

# Dyneon™ TFM™ PTFE

Improved performance and design flexibility



*A 3M Company*



# Innovation Expands Capabilities

Because of its unique properties, polytetrafluoroethylene (PTFE) has been used successfully in a wide variety of industrial applications. For some, that would be enough, but not for Dyneon.

We developed Dyneon™ TFM™ PTFE to better meet your design needs. Besides retaining all the proven advantages of conventional PTFE, it offers some significantly enhanced properties:

- substantially lower deformation under load
- lower permeation due to denser polymer structure and fewer voids
- better weldability
- improved stress recovery, particularly at elevated temperatures
- smoother surface finishes
- higher transparency

## New applications

The enhanced properties of TFM™ PTFE make it ideal for applications beyond those of conventional PTFE. Additional processing options and greater freedom of design open up entirely new applications and markets.

*Skived film produced from compression molded, sintered billets made of Dyneon™ TFM™ PTFE and Dyneon™ PTFE resins. The higher transparency of TFM™ PTFE is a distinct advantage vs. conventional PTFE.*



## ***Economic Value***

*The use of TFM™ PTFE in seals, gaskets, and components for valves, pumps and manufacturing equipment not only results in improved properties, but helps extend service life, increase plant reliability, and ultimately raise profitability by reducing downtime.*

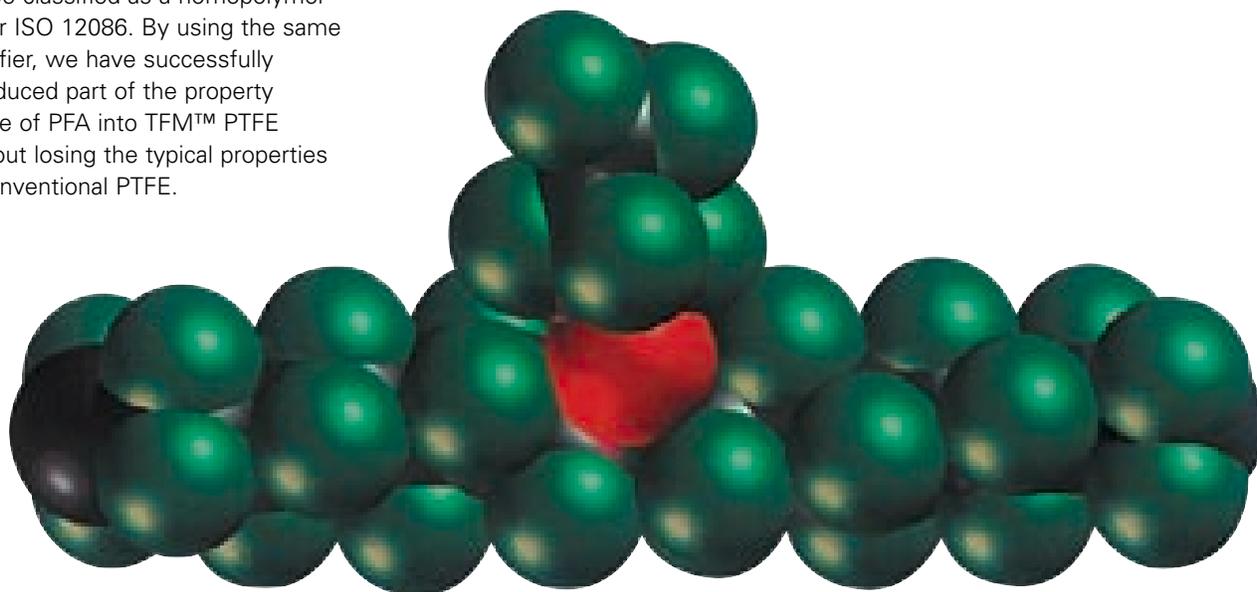
# Proven Performance, Product Extension: Dyneon™ PTFE and Dyneon™ TFM™ PTFE

Dramatic effects are often the result of small changes. That's the difference between conventional, unmodified PTFE and TFM™ PTFE.

## Dyneon™ TFM™ PTFE

The molecular structure of Dyneon™ TFM™ PTFE incorporates a perfluoropropyl vinyl ether (PPVE) modifier. This is the same chemical modifier used in the melt-processable fluorothermoplastic, PFA. However, the modifier content in TFM™ PTFE is very low (less than 1%). For this reason, Dyneon™ TFM™ PTFE can still be classified as a homopolymer under ISO 12086. By using the same modifier, we have successfully introduced part of the property profile of PFA into TFM™ PTFE without losing the typical properties of conventional PTFE.

mechanical properties. However, the perfluoropropyl vinyl ether (PPVE) modifier in Dyneon™ TFM™ PTFE specifically inhibits crystallization, keeping the amorphous-crystalline ratio content consistent with that of conventional PTFE and ensuring no loss of mechanical properties. In addition, the modifier ensures better distribution of particles in the amorphous matrix and dramatically reduces creep (cold flow).



In addition to the inclusion of a small amount of modifier, the molecular weight of TFM™ PTFE is reduced by one-fifth compared to that of conventional PTFE. The lower molecular weight results in lower melt viscosity and provides the advantageous properties characteristic of TFM™ PTFE.

Normally, the relatively low molecular weight of TFM™ PTFE in comparison with conventional PTFE would give rise to an end product with higher crystallinity and hence lower

Dyneon™ TFM™ PTFE has the same excellent chemical resistance and thermal stability as conventional PTFE and is processed by traditional molding and sintering methods. The lower melt viscosity of TFM™ PTFE leads to better particle fusion during sintering. As a result, a denser polymer structure with lower permeability is realized.

## Molecular structure of TFM™ PTFE

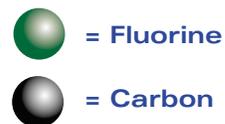
-  = Fluorine
-  = Oxygen
-  = Carbon

## Dyneon™ PTFE

Dyneon™ PTFE consists of extremely long, linear carbon chains entirely surrounded by fluorine atoms. The fluorine atoms sterically shield the carbon atoms and protect the molecule from chemical attack. The high-energy carbon-fluorine bond helps ensure that the shielding effect is retained, even under extreme service conditions. Because of the very high molecular weight of about 100 million g/mol, terminal groups are extremely rare and chemical attack at these points is virtually insignificant.



