

Quantum™ PTFE Products



Freudenberg-NOK
The Technology Specialist

Quantum™ PTFE Seals

As a leader in the global manufacturing of quality sealing products, Freudenberg–NOK strives to meet today's ever-increasing demand for high-performance materials. Our production of polytetrafluoroethylene (PTFE) seals plays a key role in delivering superior performance in the most demanding applications.

PTFE sealing technology has become an integral part of our modern daily lives, from semiconductor manufacturing and chemical processing to industrial and fluid power applications. PTFE is an extremely stable polymer which is chemically inert and functions in a wide range of temperatures (–328°F to +500°F). It has the lowest friction coefficient of any solid polymer and can be used in both static and dynamic applications, with or without lubrication. In addition, the strength and wear characteristics of virgin PTFE can be improved by adding fillers such as bronze particles, fiberglass fibers, and carbon fibers to provide a durable sealing material with outstanding thermal and chemical resistance.

Freudenberg–NOK continues to pioneer material development and product design in PTFE products. As **The Technology Specialist**, we employ premier Quantum™ PTFE materials and designs to provide cost-effective sealing solutions for the most demanding engineering applications.

Freudenberg–NOK offers customer consultations and advice from our highly qualified application engineers who offer on-site technical support and a diagnosis of our clients' entire systems, not just the individual parts. Our support teams are specialized by product line to match optimal design, materials, and processes to your specific requirements.

Despite the fact that the market is now saturated with a variety of fluoroplastics, PTFE, because of its outstanding material properties, has been able to hold its leading position in the sealing technology marketplace. Moreover, special compounds also offer improved properties, longer service life, and increased safety. These factors make PTFE ideal for use under extreme conditions and in contact with aggressive media.

With the help of ultra-modern simulation methods and its own PTFE material model, Freudenberg–NOK is in a position to optimize the function and design of components, thereby offering customers additional advantages for all areas of application.

PTFE Sealing Applications

Due to its unique performance characteristics, PTFE is used in a wide variety of markets, including aerospace, consumer appliance, medical, recreation, semiconductor, and more. PTFE offers a wide range of applications in the transportation and automotive industries providing superior solutions in the sealing of automobile air conditioning systems, interior bushings, suspensions, brake systems, steering systems, gas springs, engines, and transmissions.



PTFE seals are an integral part of most automobile systems.



Specific Quantum™ PTFE Sealing Applications include:

- Ball Valve Seals
- Cartridge Valve Seals
- Chemical-Resistant Bellows
- Compressor Pistons
- Compressor Shafts
- Gas Direct Injection
- Engine Cams
- Engine Crankshafts
- Low-Friction Bearings and Bushings
- Power Steering Valves
- Power Steering Racks
- Pneumatic and Hydraulic Cylinders and Actuators
 - ▶ Backup Rings
 - ▶ Piston Seals
 - ▶ Rod Seals
- Shock- and Strut-Banded Pistons
- Spring-Energized Seals
- Steering and Brake Line Seals

PTFE Case Study

In a typical case study example of PTFE used as a Transmission Design Replacement material, a customer copied a transmission seal design from a European manufacturer [Scarf-cut 55% bronze/5% moly PTFE seal ring—7200 RPM, 300°F, 300 psi, 2" OD]. Freudenberg–NOK reviewed the design and discovered several areas of concern. The customer's tests showed design failure due to seal extrusion, leakage, and durability. The PTFE engineers redesigned the seal and recommended a material change to Quantum 1045. The customer then tested and passed both newly approved designs.

With the Freudenberg–NOK design, new tests found the following improvements:

- Reduced leakage rate
- No durability concerns or issues
- Seal savings of \$750,000 annually
- Passed all customer testing requirements
- Improved deformation resistance

This customer implemented the Freudenberg–NOK proprietary process, **RETENTION**, to reduce assembly damage of jointed seals.

Typical PTFE Characteristics

PTFE (polytetrafluoroethylene) boasts a unique combination of outstanding material properties that makes it one of the best-performing materials in the field of sealing technology. Significant characteristics of PTFE include:

- Broad operating temperature range -328°F to $+500^{\circ}\text{F}$
- Optimum electrical insulating properties and great dielectric properties

- Superior longevity, weather-resistant
- Excellent frictional characteristics; no "stick-slip" effect
- PTFE is self-lubricating, which means that bearings and dynamic seals can run dry under certain conditions
- Anti-adhesive behavior
- Non-flammable
- Extremely low water absorption



PTFE Physical Properties

To ensure a successful PTFE application, it is absolutely essential that its special properties are taken into account.

