EVERFLON™ ETFE

Properties Handbook

Ethylene-Tetrafluoroethylene Copolymer

EVERFLON ACADEMIC

Introduction

Everflon™ ETFE is a thermoplastic fluoropolymer developed by C&F Group. It is a copolymer comprised of tetrafluoroethylene (C_2F_4) and ethylene (C_2H_4)

Everflon™ ETFE fluoropolymers are melt-processibl thermoplastics. They are part of the family of fluorinebased products that includes Everflo™ PTFE, FEP, and PFA fluoropolymer resins.

This handbook presents data for engineers and others involved in materials selection and product design. It contains detailed information for the evaluation of Everflon™ ETFE in electrical, mechanical, and chemical applications.

All properties presented in this handbook should be considered as typical values and are not to be used for specification purposes.
A variety of natural and reinforced compositions is available, permitting the selection of resins based on specific applications or processing needs.

For additional technical data, information about the current line of Everflon™ ETFE grades, or design assistance for a particular application, please contact your sales representative.

Commercially Available Everflon™ ETFE Fluoropolymers

Everflon™ETFE Grade	Resin Characteristics	Applications
4003	Premium fluoropolymer resin with a relatively low flow rate, greatly enhanced flex life, and resistance to environmental stress	Components, linings, and molded parts for use in unusually extreme thermal, mechanical, and chemical environments
4010	General-purpose fluoropolymer resin with intermediate flow rate. recommended upper service temperature is 150 °C (302 °F)	Electrical sleeving, coil forms, sockets, connectors, and switches
4020	Superior stress crack resistance with superior mechanical properties at high temperatures Highest MFR among ETFE resins	Components, linings, and molded parts for use in unusually extreme thermal, mechanical, and chemical environments
4030	Highest MFR among ETFE resins	Ideal for injection molding and thin wall extrusion
C-4003	Static dissipating semi-conductive resin with low MFR	• Extruded tubing, pipe, and other profiles for hose • Linings of components used in chemical processing industries • Industrial film • Injection- and blow-molded articles requiring superior electrical, chemical, and thermal properties and stress crack resistance
C-4010	Static dissipating semi-conductive resin	• Extruded tubing, pipe, and other profiles for hose • Injection- and blow-molded articles requiring superior electrical, • chemical, and thermal properties
JP-40	Powder for specialty applications	Ideal for when materials must be dispersed in an ETFE matrix. Materials can be well dispersed in the powder and then either compression molded or melt mixed for additional processing.
GS-40	Roto-molding and roto-lining grade	• Hollow parts • Complex geometries • Lining
X-40	Cross linkable ETFE Resin	Radiographic Crosslinking Wire

The ASTM material specification covering Everflon™ ETFE is D3159.

Everflon™ ETFE is also called out in various industrial and military specifications for tubing, molded parts, and film, as well as numerous wire and cable applications.

General Properties of Everflon™ ETFE Fluoropolymers

Everflon™ ETFE can best be described as a rugged thermoplastic with an outstanding balance of properties. Mechanically, it is tough and has medium stiffness (1,170 MPa [170,000 psi]), impact, and abrasion resistance. Flex life depends upon the grade used.

Everflon™ ETFE is typically considered to have a no-load continuous use temperature of 150 °C (302 °F). In certain specific applications, Everflon™ ETFE can have an upper service temperature in excess of 230 °C (392 °F). See “Thermal Properties” section for a more complete discussion of thermal rating.

Everflon™ ETFE is weather-resistant, inert to most solvents and chemicals, and hydrolytically stable. It has excellent resistance to radiation, but is not immune to damage by long-term exposure to gamma radiation—especially at elevated temperatures. Where specific radiation requirements must be met, adequate testing of the proposed application in the radiation environment must be carried out to establish the suitability of Everflon™ ETFE for this application.

Electrically, Everflon™ ETFE is an excellent low-loss dielectric with a uniformity of electrical properties not normally found with other thermoplastics.

Everflon™ ETFE can be extruded or injection-molded easily, using conventional techniques, and, thus, presents no unusual operator training problems. Corrosion-resistant equipment is recommended for extended production runs. Electrically heated dies are recommended for injection molds.

Everflon™ ETFE can perform successfully in applications where other materials are lacking in mechanical toughness, broad thermal capability, ability to meet severe environmental conditions, or limited by fabricating problems.

As is the case with all new developments, a thorough prototype and test program is recommended to ensure successful performance of Everflon™ ETFE compositions in specific applications.

Property	ASTM Method	Unit	Everflon™ ETFE
Mechanical			
Melt Flow Rate	D3159	g/10 min	2-40
Ultimate Tensile Strength,23 °C (73 °F)	D638	MPa (psi)	46 (6,500)
Ultimate Elogation,23 °C (73 °F)	D638	%	300
Compressive Strength,23 °C (73 °F)	D695	MPa (psi)	17 (2,500)
Flexural Modulus	D790	MPa (psi)	600–1,200 (85,000–170,000)
Impact Strength,23 °C (73 °F)	D256	J/m (ft·lb/in)	No Break
Hardness, Durometer, Shore D	D2240		67
Coefficient of Friction, Metal/Film	D1894		0.23
Deforrmation Under Load,23 °C (73 °F),1,000 psi, 24 hr	D621	%	0.3
Linear Coefficient of Expansion	E831	mm/mm· °Cx10^{-5} (in/in· °Fx10^{-5})	
0-100°C(32-212°F)			13.1 (7.3)
100-150°C(212-302°F)			18.5 (10.3)
150-200°C(302-392°F)			25.2 (14)
Specific Gravity	D792		1.71
Water Absorption, 24 hr	D570	%	0.007
Electrical			
Surface Resistivity	D257	ohm·sq	>10^{16}
Volume Resistivity	D257	ohm·cm	>10^{16}
Dielectric Strength, 23 °C (73 °F)	D149	kV/mm (V/mil)	
0.25 mm (10 mil)			64 (1,600)
3.20 mm (126 mil)			15 (370)
Dielectric Constant, 22 °C (72 °F), 1 MHz	D1531		2.6
Dissipation Factor, 22 °C (72 °F), 1 MHz	D1531		0.007
Arc Resistance	D495	sec	122
Thermal			
Melting Point	DSC D3417	°C (°F)	220–280 (428–536)
Heat of Fusion	DSC D3417	kJ/kg (Btu/lb)	50.7 (21.8)
Specific Heat	DSC	kJ/kg·K (cal/g·°C)	
25 °C (77 °F)			0.25
100 °C (212 °F)			0.3
150 °C (302 °F)			0.34
300 °C (572 °F) (Melt)			0.38
Heat of Combustion	D240	MJ/kg (Btu/lb)	13.7 (5,900)
Thermal Conductivity		W/m·K (Btu·in/hr·ft2·°F)	0.24 (1.65)
Limiting Oxygen Index (LOI)	D2863	%	30-32
Heat Deflection Temperature	D648	°C (°F)	
455 kPa (66 psi)			81 (177)
1620 kPa (264 psi)			51 (123)
Continuous Service Temperature		°C (°F)	150 (302)

Mechanical Properties

Strength and Stiffness

Everflon™ ETFE is less dense, tougher, stiffer, and exhibits a higher tensile strength and creep resistance than Everflon™ PTFE and Everflon™ FEP fluoropolymer resins. It is, however, similarly ductile. Everflon™ ETFE compositions display the relatively nonlinear stress-strain relationships characteristic of nearly all ductile materials.