Molecular structure of conventional, unmodified PTFE



## DID YOU KNOW...

The proven properties of conventional Dyneon™ PTFE include:

- Excellent all-around chemical resistance
- Very wide service temperature range
- Excellent dielectric properties
- Extreme resistance to embrittlement or aging
- Very good non-stick properties
- Dimensional stability and stress crack resistance

# Dyneon™ TFM™ PTFE

The many options available for processing Dyneon™ TFM™ PTFE open up new application areas. Processes can be optimized and manufactured products can be improved in response to practical requirements.

## **Mechanical and automotive engineering**

Seals made from Dyneon™ TFM™ PTFE compounded with select fillers have excellent fuel, lubricant and additive resistance and help increase longevity. They can replace conventional materials and make it possible to use new, more aggressive lubricants and seal designs.

## **Chemical processing**

Dyneon™ TFM™ PTFE is ideal for corrosion-resistant lining of steel parts such as valves and pipes having better barrier properties than conventional PTFE due to its lower permeability. Its improved weldability makes it ideal for the manufacture of complex components. It is also ideal for gaskets requiring low deformation under load.

## **Semiconductor industry**

Extremely high purity, ultra-smooth finished-part surfaces and good weldability are opening up new opportunities for the design and production of larger parts, such as carriers for 300 mm wafers and carriers for flat-panel displays.



# Dyneon™ TFM™ PTFE — Typical Applications

<b>Industry</b>	<b>Key Features</b>	<b>Application Examples</b>
Chemical processing Chemical transfer & storage	Exceptional chemical & thermal resistance Low permeability Reduced deformation under load Weldability High creep resistance & dimensional stability Exceptionally smooth surfaces	Pumps Valves Diaphragms & bellows Ball valve seats Molded or extruded sheet linings Seals & gaskets Spiral-wound high pressure hoses Bearings
High purity chemical processing Semiconductor manufacturing Food, bio-tech & pharmaceutical processing	All of the above plus: Low metal ion & extractables content Excellent cleanability UHP (ultra high purity) grades and packaging available FDA compliant grades available	All of the above plus: Large wafer carriers Molded equipment components Wet chemical processing equipment Encapsulated sensors Films for high purity packaging
Electrical & electronics	Excellent insulation properties Excellent dielectric properties Very smooth surfaces Low friction Statically dissipative grades available as compounds UHP (ultra high purity) grades and packaging available	Molded & machined insulators Equipment components Cable coatings

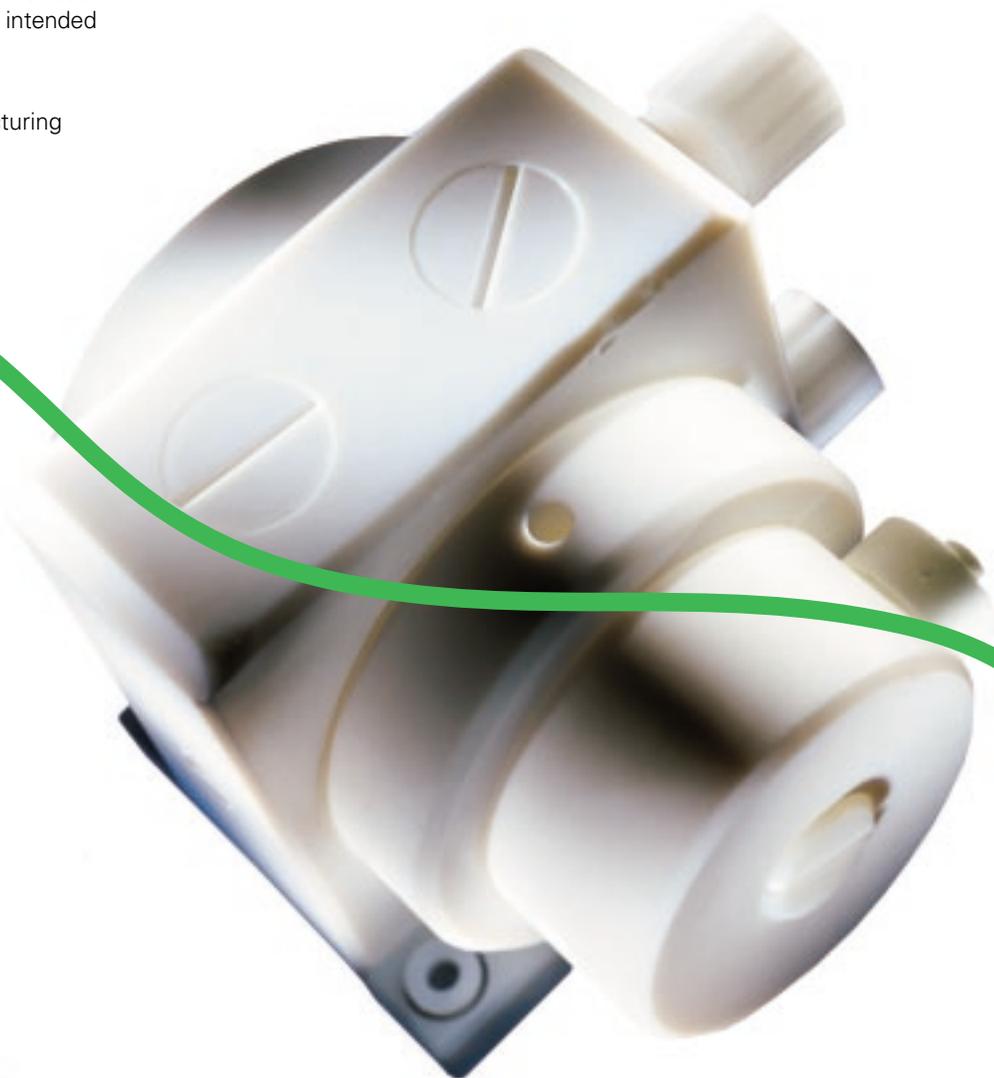
**Dyneon™ TFM™ PTFE is available as a virgin material or as a compound with fillers added. Custom TFM™ PTFE compounds can be formulated to your process and property requirements for virtually any application.**

# Dyneon™ TFM™ PTFE for Ultra High Purity (UHP) Applications

## Dyneon™ TFM™ PTFE UHP

High-purity raw materials are essential to many manufacturers of equipment for the semiconductor, bio-tech, pharmaceutical and ultra-pure chemicals industries.

