C Treatment
0 2 4 6 8 10 12 14 16 18 20
Time, hr x10³


Effect of temperature on compression creep and permanent deformation
Amount of deformation(%)
30
25
20
15
10
5
0
Creep Deformation
Fermanent Deformation
0 50 100 150 200 250
Evaluation temperature(°C)


Elongation, %
400
300
Tested at 200 °C
Tested at RT
285 °C Treatment
0 2 4 6 8 10 12 14 16 18 20
Time, hr x10³


Effect of PV value on dynamic friction coefficient.
dynamic friction coefficient
1.2
1
0.8
0.6
0.4
0.2
0
0 1 2 3 4
PV value (kg cm/cm² s)


Change in Melt Flow Rate During Prolonged Thermal Treatment
Flow Rate, g/10 min at 370 °C (702 °F)
12
11
10
9
8
7
6
5
4
3
2
1
0
230 °C
285 °C
2 4 6 8 10 12 14 16 18 20
Time, hr x10³


Effect of PV value on wear constant values
Wear constant (cm3 s/kg h)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0 1 2 3 4
PV value (kg cm/cm² s)

Data Hub

Impact strength (ASTM D256)

The notched Izod impact test is a method for evaluating the impact strength of plastic. In this test a notched piece of plastic is subject to impactand the amount of energy absorbed breakage is measured. EverflonTM PFA does not break at room temperature.

Unit: J/m

Temperature	403	410	420
-40 °C	700	680	570
25 °C	No breakage	No breakage	No breakage

Test piece:64*12.7*3.2mm

Cryogenic Temperature Effects

Tests made at liquid nitrogen temperatures indicate that Everflon™ PFA fluoropolymer resins perform well in cryogenic applications.

Property	ASTM Method	Unit	Value	
			Room Temperature, 23℃	Cryogenic Temperature, -196℃
Yield Strength	D1708	MPa (psi)	15 (2,100)	No Yield
Ultimate Tensile Strength	D1708	MPa (psi)	18 (2,600)	129 (18,700)
Elongation	D1708	%	260	8
Flexural Modulus	D790-71	MPa (psi)	558 (81,000)	5,790 (840,000)
Impact Strength, Notched Izod	D256-72	J/m (ft-lb/in)	No Break	64 (1.2)
Compressive Strength	D695	MPa (psi)	24 (3,500)	414 (60,000)
Compressive Strain	D695	%	20	35
Modulus of Elasticity	D695	MPa (psi)	69 (10,000)	4,690 (680,000)

Adhesion

Everflon™ PFA fluoropolymer resins used as thin-film hot melt adhesives give strong, highly water-resistant bonds to a variety of thermally resistant substrates. Metals, glass, and other thermally resistant materials have been adhered using this technique.

Flex life (MIT method ASTM D2176)

Using the MIT method, the flex life of PFA was measured as a simplemeans of evaluating resistance to stress cracking. Test pieces were short straps, 1.25 mm *130 mm *0.23 mm, that were bent to +-135o at a rate of 175 times per min until they broke; the number of flexes was recorded. Results show that Everflon PFA has a longer life than similar grades made by other companies.

Grade	403	410	420
Cycles	$50*10^4$	$2.5*10^4$	$1.8*10^4$

Hardness

The hardness of Everflon™ PFA fluoropolymer resins is 55–57 durometer. This result was obtained in tests run on compression-molded panels according to ASTM D2240.

Thermal Exposure

Everflon™ PFA fluoropolymer resins are rated for continuous use at temperatures up to 260 °C . However, long-term heat treatment of Everflon ™ PFA fluoropolymer resin plaques, tensile bars, and coated wires at 285 °C indicates that the resin can be continuously exposed to this temperature without deterioration of its mechanical or electrical properties.

Wear and Frictional Data

Frictional and wear tests have been run on Everflon™ PFA fluoropolymer resins to indicate level of performance (unfilled) in mechanical applications, such as bearings and seals. Tests were run on molded thrust bearings at 0.7 MPa (100 psi) against AISI 1018, Rc20, 16AA steel; tests were run at ambient conditions in air with no lubrication.

