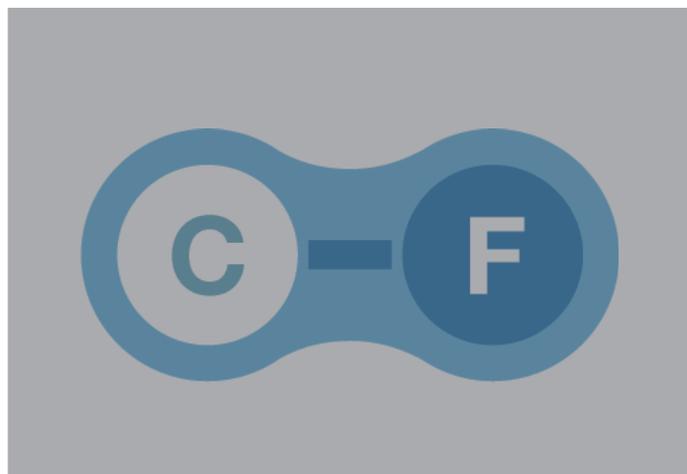


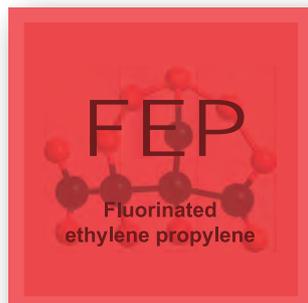
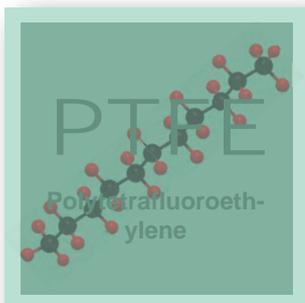


# Introduction

## Fluoropolymers



# PRODUCT FAMILIES



## PTFE Fluoropolymers

- Everflon™ PTFE Granular Molding Resins
- Everflon™ PTFE Fine Powders
- Everflon™ PTFE Aqueous Dispersions
- Everflon™ PTFE Fluoroadditives

## Melt-Processable Fluoropolymers

- Everflon™ FEP Resins and Dispersions
- Everflon™ PFA Resins and Dispersions
- Everflon™ ETFE Resins
- Everflon+™ Fluoropolymer Foam Resins
- Everflon+™ Fluoropolymer Color Masterbatch
- Everflonultra™ High Purity Fluoropolymer Resins
- Everflonultra™ Modified Fluoropolymer Resins

## Outstanding Properties of Everflon™ Fluoropolymers

- Chemical inertness
- Non-stick/self-cleaning
- Low friction/self-lubricating
- Dielectric properties
- Weather resistance/non-aging
- Insensitive to UV
- Non-toxic
- Broad temperature range (–200 to 260 °C [–328 to 500 °F])
- Nonflammable

# PROPERTIES OF EVERFLON™

## FLUOROPOLYMERS

### Chemical Inertness/Solvent Resistance



Fully fluorinated fluoropolymers (PTFE, FEP, and PFA) are virtually inert to the most aggressive organic and inorganic chemicals and solvents over a wide temperature range.

Chemical inertness means that Everflon™ fully fluorinated fluoropolymers can be in continuous contact with another substance with no detectable chemical reaction or degradation taking place. Among others, they are resistant to fuming sulfuric and nitric acids, bases, aggressive peroxides, antioxidants (as used in high temperature oils), and methanol (as used in fuel).

This nearly universal chemical compatibility stems from three causes:

- Very strong interatomic bonds between carbon-carbon and carbon-fluorine atoms
- Almost perfect shielding of the polymer's carbon backbone by fluorine atoms
- Very high molecular weight (or long polymer chain length) compared to many other polymers



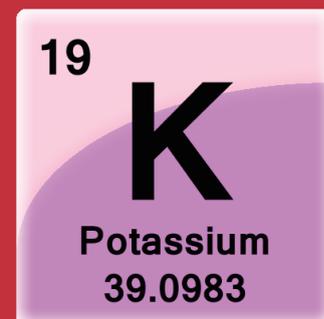
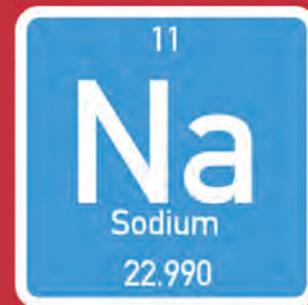
Within normal use temperatures, Everflon™ resins are chemically attacked by so few chemicals, that it is more practical to describe the exceptions rather than to tabulate the chemicals with which they are compatible.

The only materials known to react with fluoropolymers are:

- Elemental alkali metals like sodium, potassium, and lithium (molten or in solution)
- Intimate blends of finely divided metal powders (e.g., aluminum or magnesium) with powdered fluoropolymers can react violently when ignited, but ignition temperatures are far above the published recommended maximum service temperature for fluoropolymers
- Extremely potent oxidizers, fluorine (F<sub>2</sub>) and related compounds like chlorine trifluoride (ClF<sub>3</sub>)
- 80% NaOH or KOH solutions at or near the upper service temperature

Organic solvents do not attack or dissolve fluoropolymers, although some permeation may occur as a result of both absorption and diffusion.

Similar to the fully fluorinated polymers, Everflon™ ETFE has outstanding resistance to attack by chemicals and solvents that often cause rapid deterioration of other plastic materials. Strong oxidizing acids, organic bases, and sulfonic acids at high concentrations and near their boiling point may affect Everflon™ ETFE resin.



# PROPERTIES OF EVERFLON™

## FLUOROPOLYMERS

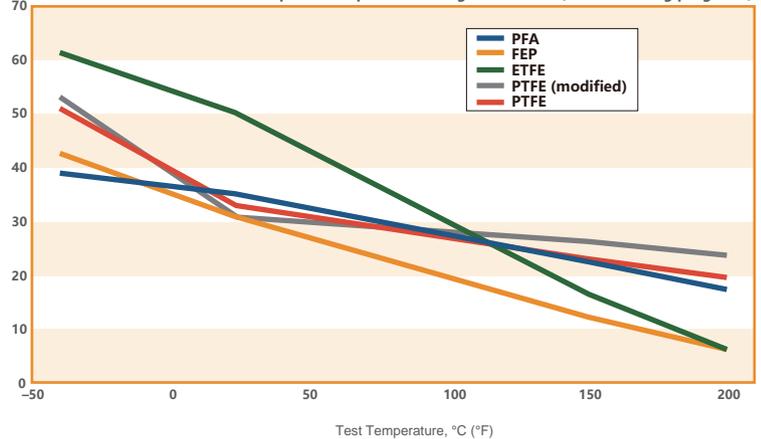
### Mechanical Properties

Tensile strength properties over a wide temperature range are shown in Figure measured on grades representative of the different fluoropolymer families.

Everflon™ ETFE is tougher than fully fluorinated fluoropolymer grades at low and ambient temperatures. At higher temperatures, the lines converge and above 120 °C (248 °F), PTFE and PFA have higher tensile strength than both ETFE and FEP.