- Dyneon™ TFM™ PTFE is available in ultra high purity (UHP) grades.
- Finished parts made from Dyneon™ TFM™ PTFE UHP have extremely smooth, pore-free surfaces that prevent contaminants from adhering to them and facilitate cleaning.
- Clean-room processing of Dyneon™ TFM™ PTFE UHP is recommended to ensure high purity in finished parts intended for clean-room applications.
- UHP grades are specially packaged in Dyneon's clean-room-quality manufacturing and packaging environment.



*Compressed-air diaphragm pump made from Dyneon™ TFM™ PTFE UHP for high-purity manufacturing in the semiconductor industry.*

# Comparison of Dyneon™ PTFE and Dyneon™ TFM™ PTFE

<b>Property</b>	<b>Unit</b>	<b>Test Method</b>	<b>Dyneon™ TFM™ 1700 PTFE</b>	<b>Dyneon™ TF 1750 PTFE</b>
Bulk Density	g/l	ASTM D 4894-98a	420	380
Specific Gravity	g/cc	ASTM D 4894-98a	2.165	2.155
Shrinkage	%	ASTM D 4894-98a	5.7	4.3
Tensile Strength	psi	ASTM D 4894	4000	4800
	psi	DIN53455	6400	6000
Elongation at Break	%	ASTM D 4894	350	450
	%	DIN53455	430	600
Deformation Under Load, 2175 psi	%	ASTM D 621		
		24 hours	8	15
		100 hours	9	17
		Permanent	4	11
Void Content	%	Dyneon Method	0.26	0.75
Permeability:				
SO <sub>2</sub> (@ 23°C)	cm <sup>3</sup>	Based on ASTM D 3985 film thickness 1 mm	210	310
HCl (@ 54°C)	m <sup>2</sup> x d x bar		460	640
Cl <sub>2</sub> (@ 54°C)			160	320
Tensile Modulus	psi	ASTM D 638	94,250	87,000
Dielectric Strength	kV/mil	ASTM D 149-95a film thickness 100 µm	3.7	3.5

**Typical values. Not for specification purposes.**

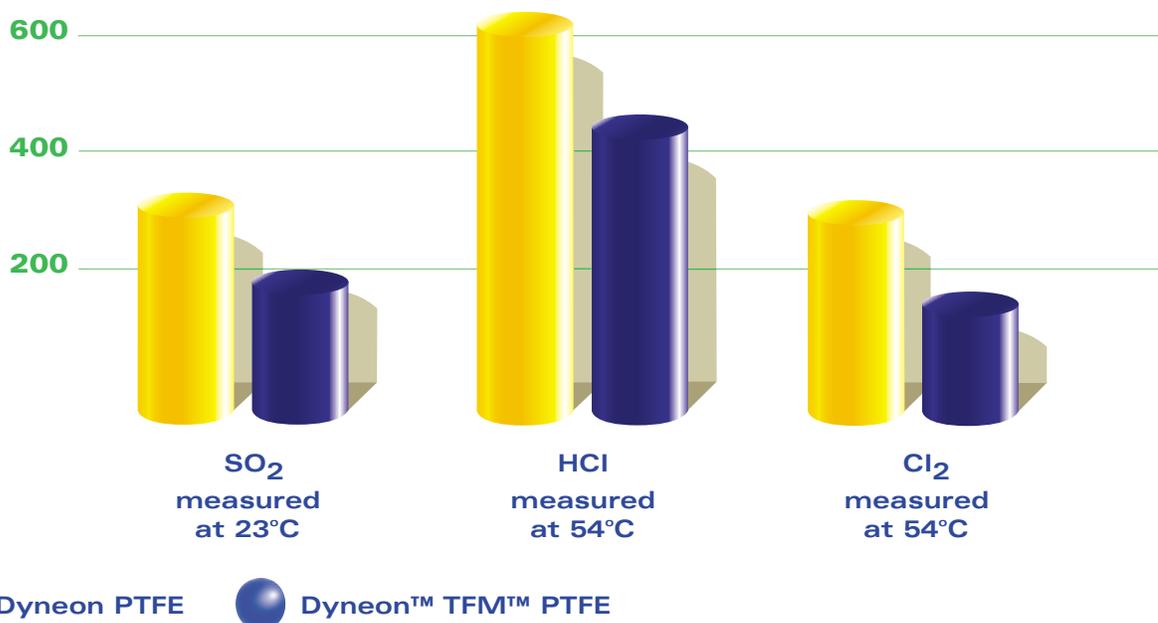
# Reduced Permeation of Dyneon™ TFM™ PTFE Versus Conventional PTFE

The improved particle coalescence of Dyneon™ TFM™ PTFE during sintering results in better particle fusion within manufactured parts and, therefore, lower permeation. Lower permeation is particularly advantageous for corrosive applications or those applications where PTFE is used as a barrier to protect against or contain aggressive chemicals, such as lined steel pipe, valves assemblies and gaskets used in chemical plants.

The improved particle coalescence of Dyneon™ TFM™ PTFE during sintering, based on its lower melt viscosity, also results in a denser polymer structure in the finished part. This denser polymer structure, which can be viewed under magnification, results in smoother machined surfaces of TFM™ PTFE parts as well as reduced permeation.