Impact Strength

As a method of evaluating the impact strength of plastics, the Izod impact test, ASTM D256, or the Charpy impact test is used. Everflon™ ETFE has an extremely large capacity for absorbing impact energy, and maintains excellent impact resistance over a wide range of temperatures even in impact tests with a notch.

Friction and Wear Properties

The coefficients for determining the friction and wear properties vary depending on the methods and conditions chosen. Thus, it is necessary to carry out a comparative test that suits the desired application. The critical PV value of Everflon™ ETFE is about 2.0 (kg·m/ crri ·sec)

Everflon™ ETFE is also significantly resistant against low temperature impact, and as apparent from the results shown in Figure , no impact breakage occurs down to -80°C. Destruction begins around -l00°C and the energy required for breakage in the range of -120°C to -200°C is about constant. The fragility point according to ASTM D746 is -125°C, which suggests that the glass transitiontemperature of the noncrystalline portion of Everflon™ ETFE exists around this range.

Effect of Temperature on Tensile Elongation
Effect of Temperature on Charpy Impact
Impact Strength(ft.lb/in with notech, 25°C)
ETFE
PVDF
PCTFE
PTFE
FEP
Polyacetal
Polycarbonate
Polyethylene
No breakage
No Breakage
Effect of Temperature on Tensile Strength
Dependence of Compression Creep Characteristics on Load
Compression Stress Relaxation
Everflon™ ETFE
Compression Stress-Strain Curve
Dynamic Friction Coefficient and PV Value
Wear Constant and PV Value
Tensile Strength vs. Temperature
Elongation vs. Temperature
Compression Stress-Residual Strain Curve
Tensile Modulus vs. Temperature
Temperature (°C)
Time(hr)
Strain(%)
Residual Strain (%)
PV Value(kg.m/cm².sec)
Data Hub

Mechanical Properties of Various Plastic

	ETFE	PTFE	PFA	ECTFE	PVDF	PE	PVC	Nylone6	Polyacetal
Specific Gravity	1.75	2.2	2.15	2.17	1.75	0.95	1.4	1.1	1.42
Tensile Strength(MPa)	40-54	20-39	32-39	19-22	49-60	10-44	40-70	50-80	60-70
Elongation(%)	350-450	230-600	340-400	250-330	200-300	20-700	2-40	60	16
Tensile Modulus(MPa)	500-800	400	---	670	800-1400	---	2500-4000	2700	3000-4500
Flexural Modulus(MPa)	850-1000	400-600	530-630	350	1400-1800	500-1000	2500-2800	1000-2800	2600-2900
Flexural Strength(MPa)	20-30	13	---	No Breakage	---	11-110	70-110	56-110	100
Compressive Modulus(MPa)	670	410	---	430	1300	---	---	---	4600
Rockwell Hardness	R55	R20	R50	R25	R110	D50-70	M5-120	R100-120	R120
Izod Impact Strength(ft/lb.in, with notch)	No Breakage	3.0	No Breakage	---	3.5-3.8	0.5-20	0.5-20	1-3.5	1-4
Frictional Coefficent(against SUS)	0.20	0.09	0.20	0.20	0.21	0.35	0.45	0.15-0.40	0.14

Chemical Properties

Chemical Stress Crack

Some polymer materials form cracks when placed under stress in chemicals over a long period of time. The Table shows the results of testing method ASTM D 1693, where a narrow strip of plastic sheet, 2.3 mm thick and 38 mm long, was bent 180° and soaked in chemicals for 10 days. The sheet was then examined for crack formation. The Everflon™ ETFE has good adaptability in chemical stress.

Chemical Resistance

Everflon™ ETFE has outstanding resistance to attack by chemicals and solvents that often cause rapid deterioration of other plastic materials. It is surpassed only by Everflon™ fluoropolymers in resistance to chemicals.

Everflon™ ETFE is inert to many strong mineral acids, inorganic bases, halogens, and metal salt solutions. Carboxylic acids, anhydrides, aromatic and aliphatic hydrocarbons, alcohols, aldehydes, ketones, ethers, esters, chlorocarbons, and classic polymer solvents have little effect on Everflon™ ETFE. Under highly stressed conditions, some very low surface tension solvents tend to reduce the stress-crack resistance of the lower molecular weight products. Very strong oxidizing acids such as nitric, organic bases such as amines, and sulfonic acids at high concentrations and near their boiling points will affect Everflon™ ETFE to varying degrees.

Effects of Radiation

Everflon™ ETFE is much more resistant to electron beam and gamma radiation than other fluoropolymers. Tests have shown that both elevated temperatures and the presence of oxygen have a deleterious effect on physical properties when Everflon ™ ETFE is exposed to gamma radiation. The effect on physical properties is significantly decreased in an inert atmosphere, such as nitrogen.

Everflon™ ETFE appears to be degraded much less with electron beam radiation than with gamma radiation at equivalent levels of total exposure. The difference is probably due to the much higher dosage rate under electron beam conditions. The higher dosage rate apparently allows cross-linking reactions to predominate, while the much slower rate under gamma radiation apparently allows competing oxidation and degradation reactions to predominate. Controlled exposure to low levels of electron beam radiation, especially in inert atmospheres, appears to result in a low level of cross-linking with an inherent improvement in some properties. However, exposure beyond the low level controlled conditions results in detrimental effects on physical properties. As with gamma radiation, oxidation reactions are inhibited under inert atmospheres.

Hydrolytic Stability and Water Absorption

Hydrolytic stability is indicated by lack of deterioration in physical properties after long periods of exposure to boiling water. Using room temperature tensile strength and elongation as control properties, Everflon™ ETFE is essentially unaffected after 3,000 hr exposure to boiling water. Data are shown in Table. Water absorption for unfilled Everflon™ ETFE is less than 0.03% by weight as determined by ASTM D570

40 145

135

Hot Water Resistance

The water absorption of Everflon™ ETFE was measured according to test methods ASTM D570, where a sheet, 6 mm in thickness, is soaked in boiling water for 2 hours. The water absorption is found to be extremely small, thus, indicating that the electrical and mechanical properties are not affected by the presence of moisture.