#### Tensile Strength as a Function of Temperature

ISO 12086 microtensile specimen, speed of testing 50 mm/min (various testing programs)



Flex fatigue resistance is an important property for parts subjected to repeated stress. It correlates well with the stress-crack resistance of a material. Fatigue resistance and, therefore, stress-crack resistance of a part can vary by magnitudes depending on the resin grade used, processing conditions, and in-use stress level. Molecular weight, composition, crystallinity, and void content are the main parameters influencing flex fatigue resistance. PTFE in general and Everflon™ fluoropolymer in particular have the highest flex fatigue life among all fluoropolymers and are, therefore, very well suited for applications with alternating and/or long-term stresses.

Creep and cold flow occurs when a material is subjected to a continuous load. With most plastics, however, deformation can be significant even at room temperature or below; thus, the name “cold flow”.

Everflon™ ETFE, being a tougher material than Everflon™ PTFE, FEP or PFA, is more creep resistant than Everflon™ fluoropolymers.

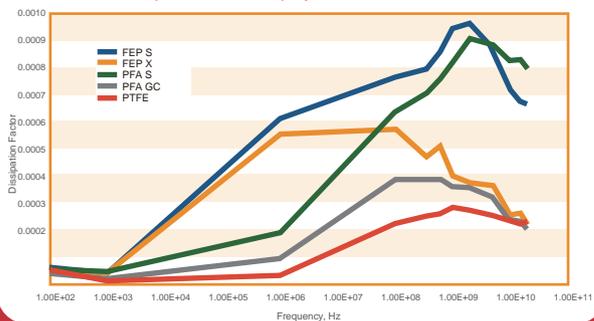
The modified grades of granular PTFE have been developed among others to improve the deformation under load. Also the use of a small percentage of filler reduces the deformation under load substantially. For instance, glass fiber reinforced with Everflon™ resin has only 1/5 of the deformation under load of an unreinforced ETFE.

# PROPERTIES OF EVERFLON™

## FLUOROPOLYMERS

### Dielectric Properties

Dielectric Properties of Fluoropolymers



The dissipation factor is affected by signal frequency, operating temperature, and chemical composition, crystallinity, and void content of the insulation. At room temperature, the dissipation factor of Everflon™ PTFE remains very low at less than 0.0002 for a frequency range of 100 Hz to 10 MHz; the dissipation factor makes a peak between 100 MHz and 20 GHz (10<sup>8</sup> – 20 x 10<sup>9</sup> Hz) when tested at room temperature. The peak dissipation factor is around 0.0003. PFA peaks at 0.0010 between 1 GHz and 20 GHz. The family of modified PFA such as PFA HP and HP Plus grades have significantly lower peak dissipation factor of 0.0004 close to PTFE.

For FEP, the dissipation factor increases slowly from less than 0.0001 at 1 kHz to 0.0006 at 30 MHz and peaks out at 0.0010 between 1 GHz and 5 GHz. Special chemically modified grades of FEP have a lower dissipation factor

Everflon™ ETFE has a dielectric constant of 2.6 and dissipation factor of 0.0006 at low frequency (<100 Hz) increasing to 0.0200 at 100 MHz. There is no measurable effect of humidity on the dielectric constant and dissipation factor of ETFE.

Everflon™ PTFE, FEP, and PFA fluoropolymers have unique electrical properties: a very low dielectric constant (relative permittivity) of 2.1 over a wide frequency range from 100 Hz to 50 GHz. It is important to note that the velocity of propagation of a signal down the length of cable is directly influenced by the dielectric constant and dissipation factor of the insulation material. The lower the dielectric constant, the higher the velocity. The dielectric constant can be decreased by reducing the density of the insulation. Techniques have been developed to lower the dielectric constant and dissipation factor of the dielectric material by creating voids; thereby, allowing data cables to have lower capacitance, lower attenuation, lower dielectric heating, and higher velocity of propagation.

Surface arc resistance of Everflon™ resins is high and is not affected by heat aging. When Everflon™ resins are subjected to a surface arc in air, they do not track or form a carbonized conducting path. When tested by the procedure of ASTM D495, Everflon™ PTFE and FEP resins pass the maximum time of 300 sec without failure.

No tracking was observed with PFA for the duration of the test (test was stopped after 180 sec without any sign of tracking).

Everflon™ ETFE has a dry arc resistance of about 70 sec.

The dielectric strength (tested in oil) of Everflon™ is high and unaffected by thermal aging at temperatures up to 200 °C (392 °F). Service life at high dielectric stress is dependent on corona discharge.

Volume resistivity is above 10<sup>16</sup> Ω.m (for ETFE, above 10<sup>14</sup> Ω.m). Resistivity is not affected by heat aging nor temperatures up to recommended service limits. For applications where tribocharging (electrostatic charge) may occur, special grades exist that dissipate static electricity.

# PROPERTIES OF EVERFLON™ FLUOROPOLYMERS

## Friction and Anti-Stick Properties

PTFE has an extremely low coefficient of friction. Values of 0.02 have been reported. The lowest values are obtained under condition of high pressure (>3 MPa) and low velocity (<0.1 m/min).

Due to its very low surface energy (18.5 mN/m), PTFE has excellent anti-stick properties.

## Weather/UV Resistance

Everflon™ fluoropolymers 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™ PTFE, FEP, and PFA and ETFE fluoropolymers are fully weather-resistant. Results show neither aging nor embrittlement. Because no plasticizers, anti-oxidants or other additives are used during its processing, there is no leaching out of substances.

## Temperature Resistance

Everflon™ fluoropolymers are extremely stable at high temperatures; PTFE and PFA can be used continuously at 260 °C (500 °F), FEP at 205 °C (401 °F), and ETFE at 155 °C (311 °F).

At those temperatures, at least 50% of their respective and original mechanical properties are retained after 20,000 hr (according to ISO 2578 and IEC 60216). At cryogenic temperatures, these products retain a measure of toughness and strength. PTFE has been used safely in outer space at temperatures approaching absolute zero.

## Flammability

Everflon™ PTFE, FEP, and PFA are essentially nonflammable. They will sustain combustion only in an environment containing >95% oxygen (oxygen index). The flash point is 530 °C (986 °F). Everflon™ ETFE has an oxygen index of 30. PTFE, FEP, PFA, and ETFE are rated by UL as Flame Class UL 94V-0. Heat of combustion is extremely low at 5 kJ/g (for ETFE 12.5 kJ/g); this provides an additional safety advantage as the “fuel-load” or the energy contained in the material that could be released in a fire event is very low. For comparison, the heat of combustion of polyethylene is 46 kJ/g; therefore, PE will generate more heat in a fire situation and will propagate a fire contrary to fluoropolymers (which are self-extinguishing).

Flame propagation and rate of heat release of fluoropolymers are low. When exposed to flame, they burn but do not continue to burn when the flame is removed. Flame rating according to ASTM D635 is average time of burning (ATB) <5 sec and average extent of burning (AEB) <10 mm.

These properties make fluoropolymers in particular useful in applications where fire hazards must be kept to a minimum.