Velocity, ft/min	Wear Factor, K x 10^{-10}	Dynamic Coefficient of Friction	Duration, hr
3	1,591	0.210	103
10	1,837	0.214	103
30	983	0.229	103
50	694	0.289	103

Chemical Properties

Everflon™ PFA fluoropolymer resins are known to retain high levels of mechanical performance after chemical exposure; in fact, the fully fluorinated Everflon™ PFA fluoropolymer resin series is known to have the highest levels of chemical inertness due to its lack of reactive end groups.

• They are not degraded by chemical systems commonly encountered in chemical processes.

• They are inert to:

– Strong mineral acids– Inorganic bases – Inorganic oxidizing agents– Salt solutions

• They are also inert to such organic compounds as:

– Organic acids – Anhydrides– Aromatics– Aliphatic hydrocarbons– Alcohols– Aldehydes– Ketones– Ethers– Esters– Chlorocarbons– Fluorocarbons – Mixtures of the above compounds

As in the case of other perfluorinated products, Everflon™ PFA fluoropolymer resins can be attacked by certain halogenated complexes containing fluorine.These include chlorine trifluoride, bromine trifluoride, iodine pentafluoride, and fluorine itself. Everflon™ PFA fluoropolymer resins can also be attacked by such metals as sodium or potassium, especially in their molten states. Great care should be used when mixing finely divided fluoropolymers with finely divided metals, such as aluminum, magnesium, or barium, because these can react violently if ignited or heated to a high temperature. Certain complexes of these metals with ammonia or naphthalene (in either solvent) also attack the product.

Indeed, these complexes are used to provide films or tubes of Everflon™ PFA fluoropolymer resins with a cementable surface. Certain metal hydrides, such as boranes (B2H6), aluminum chloride (AlCl3), and certain amines have also been observed to attack fluorocarbon resins at elevated temperatures.

Physical damage resulting from absorption of various chemicals into the walls of fabricated articles (particularly when combined with cycling temperatures), rapid changes in pressure, and mechanical abuse provide the most frequent cause of failure in articles fabricated from Everflon™ PFA fluoropolymer resins.

Table shows the performance in tensile testing and the weight gain of fabricated pieces of Everflon ™ PFA fluoropolymer resins after immersion in inorganic chemical media. There is usually no measurable effect of the common inorganic reagents on the tensile properties of Everflon™ PFA fluoropolymer resins; however, if there is, a measurable weight gain or loss is observed. Sulfuryl chloride presents a special case in which a "hybrid" compound is absorbed by fabricated forms to give low retention of properties. In none of the above cases are chemically degradative interactions observed.

Table also shows the change in tensile properties and the weight gained when fabricated forms of Everflon™ PFA fluoropolymer resins are subjected to typical organic liquids representing a range of classic compounds. Everflon™ PFA fluoropolymer resins resins have equivalent or better chemical resistance performance.

These data show that liquids that wet the resin will tend to give high weight gains and low retention of tensile strength, especially when heated to high temperatures.

Everflon™ PFA has excellent chemical resistance to other inorganic acid and bases and organic solvent. It should be noted, however, that Everflon™ PFA shares with PTFE and other fluororesins a propensity to react with alkali metals (metallic sodium) and flourine.

Chemical	Temp	Days	Number of cracked
Non chemical heat cycle		21	0/5
Toluene	100℃	7	0/5
Nitrobenzene	100℃	7	0/5
Acetophenone	100℃	7	0/5
Perchloroethylene	100℃	7	0/5
Sulfuryl chloride	23℃	7	0/5
Carbon tetrachloride	75℃	7	0/5

Effect of Chemical Immersion on Everflon™ PFA Series Fluoropolymer Resins (168 hr)