Table shows the change in strength of Everflon™ ETFE, measured at room temperature after soaking a Imm thick sheet in boiling water for a given amount of time.As the chemical resistance data suggests, Everflon™ ETFE shows excellent resistance to hot water too.

Product	Tensile Strength psi	Tensile Strength Mpa	Elongation, %
4010 (No exposure)	5800	40	400
3,000 hr Boiling Water	5800	40	390

Gas Permeation and Moisture Permeation

The permeation of oxygen, nitrogen, carbon dioxide, etc., are approximately constant regardless of film thickness. The activation energy is 6-8 kcal/mol.

The gas permeation and moisture permeation of EverflonTM ETFE are similar to those of polyethylene or polypropylene. Gas permeability was obtained by ASTM D1434, moisture permeability by the cup method of ASTM E96

Material	Permeability, $cm^3/100\ in^2 24\ hr \cdot atm/mil$
Carbon Dioxide	250
Nitrogen	30
Oxygen	400

Flame Resistance and Smoke

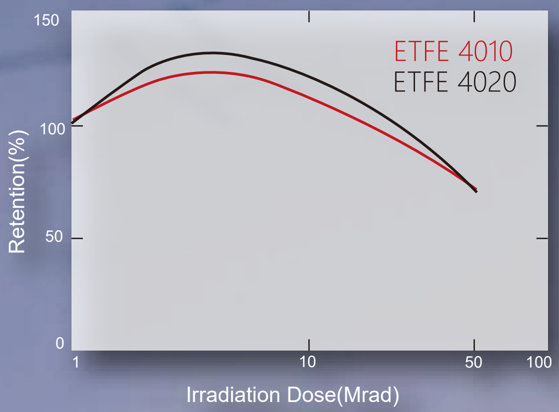
Everflon™ ETFE is rated UL 94 V-0 for unpigmented resins down to 0.062 in thick. Its limiting oxygen index (LOI) is 30 by ASTM D2863, which means that an atmosphere containing at least 30% oxygen is required to maintain combustion in a downward burning flame. By ASTM D635, Everflon™ ETFE has an average time of burning (ATB) of less than 5 sec and an average length of burn (ALB) of 10 mm (0.39 in).

Loss of Weight with Aging

The weight loss of Everflon™ ETFE below the melting point is from 0.1 to 0.3%, most of which is moisture.

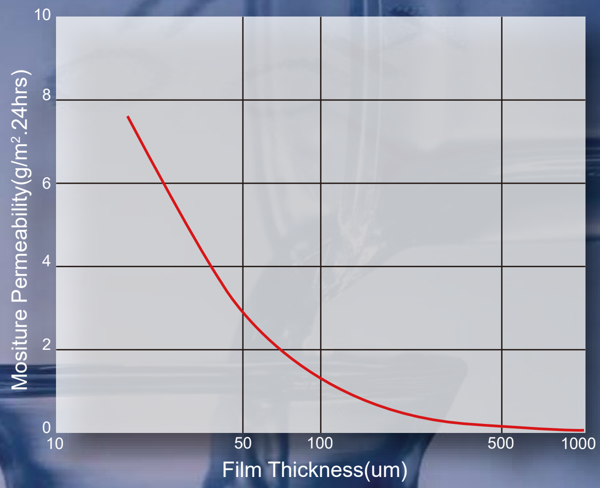
Weatherability

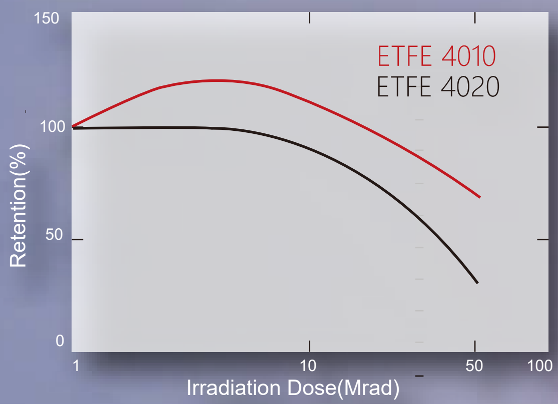
Everflon™ ETFE shows good weatherability, and "Techyours™ ETFE Film", a film obtained by extrusion molding, will not change in properties even when used outdoors as a coating material.



Change in Tensile Strength

Effect of Film Thickness on Moisture Permeability





Change in Tensile Elongation

4010

Data Hub

Chemical Stress Crack of Everflon™ ETFE

Chemical	Temperature ˚C	No. of cracked pieces ETFE 4010	No. of cracked pieces ETFE 4020
Nitrobenzene	121	0/5	0/5
Aniline	121	0/5	0/5
Benzaldehyde	121	0/5	0/5
Chlorobenzene	121	0/5	0/5
Ethylenediamine	117	0/5	0/5
Dimethylformamide	121	0/5	0/5
Dimethylsulfoxide	121	0/5	0/5
Dimethylacetamide	121	0/5	0/5
Nitric acid 60%	121	0/5	0/5

Weatherability of Everflon™ ETFE

Characteristics	15um ETFE Film			25um ETFE Film		
Exposure Time (hrs)	0	1000	2000	0	1000	2000
Tensile Strength(Mpa)	48	48	48	48	48	48
Tensile Retention(%)	-	102	102	-	102	102
Elongation(%)	340	390	390	340	390	390
Modulus Retention(%)	-	116	116	-	116	116
Tensile Modulus(Mpa)	780	800	800	780	800	800

Initial Weight Loss of Everflon™ ETFE Resins Above 300 °C (572 °F)

Temperature °C	Temperature °F	Everflon™ ETFE 4010 wt loss, %/hr
300	572	0.05
330	626	0.26
35	662	0.86
370	698	1.60

Actual Laboratory Tests on Chemical Compatibility of Everflon™ ETFE with Representative Chemicals

