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DuPont Vision, Mission and Core Values

**Vision**
To be the world’s most dynamic science company, creating sustainable solutions essential to a better, safer, healthier life for people everywhere.

**Mission**
To create shareholder and societal value while reducing the environmental footprint along the value chains in which we operate.

**Core Values**
The core values of DuPont are the cornerstone of who we are and what we stand for. They are:

- **Safety and Health**
  We adhere to the highest standards to ensure the health and safety of our employees, our customers, and the people of the communities in which we operate.

- **Environmental Stewardship**
  We protect the environment and strengthen our businesses by making environmental issues an integral part of all business activities. We continuously strive to align our actions with public expectations.

- **Highest Ethical Behaviour**
  We conduct our business affairs to the highest ethical standards and in compliance with all applicable laws. We work diligently to be a respected corporate citizen worldwide.

- **Respect for People**
  We foster an environment in which every employee is treated with respect and dignity, and is recognized for his or her contributions to our business.
A primary concern of any company or organization must be the quality of its products and services. In order to be successful, a company must offer products or services that:

- Meet a well defined need, use or purpose
- Satisfy customers’ expectations
- Comply with applicable standards and specifications
- Comply with statutory (and other) requirements of society
- Are made available – at competitive prices
- Are provided at a cost which will yield a profit

Trademark

Teflon® is a registered trademark of DuPont for its brand of Fluoropolymer resins, which can only be licensed by DuPont for use in approved applications.

Without a trademark license, customers may not identify their products with the Teflon® trademark or use the diamond logo, as DuPont Fluoropolymers are sold unbranded with DuPont codes only.

The oval trademark

The DuPont Oval is the corporate trademark for DuPont and identifies our company’s products and services. It is registered in virtually every country in the world in which DuPont does business, and has been in continuous use since 1907. Only DuPont and its wholly-owned subsidiaries, when licensed to do so, may use the mark in connection with the goods and services offered globally by our company.

Safety Precautions

Industrial experience has proven that adequate ventilation, in properly maintained processing and handling areas, will eliminate known hazards to personnel during processing and handling of Teflon®, Tefzel® and Zonyl® resins and dispersions.

Resin containers should be opened and used in well-ventilated areas. Equipment used to process at melt temperatures should be provided with local exhaust ventilation to completely remove all fumes and vapours from the processing area. In addition, care should be exercised to avoid the contamination of cigarettes and other forms of smoking tobacco when using Fluoropolymer resins.

Before using, personnel should read the Safety Data Sheet and the detailed information in "Guide for the safe handling of Fluoropolymer Resins” published by PlasticsEurope (Association of Plastics Manufacturers, Bruxelles).
Background

A bit of history…….

This waxy, white powder discovered in 1938 by Dr. Roy J. Plunkett (above) at the DuPont Jackson Laboratory – turned out to be one of the miracle materials of this age: better known as PTFE under the DuPont trademark Teflon® which was registered by DuPont since 1945.

The story of DuPont™ Teflon® brand began on April 6, 1938 at the DuPont Jackson Laboratory in New Jersey, where Dr. Roy J. Plunkett was researching new refrigeration gases. Upon checking a frozen sample of tetrafluoroethylene, he and his associates discovered that it had polymerized spontaneously to a white, waxy solid: polytetrafluoroethylene or PTFE.

Testing showed that PTFE was a remarkable material. It was resistant to almost every chemical and solvent, its surface was so slippery that virtually nothing would stick to it.

Moisture did not affect it, nor did it degrade after prolonged exposure to sunlight. In addition it had an unusually high melting point and molecular weight and, unlike conventional thermoplastics the resin would not flow above its melting point. Consequently PTFE could not be fabricated by conventional thermoplastic techniques.

Borrowing from powder metallurgy, DuPont engineers were able to convert Teflon® PTFE by compressing it into blocks that were then sintered and could be machined into desired shapes.

Subsequently aqueous dispersions of PTFE were developed to coat glass cloth and metal substrates. A special fine powder grade was invented that could be extruded as a lubricated paste and then sintered to coat wire and make tubing.

After the commercialization of Teflon® PTFE in the 1940s, new opportunities for Fluoropolymers were soon developed. This led to the need for a Fluoropolymer that would retain the unique and desirable properties of PTFE but which could be processed by normal thermoplastic conversion methods.

In 1960 DuPont introduced Teflon® FEP (fluorinated ethylene propylene, i.e. a copolymer of tetrafluoroethylene and hexafluoropropylene), the first fully fluorinated melt-processable polymer that could be melt-extruded and injection-moulded. Although some temperature resistance was sacrificed relative to PTFE, Teflon® FEP remained thermally much superior to most other plastics available at that time. Today it is widely used as electrical insulation for enhanced fire performance, high speed data communication cables and high temperature wiring for automotive and appliance applications.

In the 1960s however it became evident that a melt-processable Fluoropolymer was needed with higher strength and stiffness than those of PTFE and FEP resins.

In 1970 DuPont introduced Tefzel® ETFE Fluoropolymer, a modified copolymer of ethylene and tetrafluoroethylene. This polymer has high tensile strength and toughness, which makes it particularly suitable as a wire and cable insulation (rated at 115°C for 20 000 h continuous exposure). It is now extensively used in electrical systems in aircraft, cars, computers, telecommunication installations, down hole- and logging-cables, heating circuits and other electrical applications.

In 1972 DuPont introduced Teflon® PFA, a Fluoropolymer with excellent melt processability and properties rivaling those of PTFE.

Teflon® PFA (perfluoroalkoxy, i.e. a copolymer of tetrafluoroethylene and perfluorinated vinyl ether) offers high-temperature strength and stiffness and excellent stress-crack resistance. It also has the general characteristics of Teflon® PTFE, such as resistance to virtually all chemicals, low coefficient of friction and excellent dielectric properties. Today its main use is as lining for corrosion protection in the Chemical Processing Industry and for handling high purity chemicals in the Semiconductor Industry. Low molecular weight PTFE Micropowder also called PTFE Fluoroadditive is marketed by DuPont under the trademark Zonyl®. These micropowders are commonly used as additives in a wide variety of applications primarily as minority components in other solid or liquid materials to enhance lubricity, reduce wear and improve non-stick properties.

Teflon® AF, amorphous Fluoropolymers are the latest additions to the family of Fluoropolymers.

Preparation

The manufacture of tetrafluoroethylene (TFE) monomer involves the following steps:

\[
\begin{align*}
\text{CaF}_2 + H_2SO_4 & \rightarrow \text{CaSO}_4 + 2 \text{HF} \\
\text{CH}_4 + 3 \text{Cl}_2 & \rightarrow \text{CHCl}_3 + 3 \text{HCl} \\
\text{CHCl}_3 + 2 \text{HF} & \rightarrow \text{CHClF}_2 + 2 \text{HCl} \\
2 \text{CHClF}_2 & \rightarrow \text{CF}_2=\text{CF}_2 + 2 \text{HCl}
\end{align*}
\]
Product families

Product family of DuPont™ Fluoropolymers

**PTFE Fluoropolymers**
- Teflon® PTFE Granular moulding resins
- Teflon® PTFE Fine powders
- Teflon® PTFE Aqueous dispersions
- Zonyl® PTFE Fluoroadditives

**Melt-Processable Fluoropolymers**
- Teflon® FEP Resins & Dispersions
- Teflon® PFA Resins & Dispersions
- Tefzel® ETFE Resins
<table>
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<tr>
<th>Outstanding Properties of DuPont™ Fluoropolymers:</th>
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<tr>
<td>• CHEMICAL INERTNESS</td>
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<tr>
<td>• NON-STICK / SELF CLEANING</td>
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<tr>
<td>• LOW FRICTION / SELF-LUBRICATING</td>
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<td>• DIELECTRIC PROPERTIES</td>
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<tr>
<td>• WEATHER RESISTANCE / NON-AGEING</td>
</tr>
<tr>
<td>• INSENSITIVE TO UV</td>
</tr>
<tr>
<td>• NON-TOXIC</td>
</tr>
<tr>
<td>• BROAD TEMPERATURE RANGE (- 200°C / up to + 260°C)</td>
</tr>
<tr>
<td>• NON-FLAMMABLE</td>
</tr>
</tbody>
</table>

* Depending on product type
PTFE Fluoropolymers

Some Basics

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

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 percent) 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 (see picture page 8). 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 $10^6$ to $10^7$) resulting in an extremely high melt viscosity (1 to 100 GPa.s or 10$^{10}$ to 10$^{12}$ Pa). 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 DuPont in four main types i.e. Granular moulding 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.

1. DuPont™ Teflon® PTFE Granular moulding resins

PTFE Granular resins (also called moulding 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 moulding at ambient temperature followed by sintering above the crystalline melting point.

2. DuPont™ Teflon® PTFE Fine powders

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

3. DuPont™ Teflon® 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 up to 60 weight % 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 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 avoid the dripping of burning droplets in case of a fire.

4. DuPont™ Zonyl® PTFE Fluoroadditives

Zonyl® PTFE Fluoroadditives are finely divided, free flowing white powder of polytetrafluoroethylene (PTFE) resin. They are a separate and distinctive product line, very different from the well-known Teflon® PTFE moulding and extrusion powders. The differences include:

- Lower molecular weight (in range of 2.5x10$^4$ to 25x10$^4$)
- Smaller particles sizes (2 to 20 μm)
- Different particle shapes and morphology

Zonyl® 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, enhanced abrasion resistance. The product range offers a choice of particle size and morphology to facilitate intimate mixing with dissimilar materials.

* See trademark disclaimer notice on page 46.
Melt-Processable Fluoropolymers

Some Basics

The need for resins with the outstanding properties of polytetrafluoroethylene (PTFE) but capable of being fabricated by conventional melt processing led to the development of a range of melt-processable Fluoropolymers such as fully-fluorinated FEP and PFA resins and partially-fluorinated ETFE resins.

This family of copolymers can be processed by conventional thermoplastic methods such as melt extrusion, injection moulding, transfer moulding and rotational moulding. Typical melt viscosities range from $1 \times 10^4$ to $45 \times 10^4$ P ($1$ to $45 \times 10^3$ Pa.s).