Chemical		Test Temperature °C	Test Temperature °F	% Retained Physicals Tensile	% Retained Physicals Elongation	% Weight Gain
Inorganic Chemicals						
Mineral Acid	Hydrochloric (Conc)	120	248	98	100	0.0
	Sulfuric (Conc)	120	248	95	98	0.0
	Hydrofluoric (60%)	23	73	99	99	0.0
	Fuming Sulfuric	23	73	95	96	0.0
Oxidizing Acids	Aqua Regia	120	248	99	100	0.0
	Chromic (50%)	120	248	93	97	0.0
	Nitric (Conc)	120	248	95	98	0.0
	Fuming Nitric	23	73	99	99	0.0
Inorganic Bases	Ammonium Hydroxide (Conc)	66	150	98	100	0.0
	Sodium Hydroxide (50%)	120	248	93	99	0.4
Peroxide	Hydrogen Peroxide (30%)	23	73	93	95	0.0
Halogens	Bromine	23	73	99	100	0.5
	Bromine	59	138	95	95	0.5
	Chlorine	120	248	92	100	0.5
Metal Salt Solutions	Ferric Chloride	100	212	93	98	0.0
	Zinc Chloride(25%)	100	212	96	100	0.0
Other Inorganics	Sulfuryl Chloride	69	156	83	100	2.7
	Chlorosulfonic Acid	151	304	91	100	0.7
	Phosphoric Acid(Conc)	100	212	93	100	0.0

Permeability

unit $\times 10^{-10} cm^3$ cm/sec cm^2 cmHg

	403	410	420
Oxygen	4.4	3.6	3.6
Nitrogen	1.5	1.4	1.6

Chemical		Test Temperature °C	Test Temperature °F	% Retained Physicals Tensile	% Retained Physicals Elongation	% Weight Gain
Organic Chemicals						
Acids/Anhydrides	Glacial Acetic Acid	118	244	95	100	0.4
	Acetic Anhydride	139	282	91	99	0.3
	Trichloracetic Acid	196	384	90	100	2.2
Hydrocarbons	Isooctane	99	210	94	100	0.7
	Naphtha	100	212	91	100	0.5
	Mineral Oil	180	356	87	95	0.0
	Toluene	110	230	88	100	0.7
Functional Aromatics	o-Cresol	191	376	92	96	0.2
	Nitrobenzene	210	410	90	100	0.7
Alcohol	Benzyl Alcohol	205	401	93	99	0.3
	Aniline	185	365	94	100	0.3
Amines	n-Butylamine	78	172	86	97	0.4
	Ethylenediamine	117	242	96	100	0.1
Ether	Tetrahydrofuran	66	151	88	100	0.7
	Benzaldehyde	179	355	90	99	0.5
Ketones Aldehydes	Cyclohexanone	156	312	92	100	0.4
	Methyl Ethyl Ketone	80	176	90	100	0.4
	Acetophenone	202	396	90	100	0.6
	Phosphoric Acid(Conc)	220	392	98	100	0.3
Esters	Dimethylphthalate	220	392	98	100	0.3
	n-Butylacetate	125	257	93	100	0.5
	Tri-n-Butyl Phosphate	200	392	91	100	2.0
Chlorinated Solvents	Methylene Chloride	40	104	94	100	0.8
	Perchloroethylene	121	250	86	100	2.0
	Carbon Tetrachloride	77	171	87	100	2.3
Polymer Solvents	Dimethylformamide	154	309	96	100	0.2
	Dimethylsulfoxide	189	372	95	100	0.1
	Dioxane	101	214	92	100	0.6

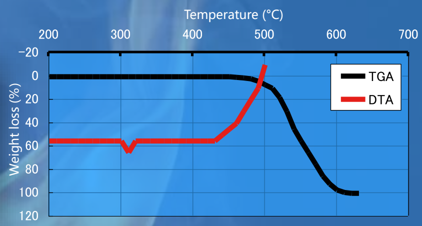
Thermal Properties

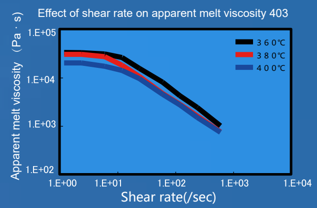
Thermal Decomposition

Up to around 400°C there is excellent thermal stability without weight loss. Moreover, at 700°C there was not decomposition residue.