Chemical	Boiling Point °C	Boiling Point °F	Test Temperature °C	Test Temperature °F	Days	Retained Properties, % Tensile Strength	Retained Properties, % Elongation	Retained Properties, % Weight Gain
Acid/Anhydrides								
Acetic Acid (Glacial)	118	244	118	244	7	82	80	3.4
Acetic Anhydride	139	282	139	282	7	100	100	0
Trichloroacetic Acid	196	384	100	212	7	90	70	0
Aliphatic Hydrocarbons								
Mineral Oil	—	—	180	356	7	90	60	0
Naphtha	—	—	100	212	7	100	100	0.5
Aromatic Hydrocarbons								
Benzene	80	176	80	176	7	100	100	0
Toluene	110	230	110	230	7	—	—	—
Functional Aromatics								
o-Cresol	191	376	180	356	7	100	100	0
Amines								
Aniline	185	365	120	248	7	81	99	2.7
Aniline	185	365	120	248	30	93	82	—
Aniline	185	365	180	356	7	95	90	—
N-Methylaniline	195	383	120	248	7	85	95	—
N-Methylaniline	195	383	120	248	30	100	100	—
N, N-Dimethylaniline	190	374	120	248	7	82	97	—
n-Butylamine	78	172	78	172	7	71	73	4.4
Di-n-Butylamine	159	318	120	248	7	81	96	—
Di-n-Butylamine	159	318	120	248	30	100	100	—
Di-n-Butylamine	159	318	160	320	7	55	75	—
Tri-n-Butylamine	216	421	120	248	7	81	80	—
Tri-n-Butylamine	216	421	120	248	30	100	100	—
Pyridine	116	240	116	240	7	100	100	1.5
Chlorinated Solvents								
Carbon Tetrachloride	78	172	78	172	7	90	80	4.5
Chloroform	62	144	61	142	7	85	100	4.0
Dichloroethylene	77	170	32	90	7	95	100	2.8
Methylene Chloride	40	104	40	104	7	85	85	0
CFC-113	46	115	46	115	7	100	100	0.8
Ethers								
Tetrahydrofuran	66	151	66	151	7	86	93	3.5
Aldehyde/Ketones								
Acetone	56	132	56	132	7	80	83	4.1
Acetophenone	201	394	180	356	7	80	80	1.5
Cyclohexanone	156	312	156	312	7	90	85	0
Methyl Ethyl Ketone	80	176	80	176	7	100	100	0

Chemical	Boiling Point °C	Boiling Point °F	Test Temperature °C	Test Temperature °F	Days	Retained Properties, % Tensile Strength	Retained Properties, % Elongation	Retained Properties, % Weight Gain
Esters								
n-Butyl Acetate	127	260	127	260	7	80	60	0
Ethyl Acetate	77	170	77	170	7	85	60	0
Polymer Solvents								
Dimethylformamide	154	309	90	194	7	100	100	1.5
Dimethylformamide	154	309	120	248	7	76	92	5.5
Dimethylsulfoxide	189	373	90	194	7	95	90	1.5
Other Organics								
Benzyl Alcohol	205	401	120	248	7	97	90	—
Benzoyl Chloride	197	387	120	248	7	94	95	—
Other Organics (continued)								
Benzoyl Chloride	197	387	120	248	30	100	100	—
Decalin	190	374	120	248	7	89	95	—
Phthaloyl Chloride	276	529	120	248	30	100	100	—
Acids								
Hydrochloric (Conc)	106	223	23	73	7	100	90	0
Hydrochloric (Conc)	106	223	106	223	7	96	100	0.1
Hydrochloric (Conc)	125	257	125	257	7	100	100	—
Hydrochloric (Conc)	—	—	23	73	7	97	95	0.1
Sulfuric (Conc)	—	—	100	212	7	100	100	0
Sulfuric (Conc)	—	—	120	248	7	98	95	0
Sulfuric (Conc)	—	—	150	302	*	98	90	0
Aqua Regia	—	—	90	194	*	93	89	0.2
Nitric—25%	100	212	100	212	14	100	100	—
Nitric—50%	105	221	105	221	14	87	81	—
Nitric—70% (Conc)	120	248	23	73		100	100	0.5
Nitric—70% (Conc)	120	248	60	140	53	100	100	—
Nitric—70% (Conc)	120	248	120	248	2	72	91	—
Nitric—70% (Conc)	120	248	120	248	3	58	5	—
Nitric—70% (Conc)	120	248	120	248	7	0	0	—
Chromic	125	257	125	257	7	66	25	—
Phosphoric (Conc)	—	—	100	212	7	—	—	—
Phosphoric (Conc)	—	—	120	248	7	94	93	0
Halogens								
Bromine (Anhy)	59	138	23	73	7	90	90	1.2
Bromine (Anhy)	59	138	57	135	7	99	100	—
Bromine (Anhy)	59	138	57	135	30	94	93	3.4
Chlorine (Anhy)	—	—	120	248	7	85	84	7

Chemical	Boiling Point °C	Boiling Point °F	Test Temperature °C	Test Temperature °F	Days	Retained Properties, % Tensile Strength	Retained Properties, % Elongation	Retained Properties, % Weight Gain
Bases								
Ammonium Hydroxide	—	—	66	150	7	97	97	0
Potassium Hydroxide—20%	—	—	100	212	7	100	100	0
Sodium Hydroxide—20%	—	—	120	248	7	94	80	0.2
Peroxides								
Hydrogen Peroxide—30%	—	—	23	73	7	99	98	0
Salt-Metal Etchants								
Ferric Chloride—25%	104	220	100	212	7	95	95	0
Zinc Chloride—25%	104	220	100	212	7	100	100	0
Other Inorganics								
Sulfuryl Chloride	68	115	68	155	7	86	100	8
Phosphoric Trichloride	75	167	75	167	7	100	98	—
Phosphoric Oxychloride	104	220	104	220	7	100	100	—
Silicon Tetrachloride	60	140	60	140	7	100	100	—
Water	100	212	100	212	7	100	100	0
Miscellaneous								
Skydrol	—	—	149	300	7	100	95	3.0
Aerosafe	—	—	149	300	7	92	93	3.9
A-20 Stripper Solution	—	—	140	284	7	90	90	—

Thermal Properties

Everflon™ ETFE is typically considered to have a no load continuous use temperature of 150 °C (302 °F). This continuous use temperature rating is based on 10,000 hr aging tests that involve exposure of standard tensile test specimens and wire insulations to a series of elevated temperatures to determine the rate of change of various physical properties with time. Elongation and tensile strength are properties that change significantly with temperature exposure.

In practice, the upper service temperature of a material depends on the specific nature of the end-use application. According to Underwriters Laboratory, fixed property level and percent-of-unaged property level are two end-of-life criteria that appear to have the most significance in relation to end-use applications. Tables contain estimated upper service temperatures depending on different possible end-use requirements. These results are consistent with the information provided graphically in Figures. Actual upper service temperatures may differ from the results in the table, depending on such factors as aging under load, chemical exposure, support from substrate, etc. These upper service temperatures should be used as guidelines. End-use performance testing should be done to verify the acceptability of Everflon™ ETFE for each specific application.

One conventional definition of upper service temperature is the lowest temperature at which one of the key physical properties is diminished by one half after 20,000 hr. Everflon™ ETFE 4010 has a 20,000 hr half-life temperature of approximately 159 °C (318 °F). (For Everflon™ ETFE, elongation decreases faster than tensile strength; thus, the 20,000 hr half life for tensile strength is 176 °C [349 °F].)