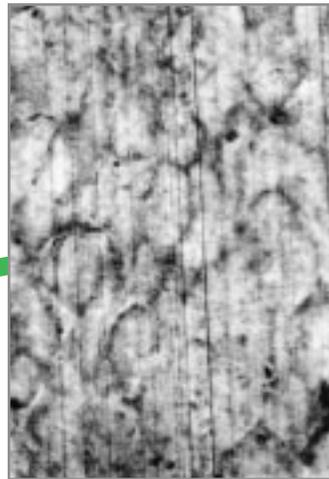
## Permeation\* of selected chemicals through a 1 mm thick PTFE skived sheet

[cm<sup>3</sup>/m<sup>2</sup> day bar]

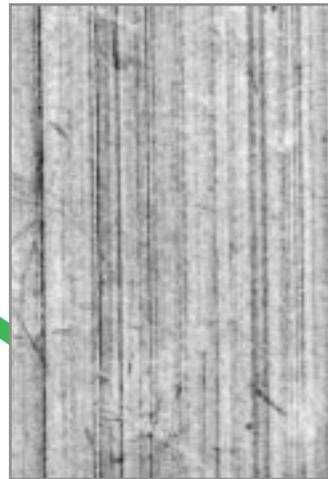


\*Based on ASTM D 3985 using film thickness of 1 mm.

**Skived films viewed under an optical microscope at 25x magnification**

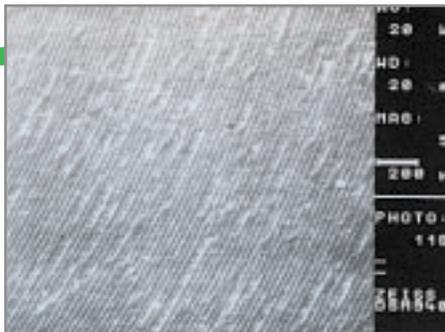


Unmodified Dyneon™ PTFE

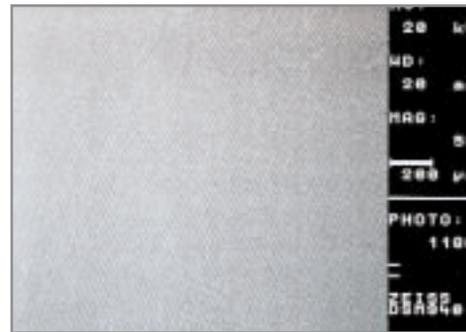


Modified Dyneon™ TFM™ PTFE

**Surface roughness of machined parts at 50x magnification**



Note the rougher surface of machined parts made from conventional PTFE.



The much smoother surface of Dyneon™ TFM™ PTFE parts can be clearly seen under the microscope.

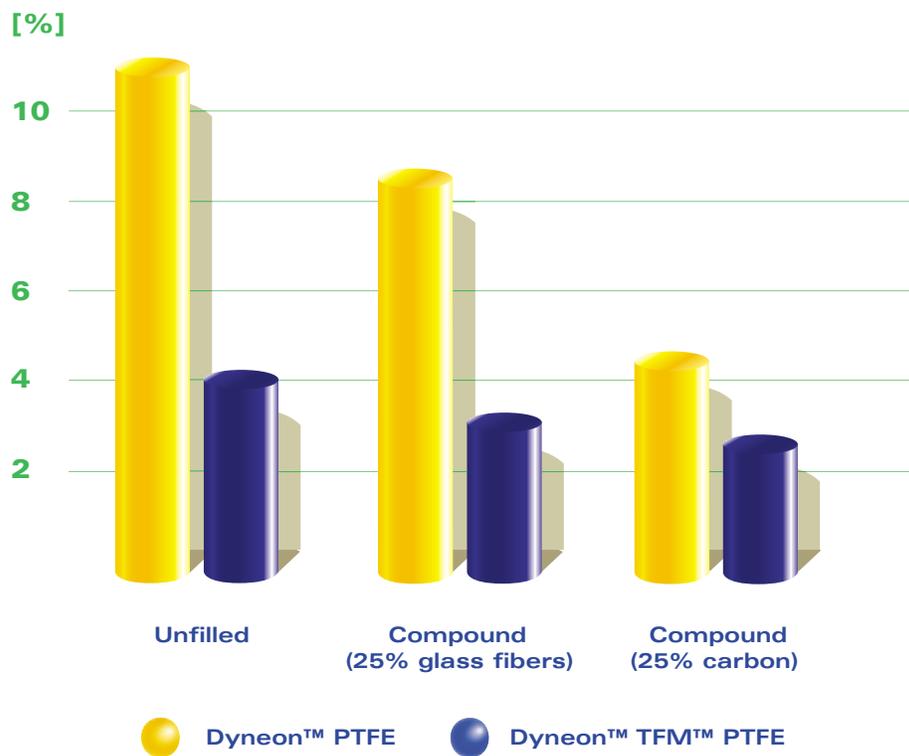
## Dyneon™ TFM™ PTFE: Reduced Creep - Improved Resistance to Cold Flow

Cold flow, measured as deformation under load, is significantly lower for Dyneon™ TFM™ PTFE than for conventional PTFE. Therefore, in applications where the use of fillers may prove disadvantageous, Dyneon™ TFM™ PTFE can often provide the needed mechanical properties without the inclusion of fillers.

Unfilled Dyneon™ TFM™ PTFE has about the same cold flow as a conventional PTFE compound with 25% glass fiber. As an example, seals made from unfilled Dyneon™ TFM™ PTFE are replacing conventional PTFE compounds in many applications where fillers can pose contamination issues or might reduce the chemical resistance of the seal. These include equipment and componentry for semiconductor manufacturing as well as the pharmaceutical and chemical processing industries. However, when increased wear and abrasion resistance and even lower deformation under load than virgin TFM™ PTFE are necessary, Dyneon™ custom TFM™ PTFE compounds are recommended and can be specially formulated to meet additional requirements.

***Corrosion and "blowout" resistant envelope gaskets made from Dyneon™ TFM™ PTFE with stainless steel rings for high-purity processing in the chemical and pharmaceutical industries.***

### Reduction in permanent deformation under load by use of Dyneon™ TFM™ PTFE and PTFE Compounds



### ***Test conditions***

**Loading:** 2175 psi

**Time:** 100 hours

**Temperature:** 23°C (74°F)

Permanent deformation after 100 hours under load, measured 24 hours after load removal.