Unit: (°C)

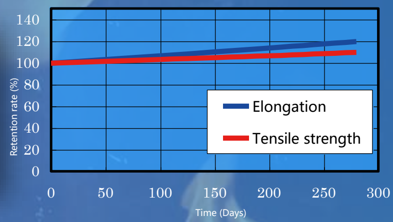
Grade	403	410	420
Initial weight loss	400	400	400
10% weight loss	510	510	510
50% weight loss	540	542	539

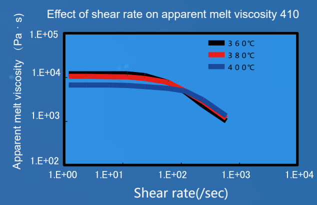




Heat Aging

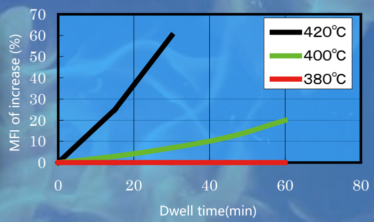
After being maintained at 280°C for 280 days, the tensile strength and elongation values were greater than the values obtained at the start of the experiment.

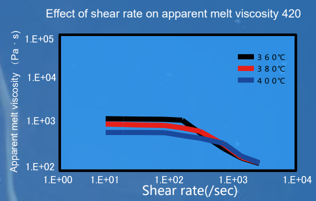




Thermal Stability

After being held at these temperatures, at the specified times, the MFR was evaluated. After being kept at 380°C for more than 1 hour, there is no change in the MFR of the resin.





Heat Distortion Temperature

The temperatures are those at which test pieces under loading, one under 0.45 MPa and the other under 1.81 MPa, showed bending of 0.254 mm as the temperature was increased at a rate of 2℃/min.

Heat distortion temperature (℃)

Loading	403	410	420
0.45MPa	91	92	93
1.81MPa	56	57	57

Vicat Softening Temperature

The values shown are the temperatures at which a needle, 1 mm in diameter and under a load of 1 kg, placed at the center of a test piece, penetrated 1 mm into the test piece as the temperature was increased at a rate of 50℃/h.

403	410	420
287℃	281℃	270℃

Linear thermal expansion coefficient

Temperature Range ℃	403	410	420
-100~-75	9	9	8
-75~-15	12	11	12
-15~100	14	14	15
100~150	16	16	17
150~210	21	21	21

Electrical Properties

Electrical applications include extruded coatings for numerous wire constructions, heater cables, heavy wall conduit, cable jacketing, and geophysical cables. Everflon™ PFA fluoropolymer resins are also injection molded into electrical switch components, connector inserts, insulating bushings, and standoff insulators.

Dielectric constant and dielectric tangent (ASTM D150)

The dielectric constant of Everflon™ PFA resins is less than 2.1 over a wide range of frequencies, temperatures, and densities.

The values for Everflon™ PFA fluoropolymer resins density vary only slightly (2.13–2.17), and the dielectric constant varies only about 0.03 units over this range—among the lowest of all solid materials. There is no measurable effect of humidity on the dielectric constant of Everflon™ PFA fluoropolymer resins.

Dielectric Strength

The dielectric strength (short-term) of all Everflon™ PFA fluoropolymer resins is 80 kV/mm (2,043 V/mil) when measured on 0.25-mm (10-mil) films by ASTM D149.

Thin films of FEP resin give similar results, while PTFE films are typically measured at 47 kV/mm (1,200 V/mil).

As with other fluoropolymer resins, Everflon™ PFA will lose dielectric strength in the presence of corona discharge.