DuPont™ Teflon® FEP Resins

FEP (Perfluorinated ethylene-propylene) resin is a copolymer of tetrafluoroethylene (TFE) and hexafluoropropylene (HFP). It retains most of the desirable characteristics of polytetrafluoroethylene (PTFE) but with a melt viscosity low enough for conventional melt processing.

The melting point of FEP is about 260°C versus a first melting point of PTFE of about 340°C. Continuous service temperature of FEP is 205°C as compared to 260°C for PTFE.

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), 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; but 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.

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

DuPont™ Teflon® PFA Resins

PFA (Perfluoroalkoxy) resin is a copolymer of tetrafluoroethylene (TFE) and perfluorovinyl ether. PFA is melt-processable with a melting point at about 305°C.

Continuous service temperature is equal to that of PTFE i.e. 260°C.

PFA offers the excellent combination of properties characteristic of Teflon® Fluoropolymers: non-ageing, chemical inertness, exceptional dielectric properties, toughness and flexibility, low coefficient of friction, non-stick characteristics, negligible moisture absorption and excellent weather and UV resistance.

Chemically modified grades of PFA are available. These grades, identified as Teflon® PFA HP, combine the properties of standard PFA with enhanced purity and improved thermal stability in processing. The enhanced purity of Teflon® PFA HP makes it particularly suitable for applications that require improved colour and lower extractable ions.

Teflon® PFA HP Plus is similar to PFA HP with the additional benefit of improved flex life, enhanced smoothness and chemical stress crack resistance.

Teflon® C PFA offers electrical conductivity to dissipate static electricity.

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

DuPont™ Tefzel® ETFE Resins

Tefzel® ETFE resin is a modified copolymer of tetrafluoroethylene (TFE) and ethylene. ETFE is melt-processable and is mechanical tougher and stiffer with higher cut-through, abrasion and creep resistance than PTFE, FEP or PFA resins.

The chemical, dielectric and thermal properties are approaching those of the fully-fluorinated Teflon® 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 Teflon® and improved radiation resistance. Tefzel® ETFE is suitable for continuous service up to 155°C based on the standard 20 000 h criterion.

* See trademark disclaimer notice on page 46.
Properties of DuPont™ Teflon® Fluoropolymers

(The properties enumerated are representative for the family of DuPont Fluoropolymers i.e. Teflon® PTFE, Teflon® FEP, Teflon® PFA, Tefzel® ETFE)

Chemical Inertness / Solvent Resistance
Fully fluorinated Fluoropolymers (PTFE, FEP, PFA) are virtually inert to the most aggressive organic and inorganic chemicals and solvents over a wide temperature range.

Chemical inertness means that Teflon® 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:

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

Within normal use temperatures Teflon® 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. aluminium 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 (F₄) and related compounds like chlorine trifluoride (ClF₃)
- 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 Tefzel® 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 Tefzel® resin.
**Mechanical Properties**

**Tensile strength** properties over a wide temperature range are shown on attached graph measured on grades representative for the different DuPont™ Fluoropolymer families.

Tefzel® ETFE is tougher than fully fluorinated Fluoropolymers grades at low and ambient temperatures. At higher temperatures the lines converge and above 120°C PTFE and PFA have higher tensile strength than both ETFE and FEP.

**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 Teflon® 62™ 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.”

Tefzel® ETFE being a tougher material than Teflon® PTFE, FEP or PFA Fluoropolymers is more creep resistant.

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 fibre reinforced with Tefzel® resin has only 1/5 of the deformation under load of an un-reinforced ETFE.

![Tensile strength as function of temperature](image)

* High molecular weight polymers
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.

Dielectric properties

Teflon® 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.

The dissipation factor is affected by signal frequency, operating temperature and by chemical composition, crystallinity and void content of the insulation. At room temperature the dissipation factor of Teflon® 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 (10^10 - 20 x 10^10 Hz) when tested at room temperature. The peak dissipation factor is around 0.0003. PFA peaks at 0.0001 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 (see graph).

Tefzel® 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 Teflon® and Tefzel®.

The dielectric strength (tested in oil) of Teflon® and Tefzel® ETFE is high and unaffected by thermal aging at temperatures up to 200°C. Service life at high dielectric stress is dependent on corona discharge.

Volume resistivity is above 10^16 Ω.m (for ETFE above 10^14 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.

Surface Arc Resistance of Teflon® resins is high and is not affected by heat-aging. When Teflon® 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 D 495, Teflon® PTFE and FEP resins pass the maximum time of 300 seconds without failure.

No tracking was observed with PFA for the duration of the test (test was stopped after 180 s without any sign of tracking). Tefzel® ETFE has a Dry Arc Resistance of about 70 seconds.
Weather / UV Resistance

Teflon® and Tefzel® Fluoropolymers are extremely hydrophobic, and sheds water almost totally. A moisture absorption of < 0,03% has been reported after 24 h in water at room temperature followed by 2 h 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 Teflon® PTFE, FEP & PFA® and Tefzel® ETFE Fluoropolymers are fully weather resistant (see note). Results show neither ageing nor embrittlement. Since no plasticizers, anti-oxidants or other additives are used during its processing there is no leaching out of substances.

Note: With the exception of glass fibre reinforced with Tefzel® resin which was affected in accelerated weathering resistance testing.

Temperature Resistance (-200°C up to +260°C)

Teflon® and Tefzel® Fluoropolymers are extremely stable at high temperatures, PTFE and PFA can be used continuously at 260°C, FEP at 205°C and ETFE at 155°C. At those temperature at least 50% of their respective and original mechanical properties are retained after 20 000 hours (according ISO 2578 and IEC 60216). At cryogenic temperatures these products retains a measure of toughness and strength. PTFE has been used safely in outer space at temperatures approaching absolute zero.

Flammability

Teflon® PTFE, FEP and PFA® are essentially non-flammable. They will sustain combustion only in an environment containing > 95% oxygen (Oxygen Index). The flash point is 530°C. Tefzel® ETFE has an Oxygen Index of 30. PTFE, FEP, PFA and ETFE are rated by Underwriters Laboratories Inc. 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 DuPont™ 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 D 635 is ATB (Average Time of Burning) < 5 s and AEB (Average Extent of Burning) < 10 mm.

These properties make Fluoropolymers in particular useful in applications where fire hazards must be kept to a minimum.
DuPont™ Teflon® PTFE Granular moulding resins

Granular PTFE moulding 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 polymers is then ground to small particles sizes.

These finely divided particles allow for moulding 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 (pelletization) 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**

<table>
<thead>
<tr>
<th>Basic grades</th>
<th>Main characteristics</th>
<th>Major uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finely divided resin (fine cut)</td>
<td>Non-free flowing, medium fill density, high property resin, low preform pressure</td>
<td>Compounding, high quality skived tape billets</td>
</tr>
<tr>
<td>Mildly pelletized resin</td>
<td>Moderate flow, high fill density, high property resin, medium preform pressure</td>
<td>High quality skived tape billets, Compression and isostatic moulding sheet moulding, bearing pads</td>
</tr>
<tr>
<td>Free-flowing resin (pelletized)</td>
<td>Free-flowing, very high fill density, high preform pressure</td>
<td>Automatic moulding, compression moulding, ram extrusion at low back-pressure</td>
</tr>
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<table>
<thead>
<tr>
<th>Modified grades</th>
<th>Main characteristics</th>
<th>Major uses</th>
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<tr>
<td>Modified, finely divided resin</td>
<td>Non-free flowing, medium fill density, high property resin, low preform pressure</td>
<td>Compounding, high quality skived tape billets, sheet moulding</td>
</tr>
<tr>
<td>Modified, free-flowing resin (pelletized)</td>
<td>Free-flowing, high fill density, high preform pressure</td>
<td>Compression and isostatic moulding sheet moulding, bearing pads.</td>
</tr>
</tbody>
</table>
Processing

Due to the extremely high viscosity above its melting point, PTFE, can not be processed using normal thermoplastic techniques. PTFE Granular moulding resins are processed by modified powder metallurgy techniques. In this technique, commonly known as compression moulding, 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 mould 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.

Compression moulding can be divided into:

➔ General compression moulding
➔ Sheet moulding
➔ Big billet moulding
➔ Automatic moulding
➔ Isostatic moulding

Ram extrusion is a way of manufacturing continuous length of rods, tubes or profile by feeding successive charges of PTFE powder to a die tube, a reciprocating ram is compacting the powder. Subsequent charges are then compressed onto each other and are forced by the ram through the die tube that is heated above the melting point of PTFE where the PTFE particles and the individual charges are sintered together.

Details of these processes can be found in DuPont brochures “Compression Moulding of Teflon® PTFE®” and “The Ram Extrusion of Teflon® PTFE”.

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
PTFE Fine powders are made by polymerizing TFE in an aqueous medium (sometimes called emulsion polymerization). The primary PTFE dispersion particles thus formed have an average particle size of 0.2 micrometer. This raw dispersion is coagulated into 350 to 650 μm agglomerates. The agglomerates are then dried gently, avoiding any shearing.

This “spongy” agglomerate has a very high specific surface area (> 10 m²/g) and can absorb low surface tension liquids (lubricants). A unique property of PTFE fine powders is that under the effect of shearing the particles become oriented in the shearing direction and are drawn into long thin fibres. This effect, called fibrillation, is used in the “paste extrusion” process whereby the coherent fibrous matrix thus formed gives structural integrity to the extrudate (green strength) before it is sintered.

The various grades of fine powders differ in molecular weight and molecular structure, extrusion pressure and reduction ratio capability and are chosen primarily on the basis of available processing equipment and end-use requirements.

Modified grades containing small amounts of other fluoromonomers have been developed. These polymers offer unique processing and end-use properties such as a wider processing “window,” superior fatigue resistance for demanding high performance applications (i.e. automotive or aerospace hose), more clarity, lower permeability as well as, in some cases, weldability.