Thermal Expansion

PTFE's melting properties are significantly different from other thermoplastics. PTFE is a partially crystalline polymer. A crystalline transformation process takes place at +66.20°F. This results in significant thermal expansion. Above +617°F, crystalline melting can be observed and during this process, crystalline PTFE moves into a glassy, amorphous state. While PTFE has an extremely high melting viscosity and parts retain their geometric form at high temperatures (in fact, PTFE parts do not start to flow until temperatures reach +617°F), some thermal expansion occurs between the range of +73.40°F and +617°F and it is vital to account for this when constructing components.



Mechanical Properties (Deformation Under Load)

One disadvantage of virgin PTFE is that it wears heavily in dynamic applications and has a tendency to cold flow or creep when put under pressure. These drawbacks can be eliminated by integrating fillers into the material. The filled compounds extend the range of applications in which pure PTFE can be used. These compounds are used for components that require low friction, high temperature resistance, low deformation under load, and enhanced wear characteristics.

Filled PTFE Seals

The use of standard fillers (like carbon, glass, and bronze) or special fillers allow scientists to make specific changes to PTFE's material properties. This means that PTFE can be adapted to meet the requirements of specific applications.

Freudenberg–NOK uses state-of-the-art test methods for the comprehensive characterization of materials. Test data is detailed in the section **The Influence of Fillers** on page 6.

Chemical Resistance

The strength of the fluorocarbon bond and the almost-complete shielding of the chains of carbon atoms by fluorine atoms results in unfilled PTFE's universal chemical resistance. This means that the PTFE is not affected by any of the following substances:

- Aggressive acids
- Alkali
- Nitrides
- Highly polarized and halogenated organic solvents
- Ketones, esters, and ethers

It is not necessary, therefore, to draw up comprehensive lists of PTFE's chemical resistance properties. However, several situations that result in a chemical reaction with PTFE should be noted:

- Alkali metals in a melted or dissolved state corrode PTFE and color it brown. This reaction is also used to make PTFE bondable.
- At higher temperatures and loads, PTFE reacts with elementary fluorine and chlorine trifluoride in what can sometimes be a violent reaction.
- PTFE can have an adverse reaction to lubrication oils, greases, and gasoline containing alcohol (gasohol).

PTFE Physical Properties

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Electrical Properties

PTFE has good electrical-insulating properties. Up to 302°F, the volume resistivity of pure PTFE is almost entirely unaffected by temperature. Dielectric strength remains virtually constant between +122°F to +482°F. The value increases as the thickness of the layer decreases. The dielectric strength of a 0.3mm-thick pore-free layer of PTFE is approximately 40k V/mm. PTFE also has an unusually low dielectric constant and, up to 10^{10} Hz, this value is almost entirely unaffected by frequency.

Tribological Properties (Friction)

Due to its very small intermolecular forces, PTFE has one of the lowest coefficients of friction of all solid materials. This gives PTFE outstanding non-stick properties (no “stick-slip” effect). The value is virtually identical in both the static and the dynamic range.

The coefficient of friction depends on several factors including: pressure, temperature, sliding speed, the counterface, and any additional lubrication.

The speed- and temperature-related coefficients of friction can be calculated on the basis of a friction master curve. For PTFE, the coefficient of friction will rise when an increase in speed occurs. This is a typical occurrence in polymers.

Wear Performance

Knowledge about the rate of wear is just as important for the selection of application-specific materials as it is for the characterization of the friction of PTFE. The relatively poor wear resistance of unfilled PTFE material is the result of PTFE particles that are only mechanically bonded during the production process (sintering process) and not bonded as if it were a real melt. This means that in the event of a dry run, the abrasion resistance is mainly influenced by the fillers and the counterface.

A pin-disk test can be used to determine the abrasion at a specific load and to derive the wear rate from the increase in the abrasion curve. The stresses selected for this purpose are in a range that is typical for PTFE seals.

Fillers such as carbon, graphite, bronze, and glass fiber significantly improve the wear resistance of PTFE; this effect differs from filler to filler. Please see *The Influence of Fillers* section on page 6.



A Fortunate Accident: PTFE was discovered on April 6, 1938, at DuPont's Jackson Laboratory in New Jersey. DuPont chemist Dr. Troy J. Plunkett was working with gases related to Freon™ refrigerants, another DuPont product. Upon checking a frozen, compressed sample of tetrafluoroethylene, he and his associates discovered that the sample had polymerized spontaneously into a white, waxy solid to form PTFE.

PTFE Physical Properties

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Properties of Standard PTFE Materials

Freudenberg–NOK uses state-of-the-art test methods for the comprehensive characterization of materials. These tests include both conventional analysis (such as those in accordance with DIN or ASTM), and special procedures

that have been developed and fine-tuned especially for PTFE. The properties of several standard materials are listed in the table below.