Dissipation Factor

The dissipation factor of Everflon™ PFA fluoropolymer resins varies with frequency and temperature.The dissipation factor at low frequency (10^2–10^4 Hz) increases at higher temperatures. Little variation with temperature is seen in dissipation factor with frequencies in the range of 10^4–10^7 Hz. As frequencies increase to 10^{10} Hz, there is a steady increase in the dissipation factor. Increases are greatest when measured at room temperature. There is also an indication that a maximum exists at about 3 x 10^9 Hz. The fully fluorinated end groups found in Everflon™ PFA fluoropolymer resins result in lower dissipation factors at high frequencies. Everflon™ PFA fluoropolymer resins are preferred when considered for use as an electrical insulation material at high frequencies.

Electrical Resistivity

The volume and surface resistivities of fluoropolymer resins are high and unaffected by time or temperature.

Measurements of the volume resistivity of Everflon™ PFA fluoropolymer resins by the method outlined in ASTM D257 gave a value greater than 10^{18} ohm-cm. The surface resistivity was greater than 10^{18} ohm/sq.

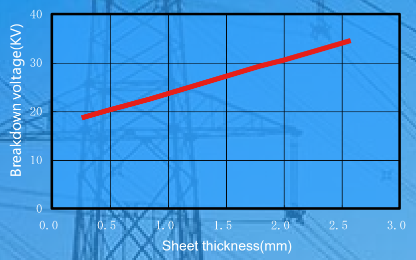
When Everflon™ PFA fluoropolymer resins were tested by the method described in ASTM D495 using stainless steel electrodes, no tracking was observed for the duration of the test (180 sec), indicating that the resin does not form a carbonized conducting path.

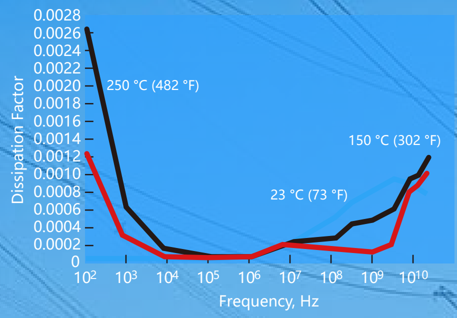
Effect of temperature on volume resistivity ASTM D257

Temperature (℃)	23	50	100
Volume resistivity (Ωcm)	$3*10^{17}$	$5*10^{17}$	$3*10^{17}$

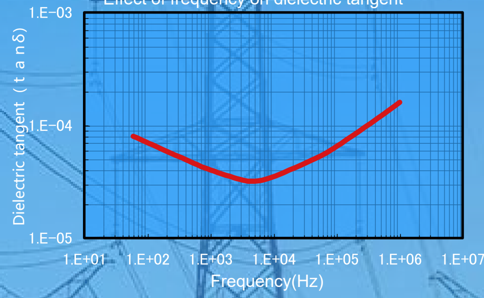
Insulation

Dependence of insulation breakdown voltage on material thickness.

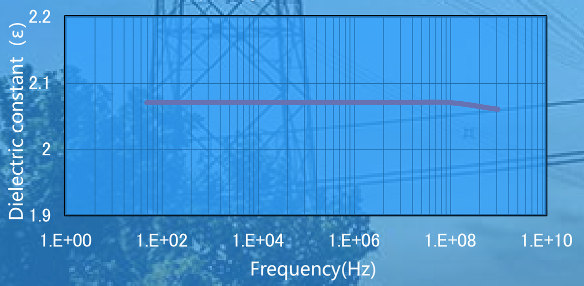




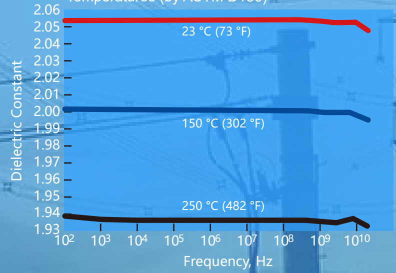
Effect of frequency on dielectric tangent