**Solution**

**THE PERFECT SOLUTION  
FOR YOUR DESIGN NEEDS**

Problem	Solution:Everflon™ Fluoropolymers
Adhesion, Release	Extremely low surface energy in the solid state; thus, providing an excellent anti-stick, non-wetting contact surface. Conversely, when these resins are in a molten state, they become low surface-tension liquids—ideal for high-performance, hot-melt adhesives.
Atmospheric Aging	Extremely resistant to oxidation, surface fouling, discoloration, UV, and embrittlement, as proven by tests conducted in Florida for periods of up to 20 years.
Biodegradation	Inert to enzymic and microbiological attack because the pure polymer does not provide nourishment or porosity for these growths.
Contamination	Except for specialized grades, Everflon fluoropolymers are chemically inert and pure. They generally contain no additives (plasticizers, stabilizers, lubricants, or antioxidants) that could contaminate process fluids.
Corrosion	Resistance to even the most aggressive organic and inorganic chemicals and solvents over a broad temperature range.
Dielectric Instability	High dielectric strength, low dielectric constant, low loss factors, and extremely high specific resistance. Everflon fluoropolymers surpass most materials in their level and stability of dielectric properties over a broad range of environmental conditions.
Flammability	Remarkable resistance to high temperature and flames because of very high melting points and auto-ignition temperatures, as well as exceptional thermal degradation thresholds. Flame propagation characteristics, such as rate of heat release and smoke generation, are very low.
Friction and Wear	One of the lowest coefficients of friction of any solid material. Abrasion resistance is adaptable to demanding environments by using inorganic fillers, such as glass fiber, graphite, and powdered metals.
Heat	Property retention after exposure to temperatures beyond the limit of almost all other thermoplastics and elastomers. Depending on the end-use requirements, these resins are often rated for continuous service at temperatures as high as 260 °C (500 °F). In certain cases, they can also withstand short excursions to higher temperatures.
Humidity	Extremely hydrophobic and completely resistant to hydrolysis. Good barriers to water permeation; typical properties and dimensional stability remain unchanged, even after year-long immersion in water.
Light Instability	One of the lowest refractive indexes. Visual appearance does not change after exposure to light ranging from ultraviolet to infrared.
Low Temperature	Excellent property retention, even at cryogenic temperatures. In addition, resistance at these temperatures exceeds that of most other polymers.
Service Life	Outstanding retention of properties after aging, even at high temperatures and in the presence of solvents, oils, oxidizing agents, ultraviolet light, and other environmental agents. Because they do not use any leachable or degradable stabilizing additives, Everflon fluoropolymers offer an important safety advantage when designing products for long service life.

# EVERFLON™ PTFE

## Basic information

Polytetrafluoroethylene (PTFE) is produced by the polymerization of tetrafluoroethylene (TFE) monomer, yielding a perfluorinated straight-chain high molecular weight polymer with unique properties.

TFE is polymerized by two different processes, i.e., granular (also called suspension) polymerization and aqueous dispersion (emulsion) polymerization.

In general, PTFE resins are homopolymers of tetrafluoroethylene or, in some special cases, modified homopolymers containing very small amounts (less than 1%) of an additional perfluorinated monomer. Modified homopolymers have special processing and/or end use characteristics while maintaining the outstanding properties of PTFE.

Many of the unique properties can be explained by the molecular structure of PTFE. The carbon-carbon bonds, which form the backbone of the polymer chain, and the carbon-fluorine bonds are extremely strong. The fluorine atoms form a regular, protective sheath over the chain of carbon atoms; this sheath protects the polymer molecule from chemical attack. It also reduces the surface energy, resulting in a low coefficient of friction and non-stick properties.

In order to achieve the desired properties such as toughness and green strength, very high molecular weight is needed (in range of  $10^6$  or  $10^7$ ), resulting in an extremely high melt viscosity (1–100 GPa·sec or  $10^{10}$ – $10^{12}$  P). The material will not flow above its crystalline melting point. Consequently, PTFE could not be fabricated by conventional thermoplastic techniques.

High molecular weight polytetrafluoroethylene is manufactured and sold by Everflon™ in three main types: granular molding powder, fine powder, and aqueous dispersion, each requiring different fabrication techniques.

Furthermore, each of the three main types is subdivided into a number of grades to suit various end uses more precisely.

# Everflon™ PTFE Granular Molding Resins

PTFE granular resins (also called molding powders) are manufactured in a variety of grades to obtain a different balance between handleability and end-use properties. Granular resins are processed in general by compression molding at ambient temperature, followed by sintering above the crystalline melting point.

## Polymerization

Everflon™ Granular PTFE molding resin is made by polymerizing TFE in an aqueous medium (so-called suspension polymerization). In the case of Modified Granular PTFE, trace amounts of fluorinated comonomers are incorporated. The Modified Granular PTFE resins offer the superior properties typical of the fluoropolymer resins; but, in addition, these resins offer weldability, improved resistance to deformation under load, increased permeation resistance, and a higher dielectric breakdown voltage.

After polymerization, the high molecular weight raw polymer is then ground to small particle sizes. These finely divided particles allow for molding of parts essentially free of voids with high properties and are most appropriate for uniform mixing with fillers. On the other hand, the small particles have more tendency to stick together, resulting in poor handleability. A balance between handleability and moldability is achieved by agglomerating (pelletizing) the finely divided resin. Various resin grades with different degrees of pelletization are available, each with its specific set of flow, fill density, and physical properties.



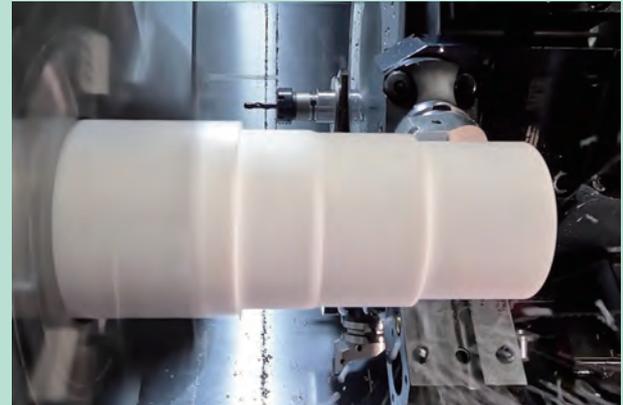
## Grades of Everflon™ PTFE Granular Molding Resins

Basic Grades	Main Characteristics	Major Uses
Finely divided resin (fine cut) Everflon PTFE M40	Non-free flowing, medium fill density, high property resin, low preform pressure	Compounding, high quality skived tape billets
Mildly pelletized resin Everflon PTFE M120	Moderate flow, high fill density, high property resin, medium preform pressure	High quality skived tape billets, compression and isostatic molding sheet molding, bearing pads
Free-flowing resin (pelletized) Everflon PTFE G401	Free-flowing, very high fill density, high preform pressure	Automatic molding, compression molding, ram extrusion at low back-pressure
Modified Grades	Main Characteristics	Major Uses
Modified, finely divided resin Everflon+ PTFE Compound	Non-free flowing, medium fill density, high property resin, low preform pressure	Compounding, high quality skived tape billets, sheet, molding
Modified, free-flowing resin (pelletized) Everflon+ PTFE Compound	Free-flowing, high fill density, high perform pressure	Compression and isostatic molding sheet molding, bearing pads

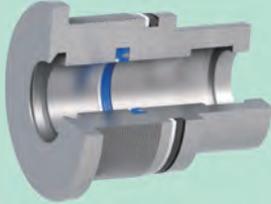
## Processing

Due to the extremely high viscosity above its melting point, PTFE can not be processed using normal thermoplastic techniques. PTFE granular molding resins are processed by modified powder metallurgy techniques.