Another definition of upper service temperature is the temperature at which the elongation drops to 50% after 20,000 exposure hr. The expected upper service temperature would be 175 °C (347 °F)

Thermal Decomposition

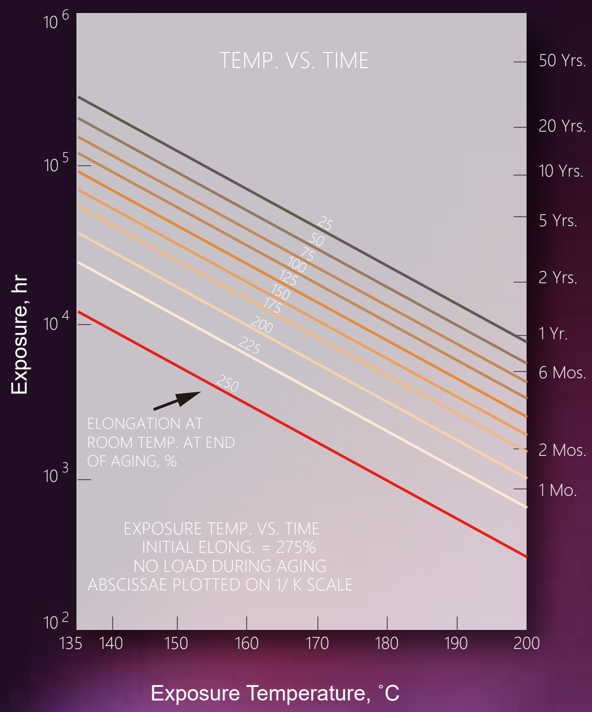
The termination temperature of weight-decrease, when the temperature is raised at the rate of l0°C is in the range of 350-360°C in air, and 390-400°C in nitrogen The activation energy of thermal decomposition is about 30 kcal/mol in air, and about 55 kcal/mol in nitrogen.

Therefore, at normal molding temperature, thermal decomposition does not occur. However, even around 300°C, if maintained for a long period of time, weight loss due to decomposition occurs. In such situation the gas generated by decomposition consists mostly of hydrogen fluoride.

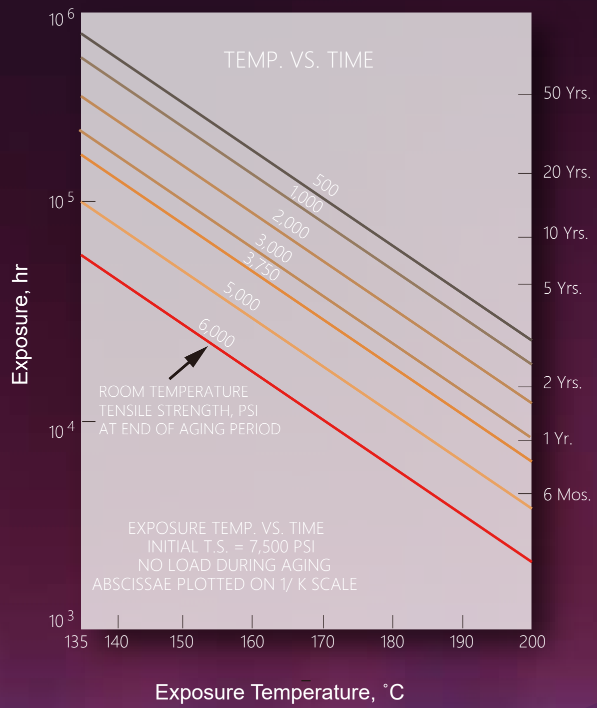
Flammability

Although Everflon™ ETFE has C_2H_4 units in the main chain, according to evaluations by UL standard subject 94, it has a 94V-0 flammability. Results of ASTM D 165 also show that it is noncombustible. Furthermore, the oxygen index based on ASTM D 2863 is 32%

Retention of Room Temperature Tensile Elongation After Aging—Everflon™ ETFE 4010



Retention of Room Temperature Tensile Strength After Aging—Everflon™ ETFE 4010



Data Hub

Estimated Upper Service Temperatures (°C), No Load Thermal Aging End-of-Life Criterion Based on Elongation and Exposure Time

End-of-Life Criterion		Exposure Time, hr					
Actual Elongation, %	Elongation Retained, %	1000	3000	10,000	20,000	50,000	100,000
135	50	210	195	172	159	143	132
50	18	**	211	188	175	158	147
25	9	**	**	196	182	165	153

Estimated Upper Service Temperatures (°C), No Load Thermal Aging End-of-Life Criterion Based on Tensile Strength and Exposure Time

End-of-Life Criterion		Exposure Time, hr			
Actual Tensile Strength	Tensile Strength Retained, %	10,000	20,000*	50,000*	100,000*
26 MPa (3,750 psi)	50	190	176	159	147
14 MPa (2,000 psi)	27	204	190	172	158

Heat Distortion Temperature of Fluoroplastic

Heat Distrition Temperature'C	Everflon™ ETFE	Everflon™ PTFE	Everflon™ FEP	Everflon™ PFA	Everflon™ PVDF
4.6 kg/ cm2	80	120	70	70	150
18.5 kg/ cm2	50	50	50	50	90

Linear Thermal Expansion Coefficient of Fluoroplastic

Linear Thermal Expansion Coefficient	Everflon™ ETFE	Everflon™ PTFE	Everflon™ FEP	Everflon™ PFA	Everflon™ PVDF
4.6 kg/ cm2	9~14	9~11	8~11	11~13	3~6

Electrical Properties

Arc Resistance

The arc resistance of Everflon™ ETFE measured according to ASTM D495 is 120 seconds. It has been reported to be 300 seconds or higher for PTFE and 170 seconds or higher for FEP. This high value is said to be due to the fact that the polymer decomposed by the arc is dispersed in the form of low-molecular-weight fluoro-carbon, and conductive materials such as carbon do not remain in the polymer.

Insulation

The insulation resistance is generally represented by the volume specific resistance, which indicates the degree by which the polymer, as an insulator, resists the flow of electric current through itself.

The larger this value, the better the polymer is as an insulator. With respect to the insulation breakdown voltage, another important characteristic of insulation materials, Everflon™ ETFE proves to be an excellent material. The insulation break-down voltage depends on the thickness of the sample.

The results of the effect of film thickness on the break-down voltage, and indicates that the break-down voltage is proportional to 0.65 power of the thickness up to 100μm.