Effect of frequency on dielectric constant

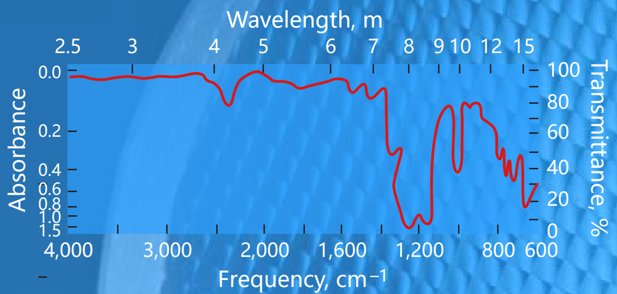


Dielectric Constant at Various Frequencies and Temperatures (by ASTM D150)



Optical Properties

In film form, Everflon™ PFA fluoropolymer resins have excellent optical properties with low haze as measured by ASTM methods. Specific values of percent transmission for given wavelengths are shown in Table. The refaractive index of film made from Everflon ™ PFA fluoropolymer resins is measured at 546 nm wavelength (green light) and room temperature. An infrared spectrum of Everflon™ PFA fluoropolymer resins is presented in Figure. This “fingerprint” is often useful for identifying the resin among other fluorocarbon polymers.



Property	Test Method	Value
Refractive Index	ASTM D542-50	1.350
Haze	ASTM D1003-52	4%
Light Transmission		
UV(0.25-0.40um)	(Cary Model 14) Spectrophotometer, 100-gauge (0.025-mm) film thickness	77–91%
Visibel(0.40-0.70um)		91–96%
Infrared(0.70-2.4um)		96–98%

Weathering

Everflon™ PFA fluoropolymer resins are extremely hydrophobic and shed water almost totally. A moisture absorption of <0.03% has been reported after 24 hr in water at room temperature, followed by 2 hr in boiling water. They are also virtually unaffected by oxygen, ozone, and visible or UV light. Test samples, exposed for many years to practically all climatic conditions, have shown that Everflon™ PFA fluoropolymer resins are fully weather-resistant. There were no significant changes in tensile properties, specific gravity, or melt flow rate after this exposure. Results show neither aging nor embrittlement. Because no plasticizers, antioxidants, or other additives are used during its processing, there is no leaching out of substances.

Radiation resistance

If Everflon™ PFA is exposed to a large amount of radiation, because it is a perfluororesin, the principal chain in the copolymer structure is liable to breakage, which reduces tensile strength and tensile elongation.

Fabrication Guide

Extrusion

Everflon™ PFA fluoropolymers are suitable for extrusion using techniques normally applied for other thermo-processable plastics, provided that the extruder is equipped with corrosion resistant alloys. Extruders with L/D ratio of 20 : 1 to 30 : 1 are recommended. Extruders should be equipped with independently controlled heaters capable of accurate temperature control up to 450 °C (840 °F). Many different screw designs can be used. Single flight screws are recommended while barrier-flights should be avoided. A typical screw design consist of a long feed section (at least 12 flights), followed by a 2 to 6 flight transition and a 5 to 7 flight metering section. Breaker plate and screen pack are not normally used even when using color master batches.

An overview of the temperature, tooling and equipment requirements for cable extrusion is given in Table.

Temperatures set must be chosen and tuned according to the extruder size and to the maximum achievable flow rate. In general, the higher the flow rate, the higher the temperature profile must be and the shorter the extruder length, the higher the temperature profile. It is worthwhile noting that the most effective temperature for changing the melt temperature and thus the pressure at the die and the line speed is the temperature in the metering zone.

The practical maximum line speed achievable with Everflon™ PFA resins is limited by the appearance of the melt fracture or draw resonance (in tubing extrusion melt fracture usually appears first on the inside surface of the cone). This phenomenon can be reduced by increasing the temperature in the die until blisters or thermal degradation effects occur. A small reduction of the melt fracture can be obtained also by heating of the inner tip. The critical shear rate of the polymer can be considered a good parameter in order to predict the maximum extrusion speed. The higher this value is, the higher the achievable line speed.

For example at the temperature of 372 °C, Everflon™ PFA 410 has a critical shear rate in the range of 50 to 70 sec-1 while the Everflon™ PFA 403 value is in the 10 to 15 sec-1 range.