In this technique, commonly known as compression molding, the dry powder is compressed into a handleable form (preform) at ambient temperature. Depending on the grade, different preforming pressures are recommended to achieve optimum properties. After compression, the preform is then removed from the mold and heated above the melting point (sintering). This coalesces the PTFE particles into a strong homogeneous structure; cooling at a controlled rate achieves the desired degree of crystallinity.



## Typical Applications



- Gaskets, seals, valve seats, bellows, diaphragms
- Piston rings, hydraulic seals
- Corrosion resistant linings
- Bearing pads
- Brake pad sensors, oxygen sensor seals
- High-tension circuit breakers, commutator rings
- Printed wiring boards
- Laboratory equipment, beakers
- Iron sole plates
- Ski binders

# Everflon™ PTFE Fine Powders

PTFE fine powders are made by coagulation of PTFE aqueous dispersion. Various grades are available corresponding to specific applications and methods of fabrication and differ in molecular weight and structure.

Fine powders are processed in general by the so-called “paste extrusion” technique; whereby, the powder is first blended with an extrusion aid (lubricant). This wetted powder (paste) is then extruded through a die at ambient temperature; after this formative stage, the lubricant is removed and then the extrudate is sintered above the crystalline melting point. This provides a practical method for producing long lengths of product from a resin that cannot be melt-extruded. PTFE fine powders have the characteristic property that the primary dispersion particles under the effect of shear form fibrils. It is this network of fibrils that gives the useful structural integrity to the extrudate and allows the manufacture of end products with unique performance.

In the case of PTFE fine powder used as an additive, the fibrillation properties are important for drip suppression in thermoplastics.

## Polymerization

Everflon™ Granular PTFE molding resin is made by polymerizing TFE in an aqueous medium (so-called suspension polymerization). In the case of Modified Granular PTFE, trace amounts of fluorinated comonomers are incorporated. The Modified Granular PTFE resins offer the superior properties typical of the fluoropolymer resins; but, in addition, these resins offer weldability, improved resistance to deformation under load, increased permeation resistance, and a higher dielectric breakdown voltage.

After polymerization, the high molecular weight raw polymer is then ground to small particle sizes. These finely divided particles allow for molding of parts essentially free of voids with high properties and are most appropriate for uniform mixing with fillers. On the other hand, the small particles have more tendency to stick together, resulting in poor handleability. A balance between handleability and moldability is achieved by agglomerating (pelletizing) the finely divided resin. Various resin grades with different degrees of pelletization are available, each with its specific set of flow, fill density, and physical properties. Polymerization



## Grades of Everflon™ PTFE Fine Powders

Final Product	Processing Capability	Major Uses
Wire and Cable	High reduction ratio (1500:1–5000:1) Everflon™ PTFE F2000	Hook-up wire, automotive wiring
	Medium reduction ratio (300:1–2000:1) Everflon™ PTFE F1000	Heating cable, appliance wiring
	Low reduction ratio (<100:1–300:1) Everflon™ PTFE F500	Coaxial cables, electrical grade tape
Hose and Tubing	High reduction ratio (>1000:1) Everflon™ PTFE F1000	Spaghetti tubing, catheter
	Low/medium reduction ratio (<100:1–1000:1) Everflon™ PTFE F500	Unsupported industrial tubing, catheter, convoluted tubing, heat-shrinkable tubing
	High performance, high flex. life Everflon™ PTFE F500S	Aircraft hose, generator hose, automotive tubing, bellows
Lined Pipe and Fittings	Large diameter (>250 mm), low reduction ratio Everflon™ PTFE 500	Pipe liners, column liners
	Small to medium diameter (<250 mm) Everflon™ PTFE F1000	Pipe liners, fittings, bellows
Unsintered Products	Low reduction ratio (20:1–100:1) Everflon™ PTFE 100	Thread seal tape, cords, gaskets

## Processing

Everflon™ PTFE Fine powders are processed by the so-called paste extrusion process. In this process, the powder is first mixed with a lubricant (typically a liquid hydrocarbon) under controlled temperature conditions; pigments and/ or fillers can also be incorporated at this stage. After mixing, the blend is conditioned for some time to allow for complete and uniform absorption of the lubricant by the resin particles. This mixture is then compacted at low pressure into a preform that is afterwards loaded into the cylinder of a paste extruder. The lubricated resin is then pressed with a piston through a tooling or shaped orifice to form a coating on a wire, tubing, beading, or ribbon.

The shear stress exerted on the lubricated resin during extrusion confers strength to the extrudate by fibrillation. After extrusion, the lubricant is completely removed (green strength) by evaporation, and the extrudate is sintered—sometimes followed by further post-forming operations. Note that in some applications, the extrudate is left unsintered (e.g., thread sealant tape, sealing cord).



# Typical Applications

- Automotive sensor wires
- Coaxial cables for radio frequency
- Seat heating wiring
- Appliance wiring
- Aircraft wiring
- Wire conduits
- Chemical transfer hose and tubing
- Convoluted tubing
- Tubing, small diameter tubing, chromatography tubing,
- heat shrinkable tubing
- Lined pipe and fittings
- Heat exchanger tubing
- Hydraulic hose
- Fuel tubing—aircraft, automotive
- Push-pull cable liner
- Gaskets, sealants
- Filters, membranes
- Monofilaments, fibers
- Profiles



# Everflon™ PTFE Aqueous Dispersions



PTFE aqueous dispersions are milky white dispersions of PTFE particles suspended in aqueous medium, stabilized by wetting agents. The dispersion typically contains 30–60 wt% polymer particles and some surfactant. The PTFE particle characteristics and surfactant type depend on the application. They can be further formulated to meet specific needs by adding other solid or liquid ingredients.

PTFE aqueous dispersions are applied to substrates by spraying, dipping or impregnation. After applying the dispersion on the substrate, the water and surfactants are removed by evaporation and the PTFE is sintered. The substrate needs to be resistant to the typical sintering temperatures of PTFE.

In special cases, such as impregnated packing, the PTFE is left unsintered to maintain flexibility.

PTFE aqueous dispersion can also be used as an additive in thermoplastics (as drip suppressant) or in dusty products to eliminate dust. As with PTFE fine powders, aqueous dispersion particles also fibrillate under shear, and these PTFE fibrils form a web within the host material that holds the dust or avoids the dripping of burning droplets in case of a fire.

Everflon™ PTFE aqueous dispersions are milky white liquids consisting of hydrophobic, negatively charged submicrometer particles of PTFE resin suspended in water. The most common dispersion has an average particle size of 0.2  $\mu\text{m}$  (200 nanometer), the optimum particle size for most applications. The raw dispersion is typically stabilized, neutralized, and concentrated.