				MATERIAL				
				PTFE Virgin	PTFE + Glass Fiber	PTFE + Carbon	PTFE + Carbon Fiber	PTFE + Bronze
Filler Content % of Weight				na	25%	25%	10%	40%
Properties	Test Standard	Unit						
Density	ASTM D792	g/cm ³		2.15	2.22	2.10	2.03	3.0
Ball Indentation Hardness	DIN 2039-1	N/mm ²		27	34	37	35	41
Tensile Strength*	DIN 12086-2	MPa	MD	29	14	12	18	24
			CD	33	17	16	19	25
Elongation at Break	DIN 12086-2	%	MD	354	353	120	307	343
			CD	357	356	170	295	293
Tensile Modulus	House standard T=104°F	MPa	MD	446	674	925	673	760
			CD	383	752	959	670	771
Deformation Under Load, 73.4°F, 24h, 15N/mm ²	Similar to ASTM D621	%	MD	13.8	11.6	7.0	11.9	8.4
			CD	16.4	13.9	6.3	13.0	9.1
Permanent Deformation	Similar to ASTM D621	%	MD	7.0	6.2	3.2	5.9	4.1
			CD	8.3	7.8	2.8	6.8	4.8
Yield Point 1%	ASTM D695	MPa	MD	11.0	12.5	13.7	11.9	13.1
Yield Point 5%	ASTM D695	MPa	MD	15.7	16.8	19.6	16.8	19.1
Surface Resistance	ASTM D257	Ω		>10 ¹⁷	>10 ¹⁵	>10 ²	>10 ¹⁰	>10 ¹²
Thermal Conductivity	ASTM D1461	W/m•K		0.24	0.30	0.68	0.37	0.47
Coefficient of Linear Expansion (+122° to +212°F)	DIN 53752	10 ⁻⁵ •K ⁻¹		10.6	9.8	8.2	11.7	8.8

PTFE can be used at continuous operating temperatures of up to +500°F.

*sample thickness: 1.5 mm

MD=mold direction CD=cross direction

PTFE Material Fillers

The Influence of Fillers in Specific Materials

To ensure a successful application of PTFE, it is absolutely essential that its special properties are taken into account. The use of standard fillers (like carbon, glass, and bronze)

or special fillers allows scientists to make specific changes to PTFE's material properties. This means that PTFE can be adapted to meet the requirements of specific applications.

Material Types	Properties	Areas of Application
Graphite up to 15%	<ul style="list-style-type: none"> ■ Resistant to most chemicals ■ Good thermal conductivity ■ Good abrasion resistance ■ Good on soft counterfaces 	Lip seals, shaft seals
Glass fiber up to 40%	<ul style="list-style-type: none"> ■ Good pressure resistance ■ Improved wear performance ■ Good chemical resistance 	Flat gaskets that are subjected to pressure, piston rings, bearings, and chemically resistant valve seats
Bronze up to 60%	<ul style="list-style-type: none"> ■ Good thermal conductivity ■ Good abrasion resistance ■ Good compressive strength ■ Limited chemical resistance 	Bearings, pistons subjected to pressure, piston rings, bearings, and chemically resistant valve seats
Carbon up to 30%	<ul style="list-style-type: none"> ■ Good compression strength ■ Wear-resistant ■ Resistant to most chemicals ■ Good thermal conductivity ■ Good abrasion resistance ■ Anti-static 	Dynamic seals, bearings, and valve seats
Carbon fiber up to 30%	<ul style="list-style-type: none"> ■ Good thermal conductivity ■ Good abrasion resistance ■ Suitable for dry running 	Dynamic seals, bearings
Organic fillers up to 25%	<ul style="list-style-type: none"> ■ Excellent thermal resistance ■ Excellent mechanical resistance ■ Wear-resistant ■ Excellent dimensional stability ■ Gentle to counterfaces 	Friction bearings, dynamic seals
Quantum Premium-Grade Materials		
Quantum 1044 19-1	<ul style="list-style-type: none"> ■ Excellent compression resistance ■ Excellent thermal resistance ■ Excellent mechanical resistance ■ Good thermal conductivity ■ Wear-resistant ■ Resistance to most chemicals 	Dynamic seals, bearings, and pistons: An alternative to several high-temperature engineered thermoplastics. With low thermal expansion and higher load bearing, this material is excellent for high PV (pressure and velocity) applications where standard PTFE compounds would not be applicable. Quantum 1044 is used successfully in PV of 1,000,000 (psi x ft. per minute).
Quantum 1045 12-4	<ul style="list-style-type: none"> ■ Excellent compression resistance ■ Excellent mechanical resistance ■ Good thermal conductivity ■ Wear-resistant 	Dynamic seals and bearings: An alternative to several high-temperature engineered thermoplastics. Has seven times greater deformation resistance than unfilled PTFE. This material has high durability and is used where wear and extrusion may be a concern.
Quantum 1046 22-2	<ul style="list-style-type: none"> ■ Excellent compression resistance ■ Gentle on counterfaces 	Friction bearings and dynamic seals: With excellent deformation resistance and non-abrasiveness, this material is ideal for aluminum and other soft metal applications.