	[°C]
Z1 (rear barrel)	250
Z2	320
Z3	355
Z4	360
Z5 (front barrel)	380
Flange	380
Adapter	380
Crosshead	380
Die	400

Melt temperature 390-400

Grade	Wall Thickness	DDR
Everflon PFA 403	0.80-1.20 mm	50-25
	1.20-2.00 mm	25-5
Everflon PFA 410	0.10-0.25 mm	250-100
	0.25-0.45 mm	100-50

The DRB must be kept close to 1

$$DDR = \frac{D^2_{die} - D^2_{tip}}{d^2_{wire} - d^2_{copper}}$$

$$DRB = \frac{D_{die}/D_{tip}}{d_{wire}/d_{copper}}$$

	Value
Cable diameter	6 mm
Wall thickness	0.25 mm
Draw down ratio	25
Draw ratio balance	1
Wire preheating	–
Screw rate	5 rpm
Pressure	40 bar
Water gap	200-400mm
Line speed	5 m/min

Screw Diameter = 35 mm, L/D = 25

	Value
Cable diameter	1.5 mm
Wall thickness	0.25 mm
Draw down ratio	110
Draw ratio balance	1
Wire preheating	180 °C
Screw rate	20 rpm
Pressure	21 bar
Water gap	200-400mm
Line speed	61 m/min

Screw Diameter = 35 mm, L/D = 25

Fabrication Guide
Molding

Transfer Molding

Everflon™ PFA can be used to produce lined items by transfer molding. This technique basically consists of the following steps:
- Melting and plasticizing
- Injection in a hot mold
- Packing and cooling

Typical transfer molding resins are the low MFI grades, such as Everflon™ PFA 403 .

The mold temperature is customarily set above the resin melting point as opposed to injection molding where the mold is kept at a much lower temperature. The best results are normally achieved using slow injection speeds and by applying a certain hold time before cooling. A quick cooling is then recommended.

Operating conditions must be optimized for every single application. For example low melt temperatures are recommended for large items or when the resin is melted and plasticized in an oven. High melt temperatures are recommended for thin parts or when melting and plasticizing is carried out by an extruder.

Compression Molding

Everflon™ PFA can be molded by compression to obtain semi-finished items such as sheets, rods and film. The most suitable molding conditions must be selected according to the specific process and the shape of the final item. In all cases the molding temperature will be in the range of 340 – 380 °C

Fabrication Guide

Injection Molding

Everflon™ PFA can be injection molded following the same processes used for normal thermoplastic resins. The low viscosity grades are particularly designed for injection molding of complex shapes.

It is recommended to use three independently controlled heater zones for the barrel and one for the adaptor. The heater controllers must be capable of accurate temperature control up to 450 °C.

Reciprocating screw equipment is recommended to assure proper plasticating and reduce polymer stagnation and thermal degradation. The screw should have a short transition section, a constant pitch and a flight depth ratio from the feed section to metering section of about 3 : 1.

Conventional type reverse tapered nozzle is recommended. The bore should be as large as possible and tapered to prevent dead spots or rapid changes in resin velocity. The non-return valve prevents the molten resin from flowing backward along the screw flights during the injection process.

Mold temperature should be set not lower than 180 °C (355 °F) to reduce delamination in the part. Optimization of mold temperature must take into account part thickness to minimize shrinkage, surface appearance and total cycle times.
Injection pressure should be set as low as possible, depending on the item to be molded. In general, low injection pressures reduce warpage thus resulting in improved dimensional stability. Injection pressure has to be set in function of the molded item, its thickness and the presence of weld lines. In most cases a hold pressure should be applied to reduce shrinkage and voids. Injection speed should be set moderately slow, thus resulting in good surface appearance without roughness.

Conversely, too low injection speeds must be avoided because they negatively affect the filling stage. Generally low rotational speeds are required, even if moderately low back pressure could result in better homogenization without unmelted particles. Increasing back pressure should be carefully checked to avoid increasing the melt temperature.