Stabilization with a nonionic or anionic surfactant improves shear stability, wetting of substrate, and helps film formation in coating operations. The high utility of these dispersions is due to their fluid form. This property is especially useful because Everflon™ PTFE resins are not suitable for processing in molten or dissolved form. Everflon™ PTFE aqueous dispersions are available in different grades designed according to the application, each with a specific molecular weight and molecular structure, dispersion particle size and shape, added surfactant type and quantity, pH and solids content.

Aqueous dispersions of Everflon™ FEP and PFA meltprocessable fluoropolymers as well as Everflon™ PTFE fluoroadditives are also available.

## Grades of Everflon™ PTFE Aqueous Dispersions

Grades	Main Characteristics	Major Uses
General-Purpose Everflon™ PTFE D60P	Ease of handling, good wetting	Impregnation of yarns for gaskets and packing
Fabric Coating Everflon™ PTFE D60F	High buildup, surface smoothness, weldability, good wetting, low foam, shear stable	Coated architectural fabrics, coated glass fabric for belting, flexible wiring boards, cast film
Metal Coating Everflon™ PTFE D60C	Film forming, good properties at high temperature, impermeable, high critical cracking thickness (CCT)	Coatings for industrial and cookware applications
Specialties Everflon™ PTFE D60P	Wetting, good fixation, high temperature, long-lasting	Compounding, high quality skived tape billets, sheet, molding
Additive Everflon™ PTFE D60A	<sup>70</sup> Homogeneous, ease of handling	Compression and isostatic molding sheet molding, bearing pads

## Processing

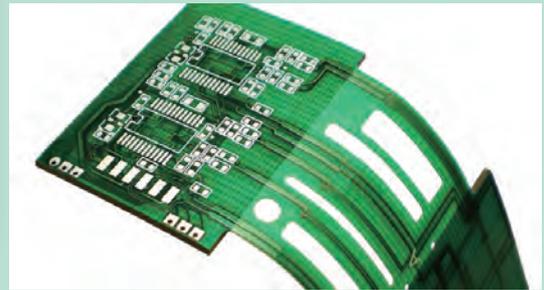
Uses for Everflon™ PTFE dispersions fall into general categories of coating, impregnation, finishing, and blending. In the case of coating of glass fabric, PTFE aqueous dispersion is applied by dipping the glass fabric in a bath with dispersion. In a typical coating process, the glass fabric is continuously unwound from a roll and fed into a dip bath, where it is submerged in a Everflon™ PTFE aqueous dispersion. The impregnated fabric emerges from the bath, excessive dispersion is wiped off the fabric, the fabric enters the drying zone to remove water, followed by “baking” to remove organic wetting agent(s), and finally a sintering zone. Finished or semi-finished product is wound up on a receiving roll. The same fabric is passed through the equipment a number of times until the desired weight and thickness are achieved.

A variety of porous structures can be impregnated with Everflon™ PTFE dispersion. The dispersion is well-suited for impregnation because of its low viscosity, extremely small particles, and the effect of the surfactant that aids in wetting the surfaces and promotes capillary action.



# Typical Applications

- Architectural membranes (flexible coating)
- Electrical insulation in motors, generators
- Top-coat for aerospace wiring
- Flexible wiring boards
- Non-stick conveyor belting
- Non-stick film for heat sealers
- Impregnated yarns for gaskets and packing
- Coated filter bags
- Bearings
- Fibers
- Binders for disposable or rechargeable batteries



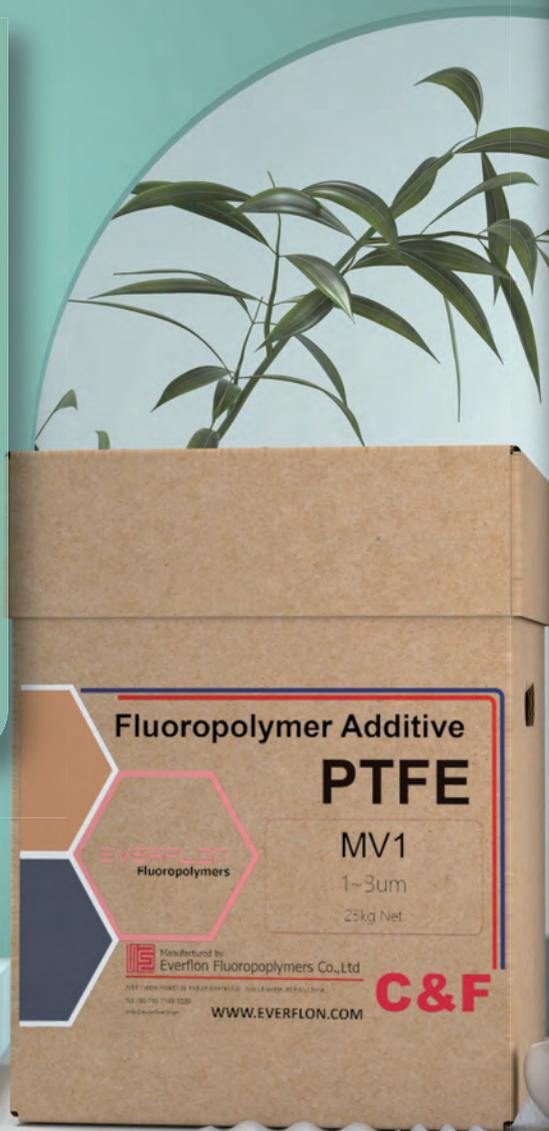
# Everflon™ PTFE Fluoroadditives

PTFE fluoroadditives are finely divided, freeflowing white powder of PTFE resin. They are a separate and distinctive product line, very different from the wellknown Everflon™ PTFE molding and extrusion powders.

The differences include:

- Lower molecular weight (in range of  $2.5 \times 10^4$  to  $25 \times 10^4$ )
- Smaller particles sizes (1–20  $\mu\text{m}$ )
- Different particle shapes and morphology

Everflon™ PTFE fluoroadditives are designed primarily for use as minority components in mixtures with other solid or liquid materials. Even in small quantities, they can impart some of the unique properties of PTFE to various hosts, such as reduced coefficient of friction and mechanical wear, and enhanced abrasion resistance. The product range offers a choice of particle size and morphology to facilitate intimate mixing with dissimilar materials.



Everflon™ fluoroadditives are part of the C&F Chemicals family of fluoropolymers. They are white, free-flowing, low molecular weight PTFE powders designed for use as additives in other materials or systems. They differ from PTFE granular resins and fine powders because of their very small particle size, typically in the range of 2 to 20  $\mu\text{m}$ , low molecular weight, and the way they are handled and processed. Everflon™ MV fluoroadditives can be used over a wide range of temperatures from -190 to 250 °C (374 to 482 °F) and, depending on the application, may provide non-stick properties, improved lubricity, and better wear resistance and reinforcing properties.