Based on ASTM D 621

# Dyneon™ TFM™ PTFE: Reduced Permanent Deformation after Cyclic Loading

The difference in cold flow behavior between Dyneon™ TFM™ PTFE and conventional PTFE is significant, particularly after repeated loading and at elevated temperatures.

TFM™ PTFE exhibits reduced permanent deformation after cyclic loading such as is typically found in dynamic sealing applications. The advantage of TFM™ PTFE over conventional PTFE is attributed to its denser polymer structure and is illustrated here.

## Test conditions

**Loading:** 2175 psi, repeated compressive loading of a test specimen.

**Test cycles:** 4

**Time:** 100 hours per cycle

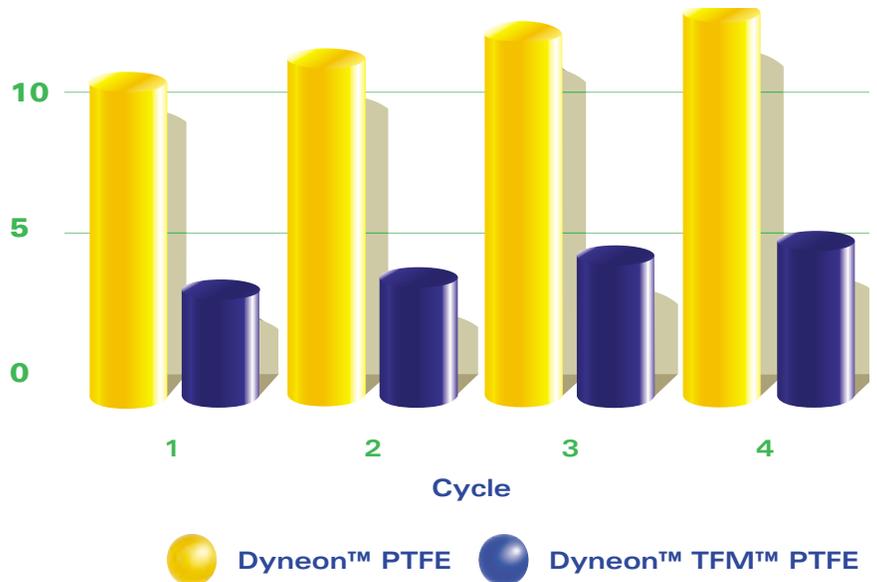
**Temperature:** 23°C (73°F)

Permanent deformation after 100 hours under load, measured 24 hours after load removal.

Based on ASTM D 621

## Permanent total deformation at 23°C

[%]



## Test conditions

**Loading:** 2175 psi, repeated compressive loading of a test specimen.

**Test cycles:** 2

**Time:** 100 hours per cycle

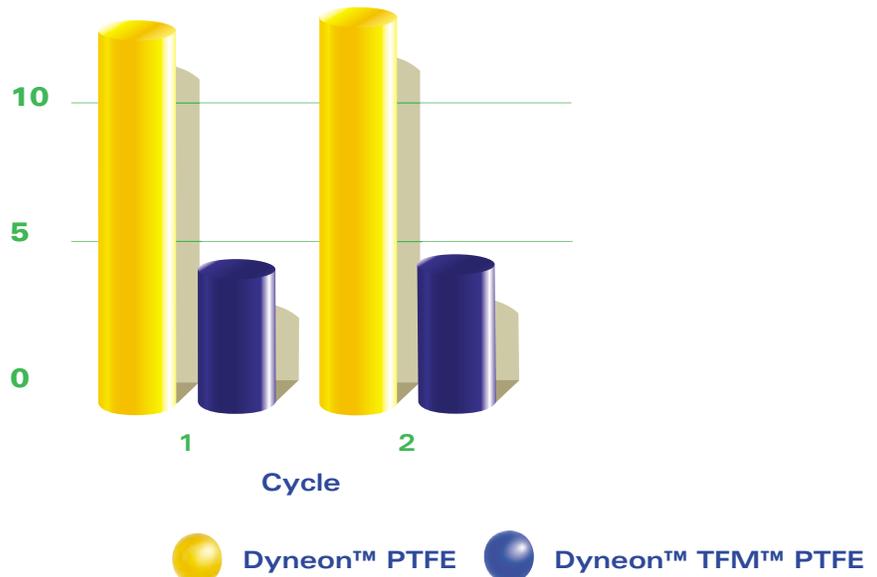
**Temperature:** 150°C (302°F)

Permanent deformation after 100 hours under load, measured 24 hours after load removal.

Based on ASTM D 621

## Permanent total deformation at 150°C

[%]



# Dyneon™ TFM™ PTFE Custom Compounds: Strain Behavior Under Static Tensile Load

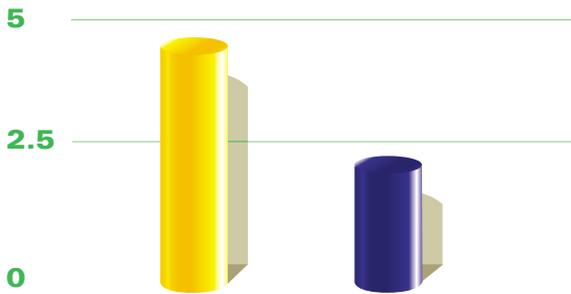
Dyneon™ TFM™ PTFE exhibits a dramatic reduction in tensile strain compared to conventional PTFE, particularly at elevated temperature. Strain values at room temperature differ by a factor of 2. This difference jumps to a factor of about 10 at 100°C (212°F) which translates to much lower tensile flow in TFM™ PTFE. This is an important characteristic for components that require stretching during installation.