Temperature profile along the injection cylinder should be increased from the rear zone to the nozzle as reported hereinafter to avoid thermal degradation. Melt temperature should not be higher than 400 °C (750 °F) and hold-up or residence time must be obviously reduced if operating at the highest temperatures.

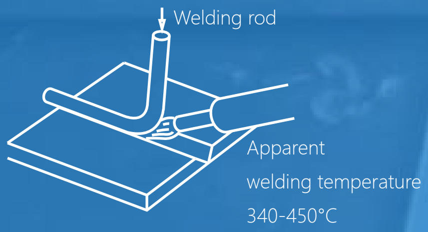
Typical molding conditions for Everflon™ PFA

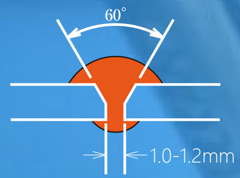
	Units	410	420
Z1	°C	300	320
Z2	°C	325	345
Z3	°C	335	355
Z4	°C	340	360
Nozzle	°C	360	380
Melt temperature	°C	380	380
Mold temperature	°C	200–240	200–240
Injection pressure	kg/cm^2 (psi)	270 (3,850)	345 (4,900)
Pack pressure	kg/cm^2(psi)	270 (3,850)	345 (4,900)
Screw velocity	cm/s (mil/s)	0.2 (80)	0.2 (80)
Screw rotation	rpm	21	21
Cycle time	s	100	100

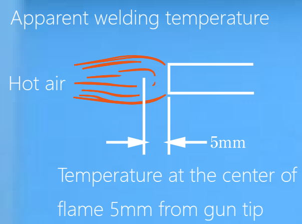
Mold dimensions: 102 mm disk, 3 mm thick

Fabrication Guide

Welding







Everflon™ PFA are thermoplastic materials that can be welded using the standard techniques known for common plastics, for example PE or PVC. In particular, hot gas welding is routinely used to thermoweld Everflon™ PFA liners. Tensile tests performed on the welded seams have proven that fusions are as 100 % reliable as the original material. The following general recommendations will apply when hot gas welding Everflon™ PFA liners.

Equipment

Use welding guns capable of good temperature control up to 650 °C (1,200 °F) and with heating power of 900 – 1,000 W or higher. Proper temperature measurement is crucial to ensure consistent welds. It is good practice to measure the temperature of the gas stream inside the nozzle, at 5 – 7 mm (1/4”) from the outlet.
If air is used for the welding, ensure that it is clean and dry. Different welding tips are available. High speed welding tips are used for the primary weld, while tacking tips can be used to hold in place the various sections of the liner.

Welding

Use round welding rods made of the sameEverflon™ PFA grade of the profiles to be welded. Welding together profiles made from different grades is not recommended.

Carefully scrape the surfaces to be welded. When using fabric backed sheets, remove the fabric along the welding line (2 – 3 mm on each sheet) to prevent fiber inclusions. Align and hold the two sheets to be welded at a distance not larger than 0.5 – 1 mm.

V-shape the groove between the two sheets using the appropriate scraper. Avoid the use of makeshift tools as it could result in an irregular weld bead. Thoroughly clean the welding area and the welding rod.
Clean the nozzle of the welding gun with a brass brush, adjust the air flow at 50 – 60 standard liters/minute, and set the temperature of the welding gun as indicated in table below.

Weld holding the gun at a 45 – 60 ° angle and adjust the welding pressure and speed ensuring that the welding rod and the sheets melt simultaneously. Welding speeds in the 5 – 30 cm/min (2 – 12 in/min) range are usually suitable.
If the speed is too low, the welding rod will overheat and might break; on the other hand, if the speed is too high, the welding rod will not melt properly and the groove between the two sheets will not be duly filled by the molten material. Similarly, if the welding pressure is too low, the groove between the two sheets will not be completely filled, while an excessive force may cause dimples along the welding bead which will eventually act as stress concentrators.

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