Depending on the material, Everflon™ fluoroadditives can enhance abrasion resistance, reduce coefficient of friction and mechanical wear, reduce surface contamination, and modify appearance of the host material. Everflon™ fluoroadditives also provide specific benefits to specialized products. For example, thermoplastic parts, such as gears, benefit from improved wear resistance and reduced friction. Stick-slip behavior can be eliminated. Elastomeric seals for diverse environments improve in tear and abrasion resistance. Lithographic, flexographic, and gravure inks can be formulated for better image protection and higher productivity.

When used alone as a powder or in a paste or spray, Everflon™ fluoroadditives can be made into all-purpose solid lubricants. As a paste, for example, they can be used as high-performance sealants or as lubricants for wear surfaces in hostile environments. The powder can be dispersed in water or an organic solvent to provide another option for direct use or as an additive.

Because of their inherent low molecular weight, Everflon™ fluoroadditives are not to be used as molding or extrusion powders. Unlike some other micropowders on the market that are based on reprocessed PTFE, Everflon™ fluoroadditives are manufactured from virgin PTFE or are directly polymerized; hence, a better uniformity and inherent cleanliness.

## Grades of Everflon™ PTFE Additives

Grades	Main Characteristics	Major Uses
Granular PTFE-Based Everflon™ PTFE MV	Low specific surface area (2.3–4.5 m <sup>2</sup> /g), non-agglomerated powder	Thermoplastics, printing inks, coatings
Fine Powder PTFE-Based Everflon™ PTFE FV	High specific surface area (5–11 m <sup>2</sup> /g), friable agglomerates of small (0.2 μm) primary particles	Thermoplastics, elastomers, coatings, lubricants and greases
As Polymerized PTFE Everflon™ PTFE TV	High specific surface area (8–12 m <sup>2</sup> /g), friable agglomerates of small (0.2 μm) primary particles. Low level of active end groups.	Elastomers, printing inks, coatings, coil coating, greases
Aqueous Dispersion Everflon™ PTFE D60A	Milky, white, 59–61% solids dispersion of 0.2 μm PTFE particles, stabilized with nonionic wetting agent	Additive for paints, coatings, mold release

## Processing

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## Typical Applications

- In modifying thermoplastics for reduced friction and stick-slip, improved wear resistance, increased PV limits
- In elastomers for improved abrasion resistance, coefficient of friction, tear strength, and mold release
- In lithographic, flexographic, and gravure inks for better rub and scuff resistance, slip, and surface smoothness
- In coatings (both water- and hydrocarbon-based) for better water repellency, stain and scrub resistance, enhanced anti-stick, and low friction behavior
- In modifying sealant and lubricants for reduced wear and friction
- In extrusion process as a processing aid



# EVERFLON™ FEP



## BACKGROUND

FEP (perfluorinated ethylene-propylene) resin is a copolymer of TFE and hexafluoro-propylene (HFP). It retains most of the desirable characteristics of PTFE, but with a melt viscosity low enough for conventional melt processing. The melting point of FEP is about 260 °C (500 °F) versus a first melting point of PTFE of about 340 °C (644 °F). Continuous service temperature of FEP is 205 °C (401 °F) as compared to 260 °C (500 °F) for PTFE.

Everflon™ FEP resins are available in various grades to meet a variety of processing and end-use requirements. The different grades of FEP vary primarily in molecular weight, while they all provide equivalent temperature rating (205 °C [401 °F]), electrical performance, and chemical resistance. As the molecular weight and, hence, melt viscosity increases, so does the mechanical performance and the resistance to stress cracking; however, these improvements occur at the expense of processing ease and mainly of processing speed. Modified grades are available that offer an improved combination of stress crack resistance and processing speed.

Everflon™ FEP is also available in aqueous dispersion form for coating and impregnation purposes.

## Grades of Everflon™ FEP Resin

Grades	Main Characteristics	Major Uses
General-Purpose	High productivity, MFR 5–7 g/10 min Everflon™ FEP T4608&4610	Wire insulation, tubing ( $\leq 2$ mm diameter), injection molded parts
Optimum Output-Performance	Optimized productivity and stress-crack resistance balance MFR 4–10 g/10 min Everflon™ FEP 4610	Wire and cable insulation and jackets
High Productivity	Highest stress-crack resistance, MFR $\leq 5$ g/10 min Everflon™ FEP 4603&4601	Tubing ( $\geq 2$ mm diameter)
High Output	Maximum productivity, MFR $> 30$ g/10 min Everflon™ FEP4630	Films, chemical linings, high stress applications, wire and cable applications
	Low dissipation factor, MFR $> 20$ g/10 min Everflon™ FEP 4622	Small wire and cable insulation ( $\leq 1.0$ mm diameter), injection molded parts
Foam Resins	Physical and chemical system compound resins Everflon+™ FEP CF&PF	Foamed cable insulations, high-frequency data cable with minimum distortion
Colored Resins	Pre-colored and color masterbatch resins Everflon+™ FEP CC&PC	Colored cable and Jackets, tubings
Aqueous Dispersion	Ease of handling, wetting Everflon™ FEP D50	Top coat on wiring or architectural fabric
Modified Resin	Improved crack resistant and working temperature Everflon <sup>ultra</sup> ™ FEP X Grade	Wire and cable insulation and Tubings

## Processing

Everflon™ FEP fluoropolymer resins are processed by conventional melt-extrusion techniques and injection, compression, transfer, and blow-molding processes.

The high melt strength and draw-down capability of these resins facilitate the use of large dies and drawdown tooling to increase production rates. Equipment in contact with molten resin should be made of corrosion-resistant metals. Larger length-over-diameter extruder barrels are used to provide enough residence time at high production rates to melt these high-temperature polymers. For injection molding, reciprocating screw designs are recommended.

# Typical Applications

- Data communication cable jackets and primaries
- Appliance wiring
- Heating cables
- Automotive engine wiring
- Aerospace wiring
- Electric submersible pump motor insulation
- Electrical motor sleeves
- Chemical lining
- Lined valves
- Heat shrinkable tubing
- Tubing, small diameter tubing, chromatography tubing
- Shatterproof lamp covering
- Architectural fabrics (top coat)



## BACKGROUND

Everflon™ PFA resin is a copolymer of TFE and perfluorovinyl ether. PFA is melt-processable with a melting point at about 305 °C (581 °F). Continuous service temperature is equal to that of PTFE, i.e., 260 °C (500 °F).

Everflon™ PFA offers the excellent combination of properties characteristic of Everflon™ fluoropolymers: non-aging, chemical inertness, exceptional dielectric properties, toughness and flexibility, low coefficient of friction, nonstick characteristics, negligible moisture absorption, and excellent weather and UV resistance.

Everflon™ PFA C offers electrical conductivity to dissipate static electricity.