* See trademark disclaimer notice on page 46.
## Grade selection

<table>
<thead>
<tr>
<th>Final product</th>
<th>Processing capability</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wire and Cable</strong></td>
<td>High reduction ratio (1500:1 – 5000:1)</td>
<td>Hook-up wire, automotive wiring</td>
</tr>
<tr>
<td></td>
<td>Medium reduction ratio (300:1 – 2000:1)</td>
<td>Heating cable, appliance wiring</td>
</tr>
<tr>
<td></td>
<td>Low reduction ratio (&lt; 100:1 – 300:1)</td>
<td>Coaxial cables, electrical grade tape</td>
</tr>
<tr>
<td><strong>Hose and Tubing</strong></td>
<td>High reduction ratio (&gt; 1000:1)</td>
<td>Spaghetti tubing, catheter</td>
</tr>
<tr>
<td></td>
<td>Low/Medium reduction ratio (&lt; 100:1 – 1000:1)</td>
<td>Unsupported industrial tubing, catheter, convoluted tubing, heat-shrinkable tubing</td>
</tr>
<tr>
<td></td>
<td>High performance, high flex. life</td>
<td>Aircraft hose, generator hose, automotive tubing, bellows</td>
</tr>
<tr>
<td><strong>Lined pipe and Fittings</strong></td>
<td>Large diameter (&gt; 250 mm)</td>
<td>Pipe liners, column liners</td>
</tr>
<tr>
<td></td>
<td>Low reduction ratio</td>
<td>Pipe liners, fittings, bellows</td>
</tr>
<tr>
<td><strong>Unsintered products</strong></td>
<td>Low reduction ratio (20:1 – 100:1)</td>
<td>Thread seal tape, cords, gaskets</td>
</tr>
<tr>
<td><strong>Additive</strong></td>
<td>Free flowing</td>
<td>Drip suppressant in thermoplastics</td>
</tr>
</tbody>
</table>
Processing

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 a shaped orifice to form a coating on a wire, a tubing, a beading or a 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 un-sintered (e.g. thread sealant tape, sealing cord).

Details of these processes thread sealant tape, sealing cord can be found in DuPont brochures “Paste extrusion of PTFE fine powder” and “Processing Guide for Fine Powder Resins”.

Typical Applications

➔ Automotive sensor wires
➔ Coaxial cables for Radio Frequency
➔ Seat heating wiring
➔ Appliance wiring
➔ Aircraft wiring
➔ Wire conduits
➔ Chemical transfer hose & tubing,
➔ Convoluted tubing
➔ Tubing, small diameter tubing, chromatography tubing, heat shrinkable tubing
➔ Lined pipe & fittings
➔ Heat exchanger tubing
➔ Hydraulic hose
➔ Fuel tubing – aircraft, automotive
➔ Push-pull cable liner
➔ Gaskets, sealants
➔ Filters, membranes
➔ Monofilaments, fibres
➔ Profiles
DuPont™ Teflon® PTFE Aqueous dispersions

PTFE Aqueous dispersions are milky white liquids consisting of hydrophobic, negatively charged submicrometer particles of polytetrafluoroethylene resin suspended in water. The most common dispersion has an average particle size of 0.2 micrometer (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 Teflon® PTFE resins are not suitable for processing in molten or dissolved form.

Grades

<table>
<thead>
<tr>
<th>Grades</th>
<th>Main characteristics</th>
<th>Major uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>General purpose</td>
<td>Ease of handling, good wetting</td>
<td>Impregnation of yarns for gaskets and packing</td>
</tr>
<tr>
<td>Fabric coating</td>
<td>High build-up, surface smoothness, weldability, good wetting, low foam, shear stable,</td>
<td>Coated architectural fabrics, coated glass fabric for belting, flexible wiring boards, Cast film</td>
</tr>
<tr>
<td>(glass fibre, Kevlar® aramid fibre, Nomex® fibre)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metal coating</td>
<td>Film forming, good properties at high temperature, impermeable, high critical cracking thickness (CCT)</td>
<td>Coatings for industrial and cookware applications</td>
</tr>
<tr>
<td>Specialties</td>
<td>Wetting, good fixation, high temperature, long lasting</td>
<td>High-performance, woven glass fibre filter bags, bearings</td>
</tr>
<tr>
<td>Additive</td>
<td>Homogeneous, ease of handling</td>
<td>Drip suppressant in thermoplastics, binder in batteries</td>
</tr>
</tbody>
</table>
Processing

Uses for 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 Teflon® 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 PTFE dispersion. The dispersion is well-suited for impregnation because of its low viscosity, extremely small particles and the effect of the surfactant, which aids in wetting the surfaces and promotes capillary action.

Details of these processes can be found in DuPont brochures “DuPont Fluoroproducts – Dispersion Properties and Processing Guide”.

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
➔ Fibres
➔ Binders for disposable or rechargeable batteries
DuPont™ Zonyl® PTFE Fluoroadditives*

Zonyl® fluoroadditives are part of the DuPont 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 the very small particle size, typically in the range of 2 to 20 µm, low molecular weight and the way they are handled and processed. Zonyl® MP fluoroadditives can be used over a wide range of temperatures from -190 to 250 °C and depending on the application, may provide non-stick properties, improved lubricity, better wear resistance and reinforcing properties.

Depending on the material, Zonyl® fluoroadditives can enhance abrasion resistance, reduce coefficient of friction and mechanical wear, reduce surface contamination, and modify appearance of the host material. Zonyl® 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, Zonyl® 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, Zonyl® fluoroadditives are not to be used as molding or extrusion powders. Unlike some other micropowders on the market that are based on reprocessed PTFE, DuPont™ Zonyl® fluoroadditives are manufactured from virgin PTFE or are directly polymerized, hence a better uniformity and inherent cleanliness.

Grades

<table>
<thead>
<tr>
<th>Grades</th>
<th>Main characteristics</th>
<th>Major uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granular PTFE based</td>
<td>Low specific surface area (2.3–4.5 m²/g), non-agglomerated powder.</td>
<td>Thermoplastics, printing inks, coatings</td>
</tr>
<tr>
<td>Fine powder PTFE based</td>
<td>High specific surface area (5–11 m²/g), Friable agglomerates of small (0.2 µm) primary particles.</td>
<td>Thermoplastics, elastomers, coatings, lubricant &amp; greases</td>
</tr>
<tr>
<td>As-polymerized PTFE</td>
<td>High specific surface area (8–12 m²/g), Friable agglomerates of small (0.2 µm) primary particles. Low level of active end groups. In compliance with FDA regulations.</td>
<td>Elastomers, printing inks, coatings, coil coating, greases</td>
</tr>
<tr>
<td>Aqueous dispersion</td>
<td>Milky, white, 59 to 61% solids dispersion of 0.2 µm PTFE particles, stabilized with non-ionic wetting agent.</td>
<td>Additive for paints, coatings, Mould release</td>
</tr>
</tbody>
</table>

* See trademark disclaimer notice on page 46.
Zonyl® fluoroadditive powders are popular because they can contribute some of their unique properties to the host material to which they are added. However, the suitability of an additive powder for mixing with and enhancing a given host is determined by many other factors, including:

- Size, distribution, and form of the particles
- Lot-to-lot uniformity
- Dispersibility
- Surface area
- Colour retention
- Contamination
- FDA compliance/EEC Food Approval

For example, particle characteristics of an additive powder can affect both the process and the performance of products made from the additive. If the particles are too small or too large, surface defects may appear in molded thermoplastic parts. Ink formulations favor a narrow distribution of relatively small particles which remain stable and uniformly distributed during processing.

Because of the careful selection of base materials, uniformity is a major feature of Zonyl® fluoroadditives. Other powders, even with ideal particle size, distribution, and other powder characteristics can cause problems if they are either not uniform from lot to lot or are contaminated.

The results of particle size and distribution measurements can depend a great deal on sample preparation and test methods. Data should, therefore, be accompanied by a detailed definition of the test method used. For example, the Coulter Counter makes electrical measurements on a dispersion of powder particles in a solution of electrolyte and it consistently yields smaller values than the L&N MICROTRAC II which makes optical measurements on a laser beam, forward scattered through a dispersion of powder particles. Both methods assume spherical particles and measure on a volume basis.

No Universal Formulas

The plastics, inks, and elastomers industries produce a vast array of products using a countless variety of processes. An additive used in these industries may end up in a molten plastic, a complex aqueous or solvent formulation of ink, or an elastomer being milled or cured at high temperature. Even small differences in host materials or processes may require different powder characteristics for best results. For these reasons, only general guidelines can be proposed for such diverse applications. The multiple product grades DuPont offers are designed to provide just the right combinations of powder characteristics to meet the needs of diverse products and processes.

Details of these products and their processing can be found in DuPont brochure “Zonyl® fluoroadditives: A Minor Component... A Major Enhancement”.

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 mould 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
DuPont™ Teflon® FEP Resins*

Teflon® FEP is a fluorinated ethylene propylene resin that meets the requirements of ASTM D 2116 “Standard Specification for FEP-Fluorocarbon Molding and Extrusion Materials.” It is available as pellets or as stabilized aqueous dispersions. Applications for this family of resins include melt extrusion, injection moulding, transfer moulding, coating, and impregnating. Products made from Teflon® FEP are known for their excellent chemical resistance, superior electrical properties, and high service temperatures of up to 205 °C based on the 20 000 h criterion and meet the requirements of International Standard ISO 6722 class G (-40 °C to +225 °C) –Road vehicles – 60 V and 600 V single-core cables. In addition, Teflon® FEP provides outstanding low-temperature toughness and unique flame resistance.

FEP compounds are available with proprietary and patented foam nucleants added for physical foaming e.g. for foamed coaxial cable dielectrics (to achieve low attenuation, low dielectric heating, high speed of propagation).