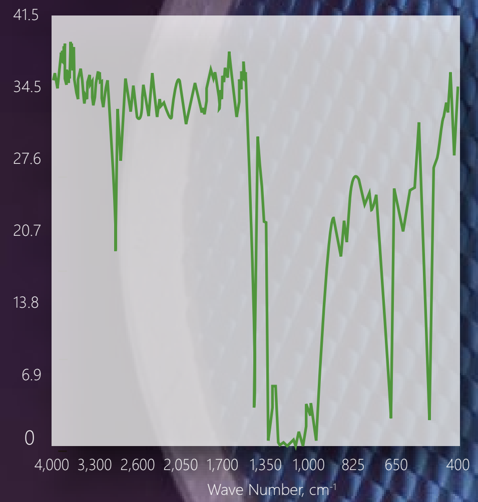
Among the electrical properties of polymers, the most important ones are the insulation and dielectric properties. In the high-frequency range, electrical energy is converted to thermal energy by the dielectric effect, causing the loss of electrical energy. Everflon™ ETFE exhibits high resistivity and low losses.

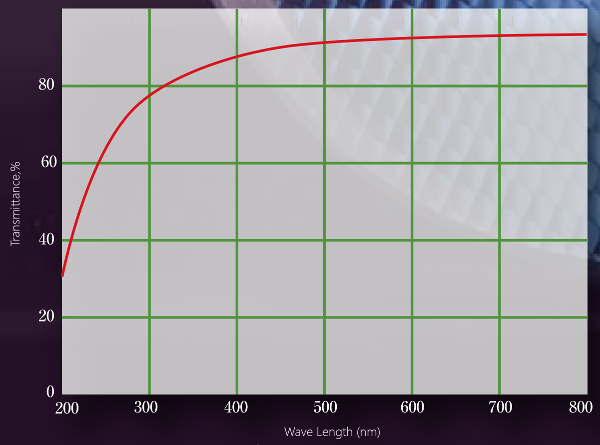
Everflon™ ETFE has a dielectric constant of 2.5–2.6 at frequencies below 10 MHz. At higher frequencies, the value decreases to approximately 2.3 at 10 GHz. The dissipation factor is below 0.001 at low frequencies, but gradually increases to a peak at about 0.023 at approximately 100 MHz—after which it decreases to below 0.01 at 10 GHz.


Effect of Frequency on Dielectric Constant
Effect of Frequency on Dielectric Tangent
Effect of Frequency on Dielectric Constant
Effect of Temperature on Dielectric Tangent
Everflon™ ETFE Dielectric Constant
Everflon™ ETFE Dissipation Factor
Everflon™ ETFE Dielectric Constant
Everflon™ ETFE Dissipation Factor
Everflon™ Dielectric Breakdown Strength
Temperature Dependence of Volume Specific Resistance
Temperature Dependence of Insulation Break-down Voltage
Dependence of Insulation break-down Voltage
Effect of Temperature on Cut-through Resistance
Data Hub

Optical Properties

Infrared Scan of Everflon™ ETFE





Light Transmittance 50um

Transmittance vs. Wavelength Data
Normalized to 0.025 mm (1.0 mil) Films

Wavelength, nm	Cathay ETFE Film Transmittance, %
Ultraviolet Range	
200	91.5
250	92
300	92
350	93
400	94
Visible Range	
500	
94	
600	94
700	95
800	95

Typical Applications

No other plastic resin comes as close to fluoropolymers in chemical and electrical properties while providing a high level of mechanical ruggedness and easy, economical processing. Everflon™ ETFE allows a range of opportunities for design engineers to achieve better product performance in many application areas.

Cable and hydraulic line clamps, cable straps, and other fasteners molded of Everflon™ ETFE perform in high temperature, corrosive environments. Nuclear applications are possible because of the radiation resistance of Everflon™ ETFE. Moisture absorption is low, providing uniformity of mechanical properties regardless of humidity. High impact strength and UV resistance are additional advantages.

Outstanding electrical properties, solvent resistance, an SE-O flammability rating, and excellent high temperature aging characteristics make Everflon™ ETFE an ideal material for high performance electrical components. Coil forms, connectors, encapsulated parts, sockets, and insulators are typical applications.

Tough insulation of Everflon™ ETFE is being used on conductors ranging from AWG #30 for wrapped computer terminations to 535 MCM for heavy power circuits. Everflon™ ETFE is performing well on steel mill cables, airframe wire, down-hole oil well logging cable, rapid transit car and locomotive control wire, and other rugged service wire and cable. It is receiving special consideration for use in nuclear power plants and other areas where exposure to radiation may be encountered.

Heat-shrinkable, plain, and corrugated tubing is available in a wide range of thicknesses and diameters. It is being used at high temperatures as electrical insulation and in service with strong chemicals. Heat-shrinkable tubing conforms to electrical terminations, hose connections, and other components to insulate, guard against abrasion, and prevent corrosion.

High impact strength, chemical resistance, resistance to high heat sterilization, and ease of processing are properties needed for biomedical and labware applications. Oxygen respirator components, blood analyzer valves, evaporating dishes, and centrifuge tubes are examples.

Chemical resistance, dimensional stability, and structural strength make Everflon™ ETFE a candidate for pump impellers, vanes, gears, and bodies.

Film of Everflon™ ETFE can be heat sealed, thermoformed, welded, heat laminated, and coated to make pressure-sensitive tapes, flexible printed circuits, liquid pouches, and other constructions where strength, thermal resistance, and electrical integrity are required.

Eveflon™ ETFE has replaced other polymers and glass as a valve lining. The outstanding resistance of Eveflon™ ETFE to acids, bases, and solvents over a broad temperature range, combined with abrasion resistance and ease of processing, results in a durable and economical valve.

Fabrication Guide

Everflon™ ETFE, as a thermoplastic polymer, can be processed by most techniques applicable to this type of resin. Included are:

- Injection molding
- Compression molding
- Rotational molding
- Extrusion

Everflon™ ETFE can also be formed, machined, colored, and printed upon using techniques described in appropriate processing bulletins.

Fabrication Guide

Extrusion

Everflon™ ETFE can be molded by extrusion into small diameter(up to 10mm rods, tubes, pipes, and electric wire coating, and by using the T-die, or by inflation molding, into films. Blow molding and uniform profile mold extrusion molding are also possible. Standard molding conditions are shown bellow.