Everflon™ PFA is also available in aqueous dispersion form for coating and impregnation purposes



## Grades of Everflon™ PFA Resin

Grades	Main Characteristics	Major Uses
General-Purpose	Highest resistance to stress cracking, high molecular weight MFR 1.6–2.3 g/10 min Everflon™ PFA 403	Lining of components for chemical processing industry, transfer molded articles, tubing extrusion
	Extrusion and injection molding resin, intermediate molecular weight, higher stress crack resistance MFR 6–14 g/10 min Everflon™ PFA 410	Tubing extrusion, injection or blow-molded articles, chemical linings
	Extrusion and injection molding resin, intermediate molecular weight MFR 20–30 g/10 min Everflon™ PFA 420	Wire and cable insulation and jacketing, injection or blowmolded articles, tubing extrusion
	High speed extrusion, high productivity, low molecular weight, MFR 35–45 g/10 min Everflon™ PFA 430	Small gauge wire coating, injection molding
High Purity	Premium resin with the lowest level of extractables, high molecular weight, high stress crack resistance MFR 1.7–2.3 g/10 min Everflon™ PFA GC403	Fluid handling components for critical-high-purity processes like semiconductor, pharmaceutical, and biotechnology
	Premium resin with the lowest level of extractables, intermediate molecular weight, higher stress crack resistance MFR 6–14 g/10 min Everflon™ PFA GC410	Fluid handling components for critical-high-purity processes like semiconductor, pharmaceutical, and biotechnology
	Premium resin with the lowest level of extractables, low molecular MFR 20–30 g/10 min Everflon™ PFA GC420	Fluid handling components for critical-high-purity processes like semiconductor, pharmaceutical, and biotechnology
	Premium resin with lowest level of extractables, low molecular weight, maximum productivity MFR 35–45 g/10 min Everflon™ PFA GC430	Low loss, small diameter data cables, small injection molded parts for high-purity applications
Rotational Molding Resin	Premium resin in powder form with the lowest level of extractables, improved flex life and stress crack resistance Everflon™ PFA GS04	Pump housing, containers, fittings with unusual shapes for handling of high purity chemicals
Anti-Static	Static dissipating semi-conductive resin Everflon™ PFA C Grade	Lined components for CPI
Aqueous Dispersion	Ease of handling, wetting Everflon™ PFA D450	Top coat on wiring and architectural fabric

# Processing

Everflon™ PFA fluoropolymer resins are processed by conventional melt-extrusion techniques and injection, compression, rotational, transfer, and blow-molding processes. The high melt strength and heat stability of these resins permit the use of relatively large die openings and high-temperature draw-down techniques that increase processing rates. For injection molding, reciprocating screw designs are recommended.

Corrosion-resistant metals should be used in contact with the molten resin. Long extruder barrels, relative to diameter, are used to provide residence time for heating the resin to required processing temperatures.

## Typical Applications

- Lined valves, fittings, and pumps
- Chemical linings
- Vessels, containers
- Wafer carriers
- Lab ware
- Heating cables
- Appliance wiring
- Logging cables
- Connectors
- Wire conduits
- Tubing
- Corrugated and convoluted tubing
- Heat shrinkable tubing
- Architectural fabrics



## BACKGROUND

Everflon™ ETFE resin is a modified copolymer of TFE and ethylene. ETFE is melt-processable and mechanically tougher and stiffer with higher cut-through, abrasion, and creep resistance than PTFE, FEP or PFA resins.

The chemical, dielectric, and thermal properties approach those of the fully fluorinated Everflon™ PTFE, FEP, PFA types, albeit that ETFE is affected to varying degrees by strong oxidizing acids, organic bases (such as amines), and sulfonic acids at high concentrations and near their boiling point. Its other main features include ease of processing, lower density (1.7) than Everflon™ FEP, PFA and PTFE, and improved radiation resistance.

Everflon™ ETFE is suitable for continuous service up to 155 °C (311 °F) based on the standard 20,000 hr criterion.

Everflon™ features easy processibility, a specific gravity of 1.7, and high-energy radiation resistance. Most grades are rated for continuous exposure at 150 °C (302 °F), based on the 20,000 hr criterion and meet the requirements of International Standard ISO 6722 class F (-40 to 200 °C [-40 to 392 °F]) – Road vehicles – 60 V and 600 V singlecore cables.

Everflon™ ETFE is also available in 25% glass-fiber reinforced composition and as an anti-static grade, as well as functionalized grades for applications that require bonding to other polymers.



## Grades of Everflon™ ETFE Resin

Grades	Main Characteristics	Major Uses
General-Purpose	General-purpose resin of intermediate molecular weight. MFR 2–4 g/10 min Everflon™ ETFE 4003	Wire and cable insulation and jacketing, Injection-molded components, films, tubing
	General-purpose resin of intermediate molecular weight with improved stress crack resistance MFR 6–14 g/10 min Everflon™ ETFE 4010	Films, tubing, injection-molded articles, wire and cable insulation and jacketing, down-hole logging cable, components for chemical Industry
	Extrusion and injection molding resin, intermediate molecular weight MFR 20–30 g/10 min Everflon™ ETFE 4020	Small wire and cable insulation (0.5 mm and smaller), thin wall extrusion, injection-molded parts
Appliance Wiring Grade	Higher temperature rating, more flexible, MFR 5–10 g/10 min	Appliance wiring UL Style 10412-600 V 200 °C
Rotational Molding Resin	Premium grade resin in powder form, designed for use in rotational molding Everflon™ ETFE GS40	Pump housing, containers, fittings, pipe sections with unusual shapes for handling of chemicals
Anti-Static	Static dissipating, semi-conductive resin Everflon™ ETFE C	Lined components for CPI, extruded tubing, hose, and pipe

## Processing

Everflon™ ETFE fluoropolymer resins are processed by conventional melt-extrusion techniques and injection, compression, transfer, rotational, and blow molding processes. The relatively high flow rate of these resins provides higher rates with less draw-down, as compared to those required for Everflon™ FEP and PFA.

Reciprocating screw injection molding machines are preferred. For longterm use, corrosion-resistant metals should be used in contact with the molten resin. Long extruder barrels, relative to diameter, should be used to provide residence time for melting these hightemperature resins.

# Typical Applications

- Automotive wiring
- Aerospace wiring
- Heating cable
- Appliance wiring
- Down-hole cables and tubing
- Valves, valve seats
- Seals
- Pumps
- Column packing
- Flow meters
- Tubing
- Architectural films
- Release films