Grades

<table>
<thead>
<tr>
<th>Grades</th>
<th>Main characteristics</th>
<th>Major uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>General purpose</td>
<td>High productivity, MFR 5 – 7 g/10 min</td>
<td>Wire insulation (≤ 2 mm diameter), tubing, injection moulded parts</td>
</tr>
<tr>
<td>Optimum output-performance</td>
<td>Optimized productivity and stress-crack resistance balance MFR 4 – 10 g/10 min</td>
<td>Wire and cable insulation and jackets</td>
</tr>
<tr>
<td>High productivity</td>
<td>Highest stress-crack resistance, MFR ≤ 5 g/10 min</td>
<td>(≥ 2 mm diameter), tubing</td>
</tr>
<tr>
<td>High output</td>
<td>Maximum productivity MFR &gt; 20 g/10 min</td>
<td>Films, chemical linings, high stress applications</td>
</tr>
<tr>
<td></td>
<td>Modified FEP, low dissipation factor</td>
<td>Small wire and cable insulation (≤ 1.0 mm diameter), injection moulded parts</td>
</tr>
<tr>
<td>Foam resins</td>
<td>Nucleating system compounded resins</td>
<td>Foamed cable insulations, high-frequency data cable with minimum distortion</td>
</tr>
<tr>
<td>Aqueous dispersion</td>
<td>Ease of handling, wetting</td>
<td>Top coat on wiring or architectural fabric</td>
</tr>
</tbody>
</table>

* See trademark disclaimer notice on page 46.
Processing

Teflon® FEP Fluoropolymer resins are processed by conventional melt-extrusion techniques and by 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 draw-down 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 moulding reciprocating screw designs are recommended.

Details of these processes can be found in DuPont brochures “Teflon®/Tefzel® Fluoropolymer Melt Extrusion Guide”, “Teflon®/ Tefzel® Fluoropolymer Transfer Moulding Guide” and “Injection Moulding Guide for Melt Processable Fluoropolymers”.

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 lamps covering
➔ Architectural fabrics (top coat)
DuPont™ Teflon® PFA Resins

Teflon® PFA is a perfluoroalkoxy copolymer resin that meets the requirements of ASTM D 3307 “Standard Specification for Perfluoroalkoxy (PFA)-Fluorocarbon Resin Molding and Extrusion Materials.” It is available as pellets, powder or aqueous dispersion.

Teflon® PFA combines the processing ease of conventional thermoplastic resins with the excellent properties of Teflon® polytetrafluoroethylene (PTFE). Products manufactured from Teflon® PFA can offer continuous service temperatures up to 260 °C. Teflon® PFA provides superior creep resistance at high temperatures, excellent low-temperature toughness, and exceptional flame resistance.

The range of Teflon® PFA HP and PFA HP Plus grades have been designed specifically for critical-purity processes where enhanced purity and improved thermal stability during processing are key requirements. PFA HP Plus has as additional benefits the improved resistance to repeated flexing and to stress cracking. Furthermore, PFA HP Plus yields parts with very smooth as processed surfaces and outstanding optical clarity.

### Grades

<table>
<thead>
<tr>
<th>Grades</th>
<th>Main characteristics</th>
<th>Major uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>General purpose</td>
<td>High speed extrusion, high productivity, Low molecular weight, MFR 20 – 30 g/10 min</td>
<td>Small gauge wire coating, injection moulding</td>
</tr>
<tr>
<td></td>
<td>Extrusion and injection moulding resin, Intermediate molecular weight, MFR 9 – 19 g/10 min</td>
<td>Wire and cable insulation and jacketing, injection or blow-moulded articles, tubing extrusion.</td>
</tr>
<tr>
<td></td>
<td>Extrusion and injection moulding resin, Intermediate molecular weight, higher stress crack resistance MFR 4 – 6 g/10 min</td>
<td>Tubing extrusion, injection or blow-moulded articles, chemical linings</td>
</tr>
<tr>
<td></td>
<td>Highest resistance to stress cracking, High molecular weight, MFR 1.6 – 2.3 g/10 min</td>
<td>Lining of components for Chemical Processing Industry, transfer moulded articles, tubing extrusion</td>
</tr>
<tr>
<td>High Purity (HP)</td>
<td>Premium resin with lowest level of extractables, Low molecular weight, maximum productivity, MFR 20 – 40 g/10 min</td>
<td>Low loss, small diameter data cables, small injection moulded parts for high-purity applications</td>
</tr>
<tr>
<td></td>
<td>Premium resin with the lowest level of extractables Low molecular weight, MFR 12 – 19 g/10 min</td>
<td>Fluid handling components for critical high-purity processes like semiconductor, pharmaceutical- and biotechnology</td>
</tr>
<tr>
<td></td>
<td>Premium resin with the lowest level of extractables Intermediate molecular weight, higher stress crack resistance, MFR 4 – 7 g/10 min</td>
<td>Fluid handling components for critical high-purity processes like semiconductor, pharmaceutical- and biotechnology</td>
</tr>
<tr>
<td></td>
<td>Premium resin with the lowest level of extractables High molecular weight, high stress crack resistance MFR 1.7 – 2.3 g/10 min</td>
<td>Fluid handling components for critical high-purity processes like semiconductor, pharmaceutical- and biotechnology</td>
</tr>
</tbody>
</table>

* See trademark disclaimer notice on page 46.
<table>
<thead>
<tr>
<th>Grades</th>
<th>Main characteristics</th>
<th>Major uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultra High Purity (HP Plus)</td>
<td>Premium resin with the lowest level of extractables, improved flex life and stress crack resistance, MFR 10 – 20 g/10 min</td>
<td>Fluid handling components for critical high-purity processes like semiconductor, pharmaceutical- and biotechnology</td>
</tr>
<tr>
<td></td>
<td>Premium resin with the lowest level of extractables, improved flex life and stress crack resistance, MFR 5 – 9 g/10 min</td>
<td>Fluid handling components for critical high-purity processes like semiconductor, pharmaceutical- and biotechnology</td>
</tr>
<tr>
<td></td>
<td>Premium resin with the lowest level of extractables, improved flex life and highest stress crack resistance, MFR 1.0 – 3.0 g/10 min</td>
<td>Fluid handling components for critical high-purity processes like semiconductor, pharmaceutical- and biotechnology</td>
</tr>
</tbody>
</table>

**Special Purpose Grades:**

- **Rotational moulding resin**: Premium resin in powder form, with the lowest level of extractables, improved flex life and stress crack resistance, MFR 5 – 8 g/10 min
  - Pump housing, containers, fittings with unusual shapes for handling of high purity chemicals

- **Anti-static**: Static dissipating semi-conductive resin
  - Lined components for CPI

- **Aqueous dispersion**: Ease of handling, wetting
  - Top coat on wiring and architectural fabric

**Processing**

Teflon® PFA fluoropolymer resins are processed by conventional melt-extrusion techniques and by 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, which increase processing rates. For injection moulding 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 the required processing temperatures.

Details of these processes can be found in DuPont brochures “Teflon®/Tefzel® Fluoropolymer Melt Extrusion Guide,” “Teflon®/Tefzel® Fluoropolymer Transfer Moulding Guide” and “Injection Moulding Guide for Melt Processable Fluoropolymers.”

**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 & convoluted tubing
  - Heat shrinkable tubing
  - Architectural fabrics
DuPont™ Tefzel® ETFE Resins

DuPont™ Tefzel® is a modified ETFE (ethylene-tetrafluoroethylene) fluoropolymer that meets the requirements of ASTM D 3159 “Standard Specification for Modified ETFE-Fluoropolymer Molding and Extrusion Materials”. Available as pellets or as powder for rotational molding. Tefzel® fluoropolymer or ETFE combines superior mechanical toughness with an outstanding chemical inertness that approaches that of Teflon® fluoropolymer resins. Tefzel® features easy processibility, a specific gravity of 1.7, and high-energy radiation resistance. Most grades are rated for continuous exposure at 150 °C, based on the 20 000 h criterion and meet the requirements of International Standard ISO 6722 class F (-40 °C to +200 °C) –Road vehicles – 60 V and 600 V single-core cables.

Tefzel® ETFE is also available in 25% glass-fibre reinforced composition and as an anti-static grade as well as functionalised grades for applications that require bonding to other polymers.

Grades

<table>
<thead>
<tr>
<th>Grades</th>
<th>Main characteristics</th>
<th>Major uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>General purpose</td>
<td>General purpose resin of intermediate molecular weight. MFR 3 – 14 g/10 min*</td>
<td>Wire &amp; cable insulation and jacketing, injection-moulded components, films, tubing</td>
</tr>
<tr>
<td></td>
<td>General purpose resin of intermediate molecular weight with improved stress crack resistance. MFR 5 – 7 g/10 min*</td>
<td>Films, tubing, injection-moulded articles, wire &amp; cable insulation and jacketing, down-hole logging cable, components for chemical industry</td>
</tr>
<tr>
<td>High output</td>
<td>Maximum productivity MFR &gt; 25 g/10 min*</td>
<td>Small wire &amp; cable insulation, (0.5 mm and smaller), thin wall extrusion, injection-moulded parts.</td>
</tr>
<tr>
<td>Appliance wiring grade</td>
<td>Higher temperature rating, more flexible MFR 5 – 10 g/10 min*</td>
<td>Appliance wiring UL Style 10412-600 V 200 °C</td>
</tr>
</tbody>
</table>

**Special Purpose Grades:**

| Rotational moulding resin | Premium grade resin in powder form, designed for use in rotational moulding, MFR 20 g/10 min* | Pump housing, containers, fittings, pipe sections with unusual shapes for handling of chemicals |
| Anti-static               | Static dissipating semi-conductive resin | Lined components for CPI, extruded tubing, hose and pipe |
| Functionalised resin      | Grafted ETFE promoting adhesion between ETFE resins and polyamide resins | Multi-layer fuel hose |

* Measured according ISO 12086 at 297 °C
Processing

Tefzel® ETFE fluoropolymer resins are processed by conventional melt-extrusion techniques and by 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 Teflon® FEP and PFA. Reciprocating screw injection molding machines are preferred. For long-term 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 high-temperature resins.

Details of these processes can be found in DuPont brochures “Teflon®/Tefzel® Fluoropolymer Melt Extrusion Guide,” “Teflon®/Tefzel® Fluoropolymer Transfer Moulding Guide” and “Injection Moulding Guide for Melt Processable Fluoropolymers”.