	Specification	Electric Wire Covering	Film	Tube
Extruder	Screw diam	40 mm	40 mm	35 mm
	Screw type	metering	metering	metering
	Screw L/D	25	22	22
	Screw comp ratio	2.6:1	2.8:1	2.5:1
	Screen	80,100,200 mesh 2 each	80,100,200 mesh 2 each	80,100,200 mesh 1 each
Die	Die i.d.	4.3 mm	Coat hanger type manifold die	13.5 mm
	Nipple o.d.	2.0 mm		12.1 mm
	Rand Length	20 mm	Lip spacing 0.2 mm	
Product		core: tin-plated soft coper wire	film thickness: 25 um	tube i.d.: 9 mm
		core diam:0.26 mm	film width: 400 mm	tube i.d.: 10 mm
		thickness:0.15 mm		thicknesss: 0.5mm
		final diam:0.56 mm		
Processing Conditions	Cylinder temp			
	C1	250-260 C	270 C	270 C
	C2	270-290 C	290 C	290 C
	C3	330-340 C	310 C	300 C
	Cross head	330-340 C		
	Die	350-360 C	315 C	310 C
	Air gap		80 mm	100 mm
	Draw down ratio	59		die diameter/sizing die diameter 1.35
	Pull speed	80-150 m/min	5 m/min cooling roller temp 120 C	4 m/min vacuum sizing

Fabrication Guide

Powder Coating

Powder coating methods such as electro-static powder coating, fluid dipping, etc., can be used for Everflon™ ETFE coating. The selection of the raw resin depends on the desired thickness and the application. The polymer is not hygroscopic, but the powder flow is affected by moisture content Therefore, compressed air used for flowing should be dried prior to the process. Furthermore, as dust mixed in the polymer may cause pinholes are coloration, the package or the hopper should not be left open.

Material and Shape of Substrate

As long as the material withstands temperatures in the range of 290-340°C, Techyours™ ETFE can be coated, not only on metallic surfaces, but on glass and ceramics, as well. The edges tend to shrink in thickness upon solidi:fication. Therefore, it is necessary to provide a roundness of IR, in thin layer lining, and for thick linings of 0.4-lmm, 3R or larger at extrusions and 5R or more at intrusions.

Pretreatment

Steel Material (Thick Lining)	Degreasing : baking 400'Cx 2 hrs or more Coarsening : blasting with 60 mesh-pass steel grid and sand (jet pressure 3~7kg/cm^2)
Steel, Stainless Steel, Aluminum (30-50um)	Degreasing : washing with trichloroethylene Coarsening : blasting with 100 mesh-pass steel grid and sand (jet pressure 3~7kg/cm^2)
Copper and Copper Alloy	At the time of baking, a fragile oxidation film is formed. Therefore, metal platinng or copper oxide film treatment (5 min boiling in a mixture of 1 part potassium persulfate, 4 parts sodium hydroxide and 95 parts water) is carried out.
Glass	Silan coupling agent treatment: washing;dipping in 30% nitric acid at 60°Cx2 hrs; soaking in 1 % ethanol solution of silane coupling agent (Union Carbide A-1120) for 24 hrs;air drying;coating

Coating

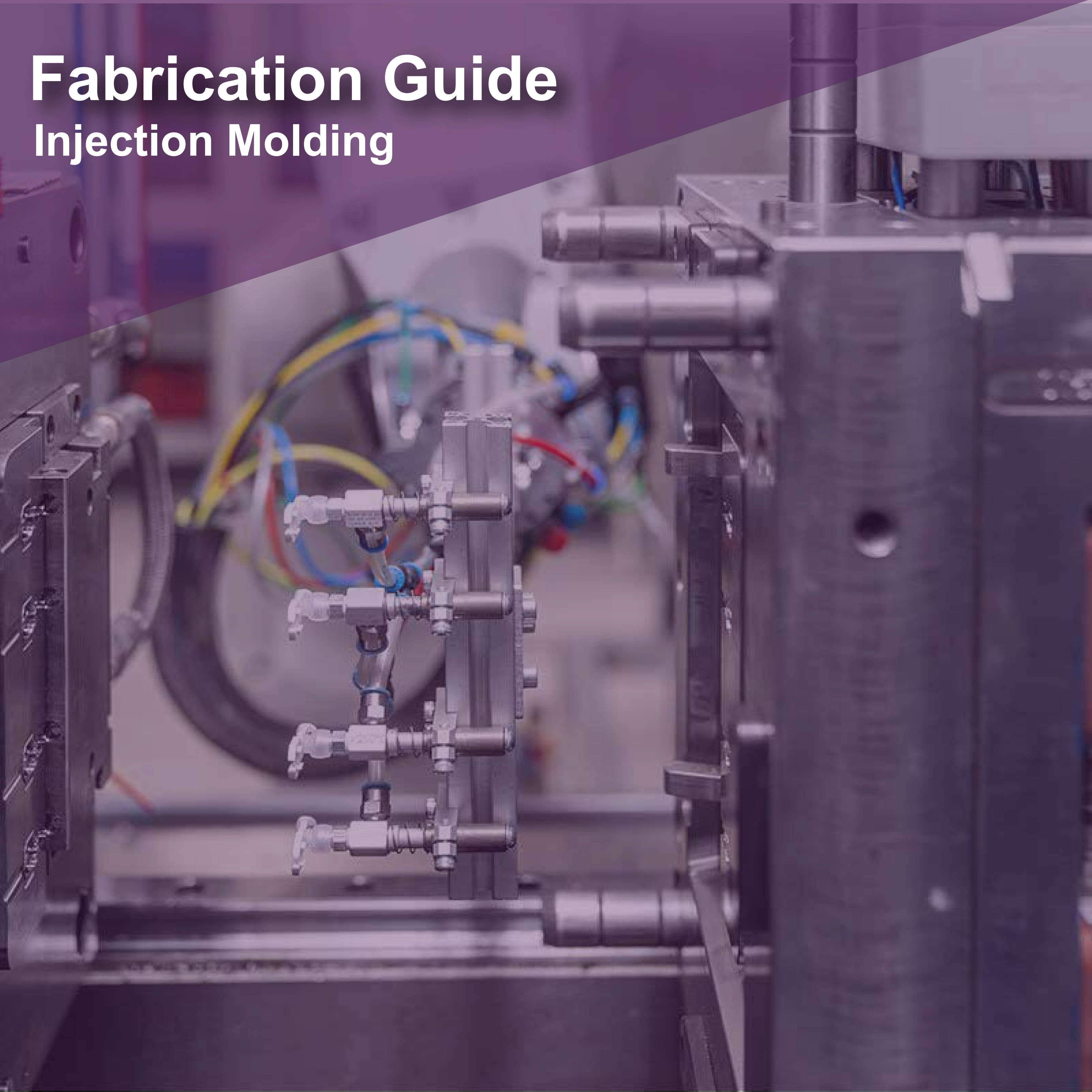
Apply a voltage of 60-90 kV, using an electrostatic coating machine, and tum off immediately before inducing electrostatic repulsion. Film thickness of the 30-150μm for the natural grades, and 1mm for the JP40 by repeating 5-7 layers of coating, can be obtained. By the fluid dipping of GS40, a film thickness of 0.6mm can be obtained with a substrate of 5mm thickness, and preheating of 340-360℃.

Baking

Baking should be carried out at a temperature in the range of 290-340℃ for 10-16 minutes, depending on the thickness of the substrate, the material, and the desired film thickness.
The film formed is tested by a method similar to the testing method for PTFE film, as well as by other methods, such as the film thickness test, pinhole test, Erichsen test, corrosion resistance test, etc epending on the application.