## Main Typical Properties of Everflon™ Fluoropolymers

Typical Properties	Test Method	Unit	Everflon PTFE	Everflon FEP	Everflon PFA	Everflon ETFE
<b>Mechanical</b>						
<b>Specific Gravity</b>	ISO 1183		2.16	2.15	2.15	1.71
<b>Tensile Strength</b>	ISO 12086	MPa				
–40 °C (–40 °F)			52	43	39	61
23 °C (73 °F)			26–36	20–34	25–35	45–51
150 °C (302 °F)			25	12	23	17
200 °C (392 °F)			22	6.3	17	6.5
<b>Elongation</b>	ISO 12086	%				
–40 °C (–40 °F)			115	235	250	180
23 °C (73 °F)			325	325	350	200–375
150 °C (302 °F)			540	375	515	740
200 °C (392 °F)			560	395	535	630
<b>Tensile Strength at Yield</b>	ISO 12086	MPa				
–40 °C (–40 °F)			28.2	26.4	26.5	41.7
23 °C (73 °F)			13.7	13.1	14.5	22.9
150 °C (302 °F)			6.2	5.5	8.3	6.0
200 °C (392 °F)			4.6	3.4	5.9	3.8
<b>Tensile Modulus</b>	ISO 12086	MPa				
–40 °C (–40 °F)			795	465	520	880
23 °C (73 °F)			480	520	435	840
150 °C (302 °F)			60	34	57	53
200 °C (392 °F)			60	20	46	30
<b>Flexural Modulus, 23 °C (73 °F)</b>	ISO 178	MPa	490	550–655	520–690	1,000–1,380
<b>Folding Endurance MIT (0.2 mm, 270° flex)</b>	ASTM D2176	Cycles	885,000–>90 x 10 <sup>6</sup>	5,000–1 x 10 <sup>6</sup>	7,000–2 x 10 <sup>6</sup>	1,500–60,000
<b>Impact Strength</b>	ASTM D256	J/m				
23 °C (73 °F)			185	No break	No break	No break
–54 °C (–65 °F)			107	158	155	>1,100
<b>Hardness</b>	ISO 868	Shore	D-55	D-55	D-56	D-67
<b>Coefficient of Friction (dyn)</b>	ASTM D3702		0.1	0.3	0.2	0.4

Typical Properties	Test Method	Unit	Everflon PTFE	Everflon FEP	Everflon PFA	Everflon ETFE
<b>Thermal</b>						
Peak Melting Temperature	ASTM D4591	°C (°F)	327 (621)	260 (500)	305 (581)	265 (509)
Service Temperature (20,000 hr)	ISO 2578	°C (°F)	260 (500)	205 (401)	260 (500)	155 (311)
Flame Class	UL94		94V-0	94V-0	94V-0	94V-0
Oxygen Index	ISO 4589	%	>95	>95	>95	30–32
Temperature Index	NES 715	°C (°F)	>400 (>752)	>400 (>752)	>400 (>752)	ca 290 (554)
Heat of Combustion	ISO 1716 (NFPA-259)	kJ/g	4.9–5.0	4.8–5.1	4.7–4.9	12.4–12.6
<b>Electrical</b>						
Dielectric Strength	IEC 60243	kV/mm				
Film 0.25 mm			85	78	74	62
Film 1.00 mm			35	35	33	30
Relative Permittivity (Dielectric Constant)	ASTM D150	1 MHz 1 GHz	2.05 1.99	2.03 2.02	2.03 2.02	2.47 2.29
Dissipation Factor	ASTM D150	1 MHz 1 GHz	0.00003 0.00028	0.00061 0.00094	0.00019 0.00082	0,00550 0,01430
Arc Resistance	ASTM D495	sec	>300	>300	>180	>72
Volume Resistivity	ASTM D257	Ω.m	>10 <sup>16</sup>	>10 <sup>16</sup>	>10 <sup>16</sup>	>10 <sup>14</sup>
Surface Resistivity	ASTM D257		>10 <sup>16</sup>	>10 <sup>16</sup>	>10 <sup>17</sup>	>10 <sup>14</sup>
<b>General</b>						
Weather Resistance	"Weather-O-Meter" (2,000 hr)		No effect	No effect	No effect	No effect
Solvent Resistance	ASTM D543		Excellent	Excellent	Excellent	Very good
Chemical Resistance	ASTM D543		Excellent	Excellent	Excellent	Very good
Water Absorption	ASTM D570	%	0.00	0.01	0.03	0.03



# FAMILY

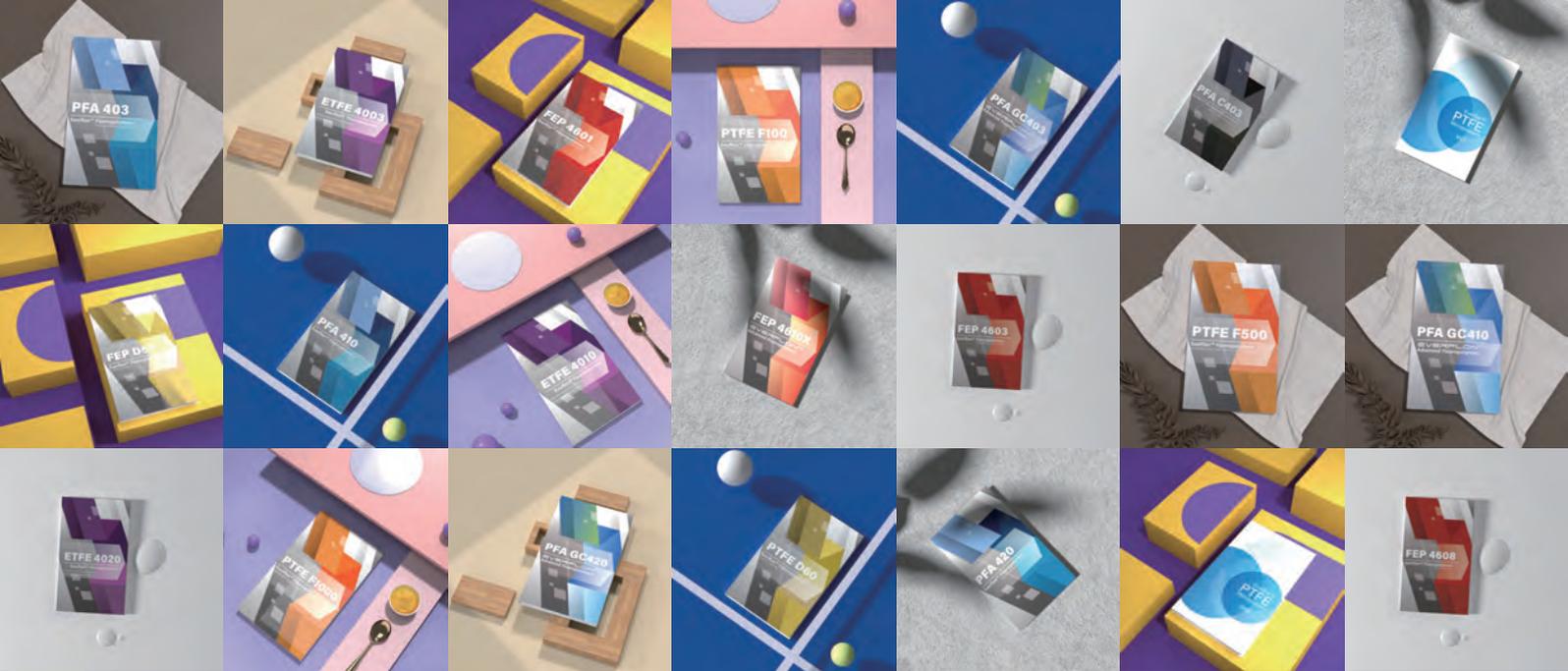




## ENABLING IMPROVEMENTS AND INNOVATIONS

For more than 20 years, Everflon™ Fluoropolymers have provided critical applications with unparalleled performance and durability. Today, the Everflon™ portfolio provides leading-edge solutions that create production and process improvements, ensure superior performance standards, & allow manufacturers to pursue new markets.





# ACADEMY



DRIVING INNOVATION

BUILDING A BETTER WORLD



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