*Seamlessly coated shock absorber piston for automotive application with an integrally molded sealing lip made from a Dyneon™ TFM™ PTFE compound.*

## Tensile strain at 23°C

[%]

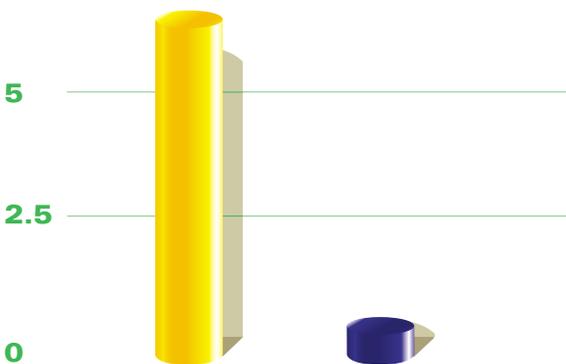


## Test conditions

**Tensile loading:** 725 psi  
Deformation after 100 hours.

## Tensile strain at 100°C

[%]



 Dyneon™ PTFE     Dyneon™ TFM™ PTFE

# Stress Relaxation of Dyneon™ TFM™ PTFE and Custom TFM™ PTFE Compounds.

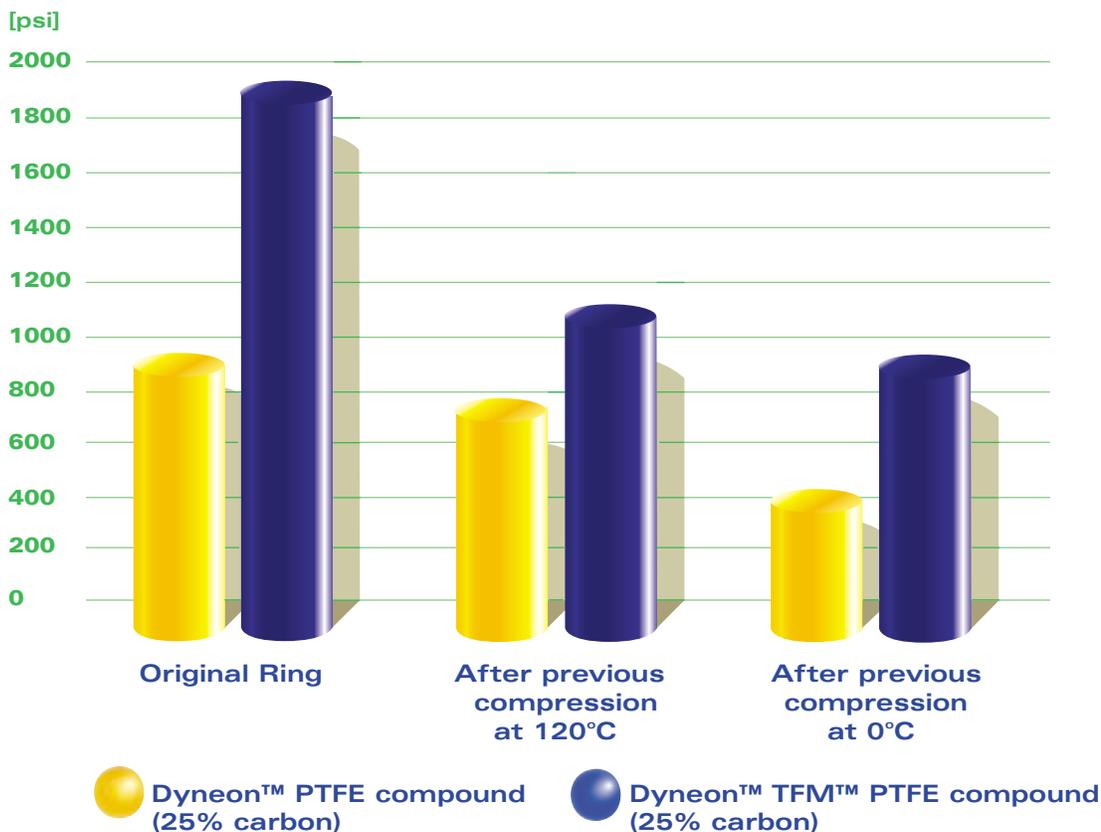
Stress recovery is important for applications such as seals, seats and gaskets where improved stress recovery can translate to longer sealability or less retorquing of parts. Dyneon™ TFM™ PTFE exhibits better stress recovery than conventional PTFE.

In a test designed to quantify improved stress recovery of Dyneon™ TFM™ PTFE, the surface pressure of original ball valve seating rings was compared to that of rings previously subjected to 8% compression loading at 120°C and 0°C (248°F and 32°F).

The higher the surface pressure, the greater the recovery force exerted by the sample, indicating better stress recovery.

The graph below illustrates the significantly better recovery of a Dyneon™ TFM™ PTFE carbon compound compared to the same compound made from conventional PTFE.