Typical Applications

➔ Automotive wiring
➔ Aerospace wiring
➔ Heating cable
➔ Appliance wiring
➔ Down hole cables & tubing
➔ Valves, valve seats
➔ Seals
➔ Pumps
➔ Column packing
➔ Flow meters
➔ Tubing
➔ Architectural films
➔ Release films
Major End-Use Industry Segments

- Chemical Processing Industry (CPI)
- Pharmaceutical/Biotechnology
- Food Processing
- Oil & Gas
  - DuPont™ StreaMax™ coatings
- Automotive
- Aerospace
- Semiconductor
- Cabling Solutions
- Electronics/Electrical
- Construction
- General Industry
- Additives
Chemical Processing Industry (CPI)

Benefits:
Sustainable Solutions against equipment failures due to corrosion cause leakages, emissions, reduced processing efficiencies, increased equipment costs and production delays in chemical production and processing operations.

Components made of Teflon® and Tefzel® fluoropolymer resins offer outstanding Corrosion Resistance over a wide temperature range, more universal and more economical than exotic metals or metal alloys.

Corrosion protection of equipment resulting in longer life, less unscheduled downtime and reduced risk of uncontrolled emission allowing for longer maintenance intervals.

Special grades of DuPont™ Fluoropolymers have been developed to meet ATEX directive.

Fluoropolymers are non-brittle, resistant to mechanical- and thermal-shocks.

Low coefficient of friction assures ease of operation in moving parts such as ball and plug valves. The inherent anti-stick properties of Fluoropolymers resist residue buildup and makes clean-up easy.

Typical Applications:
➔ Seals, O-rings, gaskets, braided packing
➔ Mechanical seals
➔ Valve seats, valve stem packing
➔ Lined valve, fittings, pumps
➔ Sight glasses, flow meters
➔ Lined pipes, dip pipes, columns, tanks
➔ Expansion joints, bellows
➔ Hose, tubing, convoluted tubing
➔ Filters, demisters, strainers
➔ Column packing
➔ Heat exchanger tubing and lining
➔ Trace heating cables
Pharmaceutical/Biotechnology

Benefits:
• The broad chemical compatibility and resistance to biofilm buildup of DuPont™ Teflon® PTFE* allows the protection of product quality and higher productivity to meet demands for increased product purity, easier cleanability, improved durability and low maintenance costs.
• Corrosion resistance over a wide temperature range, more universal and more economical than exotic metal alloys allowing equipment to make a wider range of products.
• No byproducts of corrosion to contaminate products or processes.
• No need for passivation or electro-polishing.
• Faster, easier cleaning (meets EHEDG Cleanability requirements), Cleaning in place, Steaming in place.
• Minimize drug adhesion.
• Negligible absorption of chemicals.
• Seamless weldability.
• Non-brittle, resistant to mechanical- and thermal-shocks, flexible and long-term resistant to vibrations.
• Biocompatible (USP Class VI).
• Compliant with FDA and EU requirements.
• High purity, extremely low extractable level, prevents contamination of critical chemicals and biological fluids.
• Meets drinking water requirements.
• UV resistance.

Typical Applications:
➔ Pipes, fittings, couplings, expansion joints, bellows
➔ Valves, pumps
➔ Seals, O-rings, gaskets, valve seats
➔ Sight glasses, flow meters
➔ Tanks, containers
➔ Transfer hose, tubing, convoluted tubing
➔ Small diameter tubing, multi-lumen tubing
➔ Filters, strainers
➔ Labware, trace analyzers, dispensers, bottles, screw-caps, beakers, chromatography tubing
➔ Sterilization units, Virus inactivation systems

Caution
DO NOT USE DUPONT MATERIALS IN MEDICAL APPLICATIONS INVOLVING PERMANENT IMPLANTATION IN THE HUMAN BODY. For other medical applications see “DuPont Medical Caution Statement”.

* See trademark disclaimer notice on page 46.
Food Processing

Benefits:
• The non-stick performance, chemical inertness and exceptional purity of DuPont™ Fluoropolymers are the best ways to keep food processing equipment running smoothly and profitable.
• Components and linings made with Teflon® PTFE help to cut maintenance costs, increase uptime, increase throughput, safeguard product purity and allow use of same equipment over a wide range of food products (multi-purpose plant operation).
• Corrosion resistance over a wide temperature range, more universal and more economical than exotic metal alloys.
• No chemical interaction or corrosion with foods to compromise taste or create contamination. No absorption of common food preservatives.
• Extremely low extractables and reactivity plus high purity.
• FDA/European Directive Compliant.
• Approved for Potable Drinking Water applications.
• Non-stick, easy release. Equipment surfaces are easy to clean and remain clean longer.
• Faster, easier cleaning (meets EHEDG Cleanability requirements), cuts downtime for cleaning.
• Resists onset of biological film formation.
• Reduces chemical usage for cleaning.
• Excellent steam and chemical sterilization performance (CIP, SIP).
• The use of Fluoropolymers in shatterproof coatings for fluorescent light tubes reduces the risk of glass contamination in food chain.

Typical Applications
➔ Conveyor belts
➔ Baking liners
➔ Industrial bakeware
➔ Non-stick metal coatings
➔ Seals, gaskets, packing, valve seats
➔ Valves, fittings, pumps
➔ Sight glasses, flow meters
➔ Pipes, columns, tanks, vessels
➔ Expansion joints, bellows
➔ Hose, tubing
➔ Filters, strainers
➔ Dispensers, containers
➔ Shatterproof lamps

PTFE coated glass fabric conveyor belt for food processing
Shatter proof lamp with PFA coating
Teflon® PTFE bellows for bottling of beverages
DuPont™ Teflon® non-stick coatings system for bakeware and cookware
Oil & Gas

Benefits:

Working in oil and gas refineries, pipelines as well as the downhole environments can prove environmentally challenging. Products made with Teflon® and Tefzel® Fluoropolymers have exceptional resistance to high temperatures, chemical reaction, corrosion, and stress-cracking which results in higher MTBF (Mean Time Between Failures).

Chemical resistance offered by Fluoropolymers is more universal and more economical than most exotic metal alloys.

Non-stick, easy of cleaning. Very few solid substances will permanently adhere to surfaces of Teflon® coatings reducing significantly build-up of asphaltenes, paraffins and scale, thus yielding enhanced flow of liquids and gases. Although tacky materials may show some adhesion almost all substances release easily.

Low coefficient of friction. The coefficient of friction of Teflon® PTFE is among the lowest of any solid material. This combined with the chemical and temperature resistance makes it the product of choice for slide bearings, seals and gaskets.

Unique electrical properties over a wide service temperature range. Allowing for down sizing of cables used under extreme conditions (e.g. down hole).

Based on these properties, Fluoropolymers bring solutions to the oil and gas industry that allow maximizing productivity by minimizing production interruptions due to shutdowns for clean-up or for repair or replacement.

Typical Applications:

➔ Electric Submersible Pump insulation
➔ ESP Power cable,
➔ Data logging cable
➔ Trace heating cables
➔ Gaskets, seals, packing, valve seats
➔ Slide bearings
➔ Bellows, expansion joints,
➔ Hose, tubing, down-hole tubing
Benefits:
DuPont™ StreaMax™ is a registered trademark of DuPont for its family of fluoropolymer coatings specially developed for the oil and gas industry. These coatings are specifically designed to maximize well productivity and minimize operating and maintenance costs.

Minimizing production interruptions by reducing the number of shutdowns for tubular cleanup

- Significantly reducing internal buildup of asphaltenes, paraffins and scale.
- Reducing fluid flow friction in tubulars.
- Maximize tubular fluid flow friction in tubulars.
- Sweet and sour gases in the fluid stream.
- Bacterial accumulation inside tubulars.
- Reduce overall maintenance costs:
  - May permit use of common steel pipe in place of alloy steels for corrosion. Avoids lengthy delivery times for special alloy.
  - Use of chemicals and solvents.
  - Minimize solvent treatment costs.
  - Technology Enabler.
  - Marginal wells may now be more economical to operate and be more productive.
  - Excellent thermal and electrical resistance.
  - Fluid is maintained hotter, longer.

Typical Applications:
- ➔ Down-hole production pipes

Other possible applications after full qualification:
- ➔ Water injection lines
- ➔ Safety components/valves
- ➔ Pipe-lines
**Automotive**

**Benefits:**

The Automotive Industry has to deliver better performance against ever increasing and sometimes conflicting requirements such as:

- Lower emissions (incl. evaporative emissions)
- Better fuel economy
- Increased warranty period
- Lower maintenance costs
- Higher comfort level

Fluoropolymers play an important role in meeting these requirements by offering:

- Maximum durability under extreme temperatures and harsh chemicals. Teflon® PTFE and PFA* meet ISO 6722 Class H (-40 to +250°C), FEP meets Class G (-40 to +225°C) and ETFE meets Class F (-40 to +200°C).
- Extremely low permeability and outstanding resistance to chemicals like biofuels, flex fuels, hydraulic oils, etc.
- Lowest coefficient of friction of any solid material for use in non-and minimally-lubricated mechanical systems (to improve wear resistance special technologies are available such as the incorporation of fillers).

**Typical Applications:**

- Lambda oxygen sensor wiring, seal and conduit
- Engine wiring
- Seat heating wires
- Head light wiring
- Wire conduits, harness covers, cable ties
- Static and dynamic seals, O-rings, head gaskets
- Valve stem seals
- Crank shaft rotary lip seals
- Fuel hose and tubing
- ABS interconnect hose
- Hydraulics hose
- Brake pad wear indicator
- Push-pull cable liner

*See trademark disclaimer notice on page 46.*
Aerospace

Benefits:
The Aerospace Industry requires products with a complex combination of properties: Strength and durability, lightweight, resistance to harsh environments, and ease of use in manufacturing. Safety considerations, such as flame resistance, are also of paramount importance.

DuPont™ Fluoropolymers have played a key role in the space programmes, in the development of new defense systems and in the creation of commercial jet aircraft and engines.