Fabrication Guide

Injection Molding



Injection Machine and Molding Material

Any of the plunger-type and screw-in-line-type injection machines may be used for molding, as long as the heater holds a heat capacity of up to 340 C. The material of the molding machine, corrosion resistant materials such as Hastelloy-C, X-alloy 306, Duranickel, etc., are recommended for those parts coming to contact with the polymer (inner surface of cylinder, screw, torpedo, nozzle, etc.). If not used as a machine exclusively for Everflon™ ETFE, nitrided and hard-chromium-plated materials may also be used.

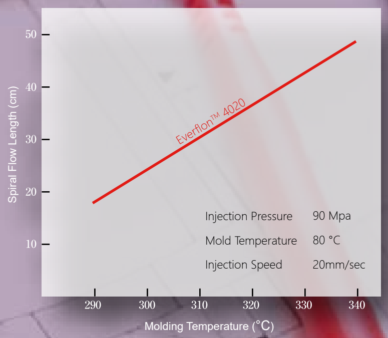
Mold

The mold used, although depending on the numher of shots, should be hard-chromium-plated on ordinary materials, and must be designed to stand temperatures up to 120°C. The gate structure may be selected from side gate, pinpoint gate, film gate, etc., depending on the product desired. The runner is desired to be designed to have a round cross section, and as short a length as possible.

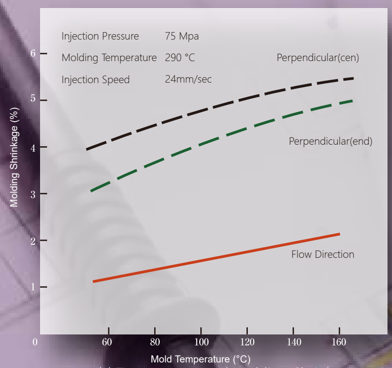
Molding Conditions

Table outlines the typical conditions for molding Everflon™ ETFE. For light-gage molding(thinner than 0.5 mm), the speed should be increased, while for heavygage molding (thicker than 5 mm), the cooling time should be increased. Furthermore, to obtain a smooth surface, the injection speed should be reduced.

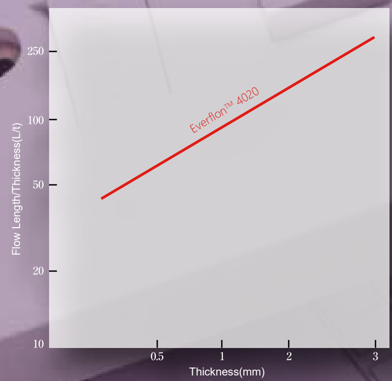
		ETFE 4010
Molding Temperature(C)	Back	260-280
	Middle	270-290
	Front	280-300
	Nozzle	290-320
Mold Temperature(C)		60-120
Injection Pressure(MPa)		50-120
Injection Speed(ram speed)(mm/sec)		1-15
Molding Cycyle(sec)		30-120



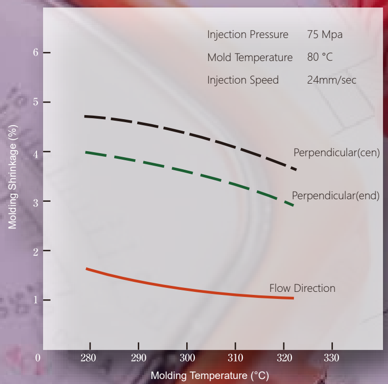
Molding Temperature and spiral Flow Length



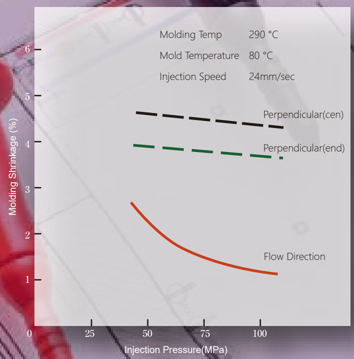
Mold Temperature and Molding Shrinkage



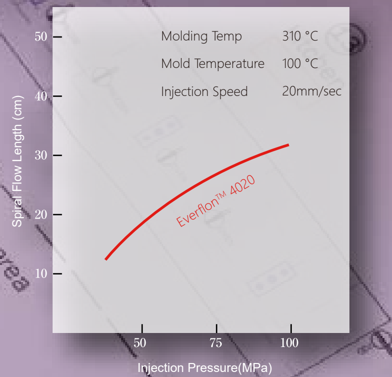
L/t and Thickness



Molding Temperature and Molding Shrinkage



Injection Pressure and Molding Shrinkage

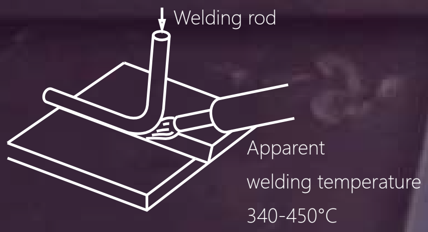


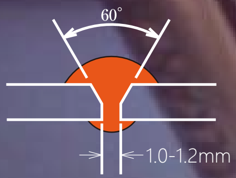
Injection Pressure and Spiral Flow Length

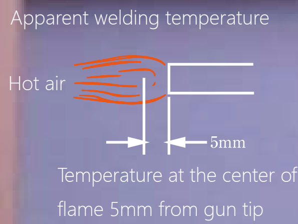
Data Hub

Fabrication Guide

Welding



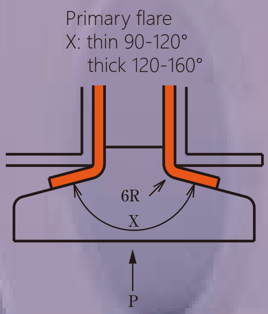


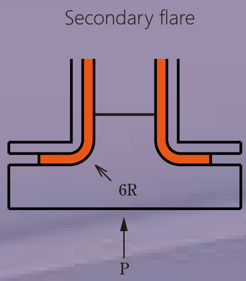


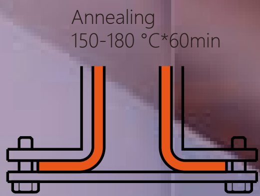
Welding requires a certain degree of skill, but by paying careful attention on the area to be welded, and by turning both the mother material and the welding rod into a waxy state, it is possible to obtain a strength equivalent to 60% that of the mother material, and achieve a welding speed of 80mm/min.

Fabrication Guide
Flare Processing

A 90° flare processing of Everflon ETFE pipes and injection moldings can be performed by using special tools. By heating the tool material at 130~ 150°C, flare processing may be done at a rate of 60mm/min.







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