**Stress relaxation as determined through surface pressure measurements**

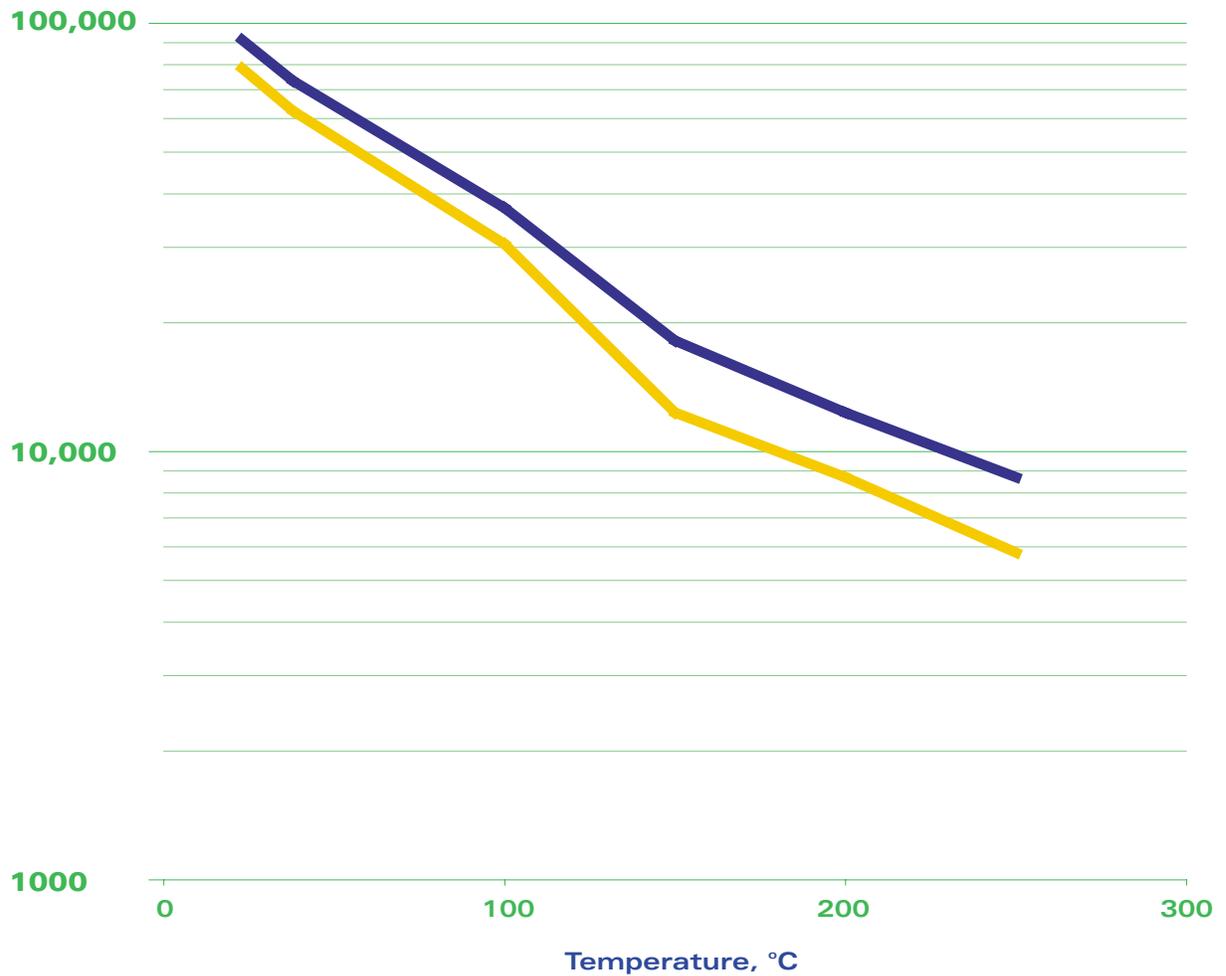


# Elastic Modulus Improvement with Dyneon™ TFM™ PTFE

Like other materials, Dyneon™ TFM™ PTFE shows a decline in elastic modulus with increasing temperature but to a lesser extent than conventional PTFE. This advantage over conventional PTFE becomes even greater at higher temperatures.

## Effect of temperature on elastic modulus

[psi]



Dyneon™ PTFE



Dyneon™ TFM™ PTFE

# Welding Dyneon™ TFM™ PTFE

## Dyneon™ TFM™ PTFE exhibits excellent weldability.

Welding of conventional PTFE is difficult at best, and welded specimens often fail at significantly lower levels of strain compared to unwelded specimens. But with Dyneon™ TFM™ PTFE and optimal welding conditions, mechanical properties of welded material are equivalent to unwelded material through the yield point. Even at the break point, welded TFM™ PTFE retains 75 - 95% of its typical unwelded strength.

The weldability of Dyneon™ TFM™ PTFE enables production of complex (e.g., hollow or concave) parts by reducing scrap and/or time for machining.

## Welding Methods

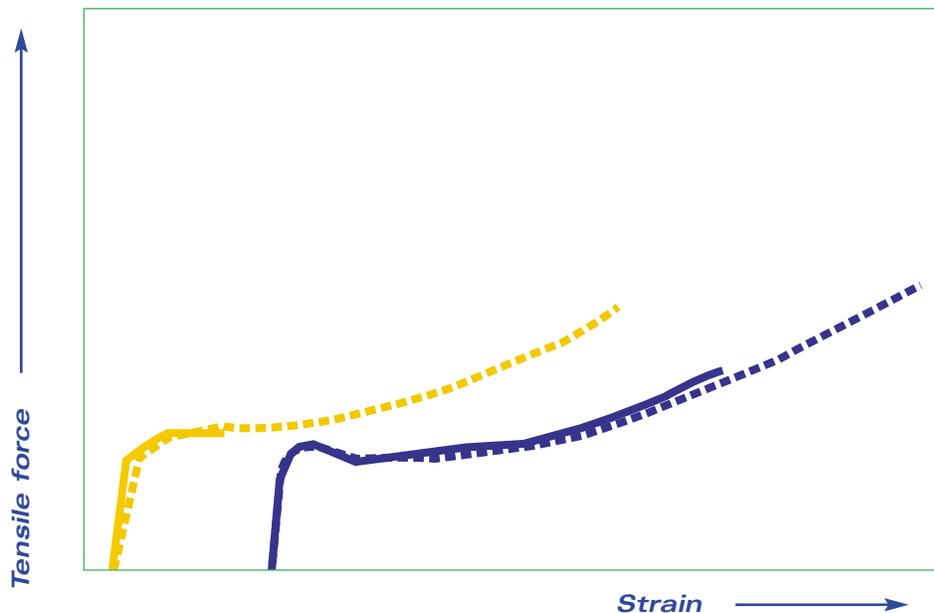
Three main production methods are used for welding Dyneon™ TFM™ PTFE:

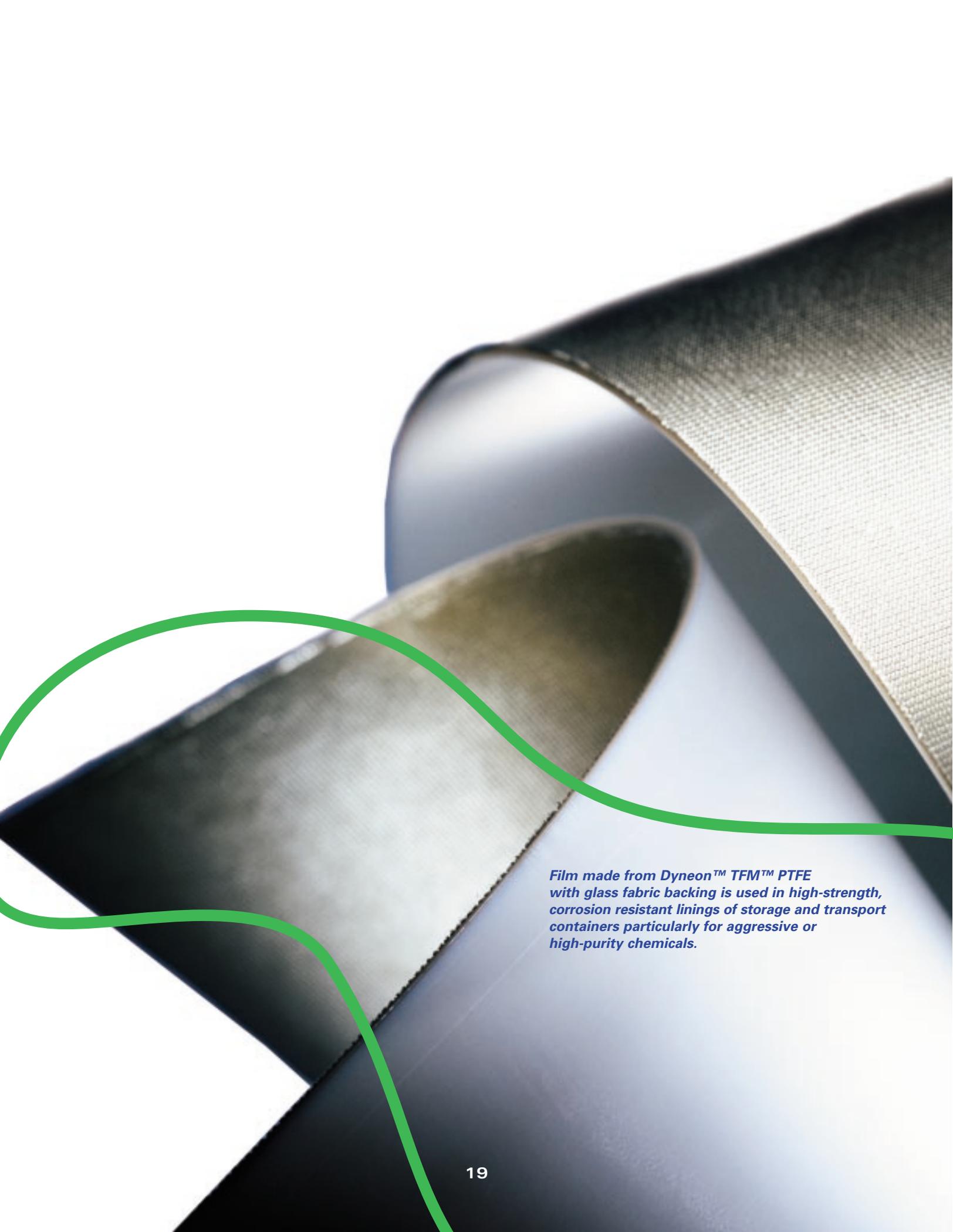
1. *Butt welding.* In this method, a localized sintering cycle is applied in the welding zone with the aid of special welding tools. This is the method generally most suited to the properties of Dyneon™ TFM™ PTFE. In addition to good contact between the parts to be joined, the temperature and contact pressure are important for good welding results.
2. *Non-contact, hot-tool butt welding.* This method, borrowed from conventional thermoplastic welding technology, involves use of a heating element which does not come in contact with the part. This method is primarily used for joining Dyneon™ TFM™ PTFE and PFA components or for joining Dyneon™ TFM™ PTFE parts with small cross sections.

3. *Hot gas welding with PFA.* If the first two methods described are unsuitable, a thin welding bead of melt-processable fluorothermoplastic, PFA, can be used to help bond the weld seams together. In this method, the Dyneon™ TFM™ PTFE parts are heated with hot air above the gel temperature and then joined using molten PFA.

Further details are available on request.

## Weldability of Dyneon™ TFM™ PTFE as demonstrated by tensile stress-strain testing





*Film made from Dyneon™ TFM™ PTFE with glass fabric backing is used in high-strength, corrosion resistant linings of storage and transport containers particularly for aggressive or high-purity chemicals.*

# Imaginative fluoropolymer solutions

At Dyneon, our goal is to provide you with design solutions to make your job easier – helping you solve problems now so that you can avoid problems later.

Whatever your challenge, you can count on Dyneon to respond with dependable, high-performance fluoropolymer products. By working directly with our customers and exploring new technologies, you can be sure that our fluoropolymers will not only meet today's needs, but future design requirements as well.

## Our worldwide commitment to quality

Indicative of our commitment, all Dyneon design, development, production and service facilities have achieved a global ISO 9001 quality management certification. Additionally, our Decatur, Alabama site and the remote functions in Oakdale, Minnesota have achieved a QS-9000 certification for our quality management system. The Decatur, Alabama and all Germany locations, as well as the production facilities at Antwerp, Belgium have also received ISO 14001 certification for their environmental management system. In addition, our Aston, Pennsylvania PTFE custom compounding facility has A2LA accreditation for its quality control laboratory.

## The Dyneon Product Portfolio:

### Dyneon™

PTFE & Custom Compounds

### Dyneon™

PFA, ETFE, FEP, THV, HTE Fluorothermoplastics

### Dyneon™

Fluoroelastomers

### Dyneon™

Polymer Additives

### Dynamar™

Polymer Processing Additives

### Dynamar™

Elastomer Additives

### Dyneon™

Monomers

## Important Notice:

Because conditions of product use are outside Dyneon's control and vary widely, user must evaluate and determine whether a Dyneon product will be suitable for user's intended application before using it. **The following is made in lieu of all express and implied warranties (including warranties of merchantability and fitness for a particular purpose): If a Dyneon product is proved to be defective, Dyneon's only obligation, and user's only remedy, will be, at Dyneon's option, to replace the quantity of product shown to be defective when user received it or to refund user's purchase price. In no event will Dyneon be liable for any direct, indirect, special, incidental, or consequential loss or damage, regardless of legal theory, such as breach of warranty or contract, negligence, or strict liability.**

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