Reasons for the use of Fluoropolymers in the Aerospace Industry are:
- Low smoke and flame
- Weight and space savings
- Operability over broad temperature range and good ageing resistance
- Self lubricating, low friction
- Flexibility, high fatigue resistance
- Excellent dielectric properties over a wide frequency range
- Withstands exposure to hydraulic fluids, solvent and cleaning solutions
- Resistance to high soldering temperatures
- Good release properties for epoxy resins
- UV resistance
- No degasing of any by products

Typical Applications:
- Rings, seals, gaskets for hydraulic systems
- Satellite propulsion systems
- Hose, tubing for hydraulic and fuel systems
- Electrical insulation for high frequency cables
- Airframe wire insulation
- Insulation for internal wire and cable in avionics
- Engine wire insulation and jacketing
- Heating cable
- Circuit boards for microwave equipment
- Wire conduits
- Wire and cable sleeves, heat-shrinkable tubing
- Release film in fabrication of composite aerospace parts

Teflon® PTFE is used for space suit as well as electrical and thermal insulation in space
Semiconductor

Benefits:

• Corrosion resistance over a wide temperature range, more universal and more economical than exotic metal alloys
• High purity (PFA HP), extremely low extractable level, no leaching out of substances that could contaminate ultrahigh-purity process fluids
• Teflon® PFA HP Plus* offers improved system reliability and reduced cost of ownership (longer lifetime, less maintenance) while maintaining same level of purity as PFA HP by delivering:
  • Longer life under dynamic loads (flex life)
  • More resistance to stress cracking by specialty fluorosurfactants such as aggressive developers
  • Smoother surfaces for resistance to microbial contamination
  • Inert non-polar polymer chain end groups for unsurpassed protection against ionic and metallic contamination, even from ozonated fluids
  • Unmatched HCl permeation resistance

Typical Applications:

➔ Shipping containers
➔ Pipes, fittings
➔ Tubing
➔ Valves, pumps
➔ Filters
➔ Wet bench tanks, sinks
➔ Level indicators
➔ Wafer carriers

* See trademark disclaimer notice on page 46.
Cabling Solutions

Benefits:

DuPont™ Teflon® PTFE®, Teflon® PFA, Teflon® FEP, and Tefzel® ETFE Fluoropolymer resins are ideal choices for insulation and jacketing applications where low flammability, exceptional dielectric properties over a wide frequency range, high stress-crack resistance, chemical inertness, high service temperature and thermal cycling capabilities are required.

DuPont Fluoropolymers offer remarkable resistance to high temperature and flames because they have very high melting points and auto-ignition temperatures, as well as exceptional thermal degradation thresholds.

Moreover, their flame characteristics, such as rate of propagation, heat release and smoke generation, are very low, enhancing the fire protection for instance in high-speed data communication cables used in concealed spaces (plenum).

Teflon® Fluoropolymers offer:

• Low dielectric constant for high speed signal transmission
• Low dissipation factor over a broad range of frequencies gives reduced capacitance and attenuation
• Resistance to high soldering temperatures

Typical Applications:

➔ Insulation and jacketing Data Communication Cable
➔ Coaxial cables for high frequency antenna systems,
➔ Automotive cable
➔ Oil-well data logging cable
➔ Heating cable
➔ Motor lead wire
➔ Appliance wiring
➔ Aircraft wiring
➔ Security system cabling

* See trademark disclaimer notice on page 46.
Electronics/Electrical

Benefits:
DuPont™ Teflon® PTFE, Teflon® PFA, Teflon® FEP*, and Tefzel® ETFE Fluoropolymer resins offer a unique combination of properties under extreme ambient conditions where most other polymers or elastomers would fail. Those properties that are most important for the electronics/electrical industry are:

- Superior insulation properties especially at high frequencies. Dielectric constant of Teflon® is lower than any other solid polymer and changes little with frequency and humidity. Low dissipation factor at radio frequencies
- High volume and surface resistivity unaffected by heat-aging or temperatures
- High dielectric strength
- High surface arc-resistance
- Thermal stability at high temperatures (no cracking or embrittlement)
- Low coefficient of friction
- Solder-iron resistant

Typical Applications:
- Wire connectors, insulators
- Printed wiring boards, flexible circuits
- High voltage circuit breakers
- Appliances, consumer electronics
- Battery binder, separator, caps
- Fuel cells
- Generator cooling hose
- Electrical motor sleeving, electrical conduits
- Electrical grade tape
- Heat shrinkable tubing
- Cable ties, protective conduits

* See trademark disclaimer notice on page 46.
Construction

Benefits:

Architectural films and membranes made of glass-fibre woven fabric coated with Teflon® Fluoropolymers® offer many advantages as a construction material over traditional materials:


Safety. Fluoropolymers are exceptionally resistant to ignition, flame spread and to heat and smoke release. Classifies as “non-combustible” roofing material.

Non-stick. Architectural membranes coated with Teflon® PTFE are self-cleaning....


Economics. Multi-functional, translucent. Full spectrum light transmission (except for harmful infrared and UV rays) allows for natural illumination during daylight hours. This helps reduce lighting costs and promote grass and plant growth. Acts as barrier to external heat and noise, while enhancing internal acoustics and preserving desired level of temperature and humidity.

Cost effective. Fabric structures offer attractive cost saving and energy efficient alternatives to traditional buildings. An Architectural membrane roof can be a fraction of the weight of conventional roof structures, allowing substantial savings in floor assemblies, walls and foundations.

Teflon® Fluoropolymers elsewhere in the building:

Enhanced Fire Performance high-speed data communication cables used in concealed spaces (plenum), bringing superior fire protection, meeting toughest fire codes for low flame spread, limited smoke generation and heat release. Excellent electrical performance for high-speed data transmission with low attenuation.

Floor Heating Cables for under-tile and under carpet heating systems providing very thin space saving heating cables for a faster warm-up and greatly reduced energy consumption.

Typical Applications:

➔ Architectural membranes of Fiberglass coated with Teflon®
➔ Architectural fabric woven of PTFE fibres
➔ Transparent architectural film
➔ Enhanced fire performance data cables
➔ Under-tile heating cables
➔ Shatterproof lamps
➔ Slide bearings
➔ Valve seats for central heating systems

* See trademark disclaimer notice on page 46.
General Industry

Benefits:
Industrial products made with DuPont™ fluoropolymer resins have exceptional resistance to low as well as high temperatures, chemical reaction, corrosion, and stress-cracking. The properties of DuPont™ fluoropolymer make it the preferred plastic for a host of industrial applications for one of the following reasons:

• Lowest coefficient of friction of any solid material
• Static coefficient of friction is lower than dynamic coefficient of friction (no stick-slip effect)
• Ability to operate without lubrication or in marginally lubricated conditions
• Long-term thermal stability at high temperatures (no cracking or embrittlement)
• Avoiding sticking, build up or corrosion
• Fragment retention
• Approved for use in pure oxygen, gaseous and liquid (applicable to specific BAM certified grades)

Typical Applications:
➔ Roll covers, heat-shrinkable tubing
➔ Shatterproof lamps
➔ Piston rings/shaft seals for non-lubricated compressors, hydraulics, seal rings for construction machinery
➔ Hydraulics hose
➔ Tubing, hose = hose for high pressure gases, oxygen hose, hose for breathing apparatus, generator hose, paint hose
➔ Consumer products = sliding pads for furniture, sporting equipment, iron sole plates, textile treatment and car care products

Additives

Benefits:
Zonyl® Fluoroadditives are designed to impart the unique properties of Fluoropolymers to a base material such as a thermoplastic, elastomer, lubricant or coating.

Depending on the host material, Zonyl® Fluoroadditives:

• Enhance abrasion and wear resistance
• Lower maintenance costs
• Enhance surface and bulk properties
• Reduce friction and stick-slip response
• Reduce mechanical wear
• Reduce surface contamination
• Improve rub and scuff resistance and surface smoothness of inks

Typical Applications:

➔ Additive to thermoplastic hosts such as acetals, polycarbonates, polyamides and other high-performance engineering resins
➔ High gloss inks
➔ Self-polishing anti-fouling marine paint
➔ Lubricating oils, greases and sealants

* See trademark disclaimer notice on page 46.
### The Perfect Solution for Your Design Needs

<table>
<thead>
<tr>
<th>Problem</th>
<th>Solution: DuPont™ Fluoropolymers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adhesion, Release</td>
<td>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.</td>
</tr>
<tr>
<td>Atmospheric Aging</td>
<td>Extremely resistant to oxidation, surface fouling, discoloration, UV and embrittlement, as proven by tests conducted in Florida for periods of up to 20 years.</td>
</tr>
<tr>
<td>Biodegradation</td>
<td>Inert to enzymic and microbiological attack because the pure polymer does not provide nourishment or porosity for these growths.</td>
</tr>
<tr>
<td>Contamination</td>
<td>Except for specialized grades, DuPont™ Fluoropolymers are chemically inert and pure. They generally contain no additives—plasticizers, stabilizers, lubricants, or antioxidants—which could contaminate process fluids.</td>
</tr>
<tr>
<td>Corrosion</td>
<td>Resistance to even the most aggressive organic and inorganic chemicals and solvents over a broad temperature range.</td>
</tr>
<tr>
<td>Dielectric Instability</td>
<td>High dielectric strength, low dielectric constant, low loss factors, and extremely high specific resistance. DuPont™ Fluoropolymers surpass most materials in their level and stability of dielectric properties over a broad range of environmental conditions.</td>
</tr>
<tr>
<td>Flammability</td>
<td>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.</td>
</tr>
<tr>
<td>Friction and Wear</td>
<td>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 fibre, graphite, and powdered metals.</td>
</tr>
<tr>
<td>Heat</td>
<td>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. In certain cases, they can also withstand short excursions to higher temperatures.</td>
</tr>
<tr>
<td>Humidity</td>
<td>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.</td>
</tr>
<tr>
<td>Light Instability</td>
<td>One of the lowest refractive indexes. Visual appearance does not change after exposure to light ranging from ultraviolet to infrared.</td>
</tr>
<tr>
<td>Low Temperature</td>
<td>Excellent property retention even at cryogenic temperatures. In addition, resistance at these temperatures exceeds that of most other polymers.</td>
</tr>
<tr>
<td>Service Life</td>
<td>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, DuPont™ Fluoropolymers offer an important safety advantage when designing products for long service life.</td>
</tr>
</tbody>
</table>
## Main Typical Properties of DuPont™ Teflon®* and Tefzel® Fluoropolymers

<table>
<thead>
<tr>
<th>Typical Properties¹</th>
<th>Test Method</th>
<th>Units</th>
<th>Teflon® PTFE</th>
<th>Teflon® FEP</th>
<th>Teflon® PFA</th>
<th>Tefzel® ETFE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mechanical</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific gravity</td>
<td>ISO 1183</td>
<td></td>
<td>2,16</td>
<td>2,15</td>
<td>2,15</td>
<td>1,71</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>ISO 12086</td>
<td>MPa</td>
<td>52</td>
<td>43</td>
<td>39</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>- 40 °C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>23 °C</td>
<td></td>
<td>26 - 36</td>
<td>20 - 34</td>
<td>25 - 36</td>
<td>45 - 51</td>
</tr>
<tr>
<td></td>
<td>150 °C</td>
<td></td>
<td>25</td>
<td>12</td>
<td>23</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>200 °C</td>
<td></td>
<td>22</td>
<td>6,3</td>
<td>17</td>
<td>6,5</td>
</tr>
<tr>
<td>Elongation</td>
<td>ISO 12086</td>
<td>%</td>
<td>115</td>
<td>235</td>
<td>250</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td>- 40 °C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>23 °C</td>
<td></td>
<td>326</td>
<td>325</td>
<td>350</td>
<td>200 - 375</td>
</tr>
<tr>
<td></td>
<td>150 °C</td>
<td></td>
<td>540</td>
<td>375</td>
<td>515</td>
<td>740</td>
</tr>
<tr>
<td></td>
<td>200 °C</td>
<td></td>
<td>560</td>
<td>395</td>
<td>535</td>
<td>630</td>
</tr>
<tr>
<td>Tensile strength at yield</td>
<td>ISO 12086</td>
<td>MPa</td>
<td>28,2</td>
<td>26,4</td>
<td>26,5</td>
<td>41,7</td>
</tr>
<tr>
<td></td>
<td>- 40 °C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>23 °C</td>
<td></td>
<td>13,7</td>
<td>13,1</td>
<td>14,5</td>
<td>22,9</td>
</tr>
<tr>
<td></td>
<td>150 °C</td>
<td></td>
<td>6,2</td>
<td>5,5</td>
<td>8,3</td>
<td>6,0</td>
</tr>
<tr>
<td></td>
<td>200 °C</td>
<td></td>
<td>4,6</td>
<td>3,4</td>
<td>5,9</td>
<td>3,8</td>
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<tr>
<td>Tensile modulus</td>
<td>ISO 12086</td>
<td>MPa</td>
<td>795</td>
<td>465</td>
<td>520</td>
<td>880</td>
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<tr>
<td></td>
<td>- 40 °C</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>23 °C</td>
<td></td>
<td>480</td>
<td>520</td>
<td>435</td>
<td>840</td>
</tr>
<tr>
<td></td>
<td>150 °C</td>
<td></td>
<td>60</td>
<td>34</td>
<td>57</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>200 °C</td>
<td></td>
<td>60</td>
<td>20</td>
<td>46</td>
<td>30</td>
</tr>
<tr>
<td>Flexural modulus 23 °C</td>
<td>ISO 178</td>
<td>MPa</td>
<td>490</td>
<td>550 - 655</td>
<td>520 - 690</td>
<td>1000 - 1380</td>
</tr>
<tr>
<td>Folding endurance²</td>
<td>ASTM D 2176</td>
<td>cycles</td>
<td>885 000 - &gt;90 x 10⁸</td>
<td>5000 - 1 x 10⁸</td>
<td>7000 - 2 x 10⁸</td>
<td>1500 - 60 000</td>
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<tr>
<td>Impact strength</td>
<td>ASTM D 256</td>
<td>J/m</td>
<td>0,1</td>
<td>0,3</td>
<td>0,2</td>
<td>0,4</td>
</tr>
<tr>
<td></td>
<td>+ 23 °C</td>
<td></td>
<td>185</td>
<td>No break</td>
<td>No break</td>
<td>No break</td>
</tr>
<tr>
<td></td>
<td>- 54 °C</td>
<td></td>
<td>107</td>
<td>158</td>
<td>155</td>
<td>&gt; 1100</td>
</tr>
<tr>
<td>Coefficient of friction (dyn.) 3 m/min, 0,7 MPa</td>
<td>ASTM D 3702</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Thermal Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Units</th>
<th>Teflon® PTFE</th>
<th>Teflon® FEP</th>
<th>Teflon® PFA</th>
<th>Tefzel® ETFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak melting</td>
<td>ASTM D 4591</td>
<td>°C</td>
<td>327</td>
<td>260</td>
<td>260</td>
<td>305</td>
</tr>
<tr>
<td>temperature</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Service temperature</td>
<td>ISO 2578</td>
<td>°C</td>
<td>260</td>
<td>205</td>
<td>260</td>
<td>156</td>
</tr>
<tr>
<td>(20 000 h)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Flame Class³</td>
<td>UL94</td>
<td></td>
<td>94V-0</td>
<td>94V-0</td>
<td>94V-0</td>
<td>94V-0</td>
</tr>
<tr>
<td>Oxygen index</td>
<td>ISO 4589</td>
<td>%</td>
<td>&gt; 95</td>
<td>&gt; 95</td>
<td>&gt; 95</td>
<td>&gt; 95</td>
</tr>
<tr>
<td>Temperature index</td>
<td>NES 715</td>
<td>°C</td>
<td>&gt; 400</td>
<td>&gt; 400</td>
<td>&gt; 400</td>
<td>&gt; 400</td>
</tr>
<tr>
<td>Heat of combustion</td>
<td>ISO 1716</td>
<td>kJ/g</td>
<td>4,9 - 5,0</td>
<td>4,8 - 5,1</td>
<td>4,7 - 4,9</td>
<td>12,4 - 12,6</td>
</tr>
</tbody>
</table>

* See trademark disclaimer notice on page 46.
### Typical Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Units</th>
<th>Teflon®&lt;sup&gt;®&lt;/sup&gt; PTFE&lt;sup&gt;*&lt;/sup&gt;</th>
<th>Teflon®&lt;sup&gt;®&lt;/sup&gt; FEP&lt;sup&gt;*&lt;/sup&gt;</th>
<th>Teflon®&lt;sup&gt;®&lt;/sup&gt; PFA&lt;sup&gt;*&lt;/sup&gt;</th>
<th>Tefzel®&lt;sup&gt;®&lt;/sup&gt; ETFE&lt;sup&gt;*&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electrical</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dielectric strength</td>
<td>IEC 60243</td>
<td>kV/mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>film 0.25 mm</td>
<td></td>
<td></td>
<td></td>
<td>85</td>
<td>78</td>
<td>74</td>
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<tr>
<td>film 1.00 mm</td>
<td></td>
<td></td>
<td></td>
<td>35</td>
<td>35</td>
<td>33</td>
</tr>
<tr>
<td>Relative permittivity</td>
<td>ASTM D 150</td>
<td>1 MHz</td>
<td>2.05</td>
<td>2.03</td>
<td>2.03</td>
<td>2.47</td>
</tr>
<tr>
<td>(dielectric constant)</td>
<td></td>
<td>1 GHz</td>
<td>1.99</td>
<td>2.02</td>
<td>2.02</td>
<td>2.02</td>
</tr>
<tr>
<td>Dissipation factor</td>
<td>ASTM D 150</td>
<td>1 MHz</td>
<td>0.00003</td>
<td>0.00061</td>
<td>0.00019</td>
<td>0.00550</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 GHz</td>
<td>0.00028</td>
<td>0.00094</td>
<td>0.00082</td>
<td>0.01430</td>
</tr>
<tr>
<td>Arc resistance</td>
<td>ASTM D 495</td>
<td>s</td>
<td>&gt; 300</td>
<td>&gt; 300</td>
<td>&gt; 180</td>
<td>&gt; 72</td>
</tr>
<tr>
<td>Volume resistivity</td>
<td>ASTM D 257</td>
<td>Ω.m</td>
<td>&gt; 10&lt;sup&gt;16&lt;/sup&gt;</td>
<td>&gt; 10&lt;sup&gt;16&lt;/sup&gt;</td>
<td>&gt; 10&lt;sup&gt;16&lt;/sup&gt;</td>
<td>&gt; 10&lt;sup&gt;14&lt;/sup&gt;</td>
</tr>
<tr>
<td>Surface resistivity</td>
<td>ASTM D 257</td>
<td></td>
<td></td>
<td>&gt; 10&lt;sup&gt;16&lt;/sup&gt;</td>
<td></td>
<td>&gt; 10&lt;sup&gt;14&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>General</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weather resistance</td>
<td>“Weather-O-meter” (2000 h)</td>
<td>No effect</td>
<td>No effect</td>
<td>No effect</td>
<td>No effect</td>
<td>No effect</td>
</tr>
<tr>
<td>Solvent resistance</td>
<td>ASTM D 543</td>
<td></td>
<td>excellent</td>
<td>excellent</td>
<td>excellent</td>
<td>very good</td>
</tr>
<tr>
<td>Chemical resistance</td>
<td>ASTM D 543</td>
<td></td>
<td>excellent</td>
<td>excellent</td>
<td>excellent</td>
<td>very good</td>
</tr>
<tr>
<td>Water absorption</td>
<td>ASTM D 570</td>
<td>%</td>
<td>0.00</td>
<td>0.01</td>
<td>0.03</td>
<td>0.03</td>
</tr>
</tbody>
</table>

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If you are interested in applying for our trademark licensing agreement contact DuPont:

**Telephone:** +34 985 123773  
**Email:** eu-info@dupont.com  
**Web:** www2.dupont.com/Teflon_Industrial/en_US/contact/index.html

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1. Typical measured values based on grades representative for each product family; these properties are not suitable for specification purposes.
2. Values for folding endurance cannot be directly compared between the different products; range indicates different types.
3. These results are based on laboratory tests under controlled conditions and do not reflect performance under actual conditions.
**DuPont Manufacturing facilities**

**Manufacturing Sites**

- Dordrecht Works (Netherlands)
- Washington Works (Parkersburg, W.Va., USA)
- MDF Mitsui - DuPont Fluorochemicals Co., Ltd., Shimizu (Japan)
- Changshu (China)

**Growing with the Market**

The unique combination of properties of Teflon® and Tefzel® has led to an ever increasing number of end-uses. As a result, worldwide demand for these products in their many forms has shown corresponding growth (typically above GNP).

To keep pace with demand, DuPont manufacturing facilities have kept expanding.

The Fluoropolymers plant, DuPont Washington Works near Parkersburg, West Virginia (USA) went on stream in 1950 and is still the major production site today.

As recent as early 2008 DuPont announced that its latest production plant located in Changshu City (China), which produces polytetrafluoroethylene (PTFE) fine powder and dispersion, has begun operations.

The combined output of these plants makes DuPont the world’s largest manufacturer of Fluoropolymers. The worldwide spread of the manufacturing facilities is also advantageous for the customer to ensure continuity of supply.
Technical Marketing

Technical Marketing plays a major role in assisting customers and end-users to get most out of the Fluoropolymers they buy from DuPont. Technical Centers in Europe, United States, Japan and China serve customers and end-users of these products in many ways.

The European Technical Centre (ETC) was created in 1989 in Meyrin, Geneva (Switzerland) to foster synergies between a number of DuPont businesses.

Today, amongst Fluoropolymers the site provides Technical and Marketing support to six DuPont Strategic Business Units across EMEA (Europe, Middle-East and Africa). Since its inception, ETC has been at the forefront of applied research and dynamic product development. ETC’s activities are fully aligned with market needs and driven by sustainable growth objectives.

The products and applications developed and tested at the ETC serve several thriving markets and industries, mainly Automotive, Food, Energy, CPI, Oil & Gas.

The closeness to the market permits the ETC experts to recognize industry trends and anticipate market needs.

At ETC, polymer products and applications are supported through their full life cycle. Products design, formulation, processing, testing, prototyping as well as product validation are performed at ETC. The products are accompanied by a staff of experts from their early development, in close cooperation with customers and end-users, through their introduction to the market and up to customers’ support (including trouble-shooting in a customers’ plant).

Most of the industrial processes used to transform polymers into finished items can be duplicated on state-of-the-art equipment representative of what is used in the industry. This allows for testing of products under “real life” processing conditions for instance before a new product is introduced to the market or for optimization of the transformation processes and for producing prototypes.

Many customers and end-users (over 2500 visitors/year) come to this Centre of Excellence for training, product demonstrations, scientific seminars, joint developments, marketing and technical expertise as well as industry standardization (ISO, ASTM, DIN, AFNOR, BSI) and product stewardship support (FDA, UL, REACH).

DuPont partners rely on ETC for expert advice in the selection of a product, the development of innovative solutions with specific functionalities or the elaboration of prototypes for new applications.

With its diagnostics/analytical capabilities ETC can offer solutions and alternatives for technical challenges.

ETC, beyond its strong involvement in the EMEA region, can tap into the increasingly global presence of DuPont laboratories and research facilities, each with a number of technological and scientific specificities. Through ETC, clients can benefit from the Global network of DuPont expertise.

European Technical Centre – a few facts and figures

- More than 225 employees (DuPont and contractors) of more than 21 nationalities
- 27,000 m² of laboratory, processing and office space
- 1/3 of the company’s revenues in EMEA are associated with the ETC Applied Research and Product innovations activities
- DuPont Global R&D investment: nearly 2 billions USD (2011)
Reference Documents

Standards:

International Standard

Products:

- ISO 12086-1: Plastics - Fluoropolymer dispersions and moulding and extrusion materials - Part 1: Designation system and basis for specifications
- ISO 12086-2: Plastics - Fluoropolymer dispersions and moulding and extrusion materials - Part 2: Preparation of test specimens and determination of properties
- ISO 13000-1: Plastics - Polytetrafluoroethylene (PTFE) semi-finished products - Part 1: Requirements and designation
- ISO 13000-2: Plastics - Polytetrafluoroethylene (PTFE) semi-finished products - Part 2: Preparation of test specimens and determination of properties

Test Methods:

- ISO 304: Surface active agents - Determination of surface tension by drawing up liquid films
- ISO 978: Rubber and Plastics - Polymer dispersions and rubber latexes - Determination of pH
- ISO 1409: Plastics and rubber - Polymer dispersions and rubber latexes (natural and synthetic) - Determination of surface tension by the ring method
- ISO 2565: Plastics - Resins in the liquid state or as emulsions or dispersions - Determination of apparent viscosity by the Brookfield Test method
- ISO 2578: Plastics - Determination of time-temperature limits after prolonged exposure to heat
- ISO 4311: Anionic and non-ionic active agents - Determination of the critical micellization concentration - Method by measuring surface tension with a plate, stirrup or ring
- ISO 13320-1: Particle size analysis - Laser diffraction methods - Part 1: General principles
- ISO 13321: Particle size analysis - Photon correlation spectroscopy
- ISO 11357-1: Plastics - Differential scanning calorimetry (DSC) - Part 1: General principles
- ISO 11357-2: Plastics - Differential scanning calorimetry (DSC) - Part 2: Determination of glass transition temperature
- ISO 11357-3: Plastics - Differential scanning calorimetry (DSC) - Part 3: Determination of temperature and enthalpy of melting and crystallization
- ISO 11359-1: Plastics - Thermomechanical analysis (TMA) - Part 1: General principles
- ISO 11359-2: Plastics - Thermomechanical analysis (TMA) - Part 2: Determination of coefficient of linear thermal expansion and glass transition temperature
- ISO 6722: Road vehicles - 60 V and 600 V single-core cables - Dimensions, test methods and requirements
- IEC 62016: Guide for the determination of thermal endurance properties of electrical insulating materials - Part 1: General procedures for the determination of thermal endurance properties, temperature indices and thermal endurance profiles

ASTM Standard

Products:

- D 2116: Standard Specification for FEP-Fluorocarbon Molding and Extrusion Materials
- D 3159: Standard Specification for Modified ETFE-Fluoropolymer Molding and Extrusion Materials
- D 3307: Standard Specification for Perfluoralkoxy (PFA)-Fluorocarbon Molding and Extrusion Materials
- D 4441: Standard Specification for Aqueous Dispersions of Polytetrafluoroethylene
- D 4745: Standard Specification for Filled Compounds of Polytetrafluoroethylene (PTFE) Molding and Extrusion Materials
- D 4894: Standard Specification for Polytetrafluoroethylene (PTFE) Granular Molding and Ram Extrusion Materials
- D 4895: Standard Specification for Polytetrafluoroethylene (PTFE) Resin Produced from Dispersion
- D 5675: Standard Classification for Fluoropolymer Micropowders

Semi-finished products, finished parts:

- D 1710: Standard Specification for Extruded and Compression Molded Polytetrafluoroethylene (PTFE) Rod and Heavy Walled Tubing
- D 2902: Specification for Fluoropolymer Resin Heat-Shrinkable Tubing for Electrical insulation
- D 3032: Standard Test Methods for Hookup Wire Insulation
- D 3294: Standard Specification for Polytetrafluoroethylene (PTFE) Resin Molded Sheet and Molded Basic Shapes
- D 3295: Standard Specification for PTFE Tubing
- D 3296: Standard Specification for FEP-Fluorocarbon Tubing
- D 3308: Standard Specification for PTFE Resin Skived Tape
- D 3368: Standard Specification for FEP-Fluorocarbon Sheet and Film
- D 3369: Standard Specification for Polytetrafluoroethylene (PTFE) Resin Cast Film
- D 4869: Standard Specification for Polytetrafluoroethylene (PTFE) Coated Glass Fabric
- D 6040: Standard Guide to Standard Test Methods for Unsintered Polytetrafluoroethylene (PTFE) Extruded Film or Tape
- D 6457: Standard Specification for Extruded and Compression Molded Rod and Heavy-Walled Tubing Made from Polytetrafluoroethylene (PTFE)
Test Methods:

D 149 Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
D 150 Standard Test methods for A-C Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials
D 257 Standard Test Methods for D-C Resistance or Conductance of Insulating Materials
D 542 Standard Test Method for Index of Refraction of Transparent Organic Plastics
D 543 Standard Test Method for Water Absorption of Plastics
D 621 Standard Test Methods for Deformation of Plastics under Load
D 635 Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position
D 638 Standard Test Method for Tensile Properties of Plastics
D 695 Standard Test method for Compressive Properties of Rigid Plastics
D 790 Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical insulating Materials
D 792 Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D 1003 Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics
D 1331 Standard Test Methods for Surface and Interfacial Tension of Solutions of Surface-Active Agents
D 1434 Standard Test Method for Determining Gas Permeability Characteristics of Plastic Film and Sheeting
D 1876 Standard Test Method for Peel Resistance of Adhesives (FPeel Test)
D 1895 Standard Test Methods for Apparent Density, Bulk Factor, and Pourability of Plastic Materials
D 2176 Standard Test Method for Folding Endurance of Paper by the M.I.T. Tester
D 2196 Standard Test Methods for Rheological Properties of Non-Newtonian Material by Rotational (Brookfield type) Viscometer
D 2240 Standard Test Method for Rubber Property-Durometer Hardness
D 2863 Standard Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)
D 3417 Standard Test Method for Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry (DSC)
D 3418 Standard Test Method for Transition Temperatures of Polymers By Differential Scanning Calorimetry
D 4591 Standard Test Method for Determining Temperatures and Heats of Transitions of Fluoropolymers by Differential Scanning Calorimetry
E 96 Standard Test Method for Water Vapor Transmission of Materials

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10) Technical Information "INJECTION MOULDING GUIDE FOR MELT PROCESSABLE FLUOROPOLYMERS" E-65070 (09/88) Du Pont de Nemours International S.A.
12) Technical Information "TEFLON®/TEFZEL® INJECTION MOULDING TROUBLE-SHOOTING GUIDE" E-96164 Rev. (09/91) Du Pont de Nemours International S.A.
13) DuPont Medical Caution Statement, H-51459
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