Manufacturing Competency

Freudenberg-NOK offers a large complement of production services, always with the highest manufacturing standards.*

COMPRESSION MOLDING

- Common uses include: seals for power steering units, transmissions, rotary valves, and compressors
- Premium Physical Properties
- **Compression Molding Specifications:**
 - ▶ Diameter: Up to 6 inches (152 millimeters)
 - ▶ Profiles: V-Rings, Rectangular Rings, Machined Shapes
 - ▶ Materials: All **Quantum** materials

EXTRUSION

- Provides ability for high-volume precision screw machining
- **Extrusion Specifications:**
 - ▶ Diameter: Up to 2 inches (51 millimeters)
 - ▶ Profiles: Rectangular Rings, Machined Shapes
 - ▶ Materials: All **Quantum** materials

PRECISION MOLDING

- Enables low material waste and lean manufacturing processes
- **Precision Molding Specifications:**
 - ▶ Diameter: Up to 6 inches (152 millimeters)
 - ▶ Profiles: Rectangular Cross Sections
 - ▶ Materials: All **Quantum** materials

NET MOLDING

- Zero material waste process for high-volume parts
- Lean one-piece-flow process
- Commonly used when unique geometry is required

HOT/COLD FORMING

- A low-cost alternative to machining
- Commonly used as an effective, lower cost alternative to O-ring energized piston rings
- **Cold Forming Specifications:**
 - ▶ Diameter: Up to 6 inches (152 millimeters)
 - ▶ Profiles: U-Cups, V-Rings, Lip Seals
 - ▶ Materials: All **Quantum** materials

PISTON BANDING

- PTFE over-molded pistons
- Commonly used for automotive struts and shocks in autos, recreational vehicles, and heavy trucks
- **Piston Banding Specifications:**
 - ▶ Materials: All **Quantum** materials

TAPE SKIVING

- Tape up to 6 inches wide provides an alternate manufacturing method to reduce cost where applicable
- Common uses include guide bands and complex (2D) geometric shapes
- **Tape Skiving Specifications:**
 - ▶ Materials: All **Quantum** materials

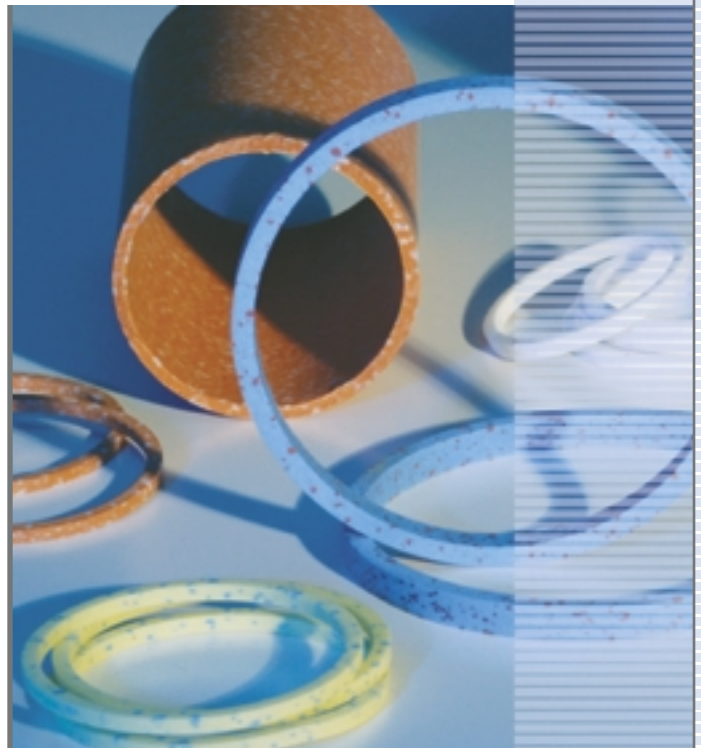
CUSTOM IDENTIFICATION

- Color coding available for easy identification
- PTFE allows etching identification

QUALITY AND LEAN SYSTEMS

- Automated Statistical Process Control systems give operators the red-yellow-green status of a run
- Automated problem alert systems measure critical part dimensions, e-mailing engineers if there is a problem
- Precision turning profiles enable the production of complex geometries
- **System Certifications:**
 - ▶ TS16949
 - ▶ ISO-14001
 - ▶ Ford Q1
 - ▶ ISO 9000
 - ▶ Growth®
 - ▶ Lean Manufacturing

*Manufacturers high-volume quantities



The Technology Specialist

Freudenberg-NOK is committed to complete customer satisfaction, by working closely with OEMs to develop and manufacture superior products which meet the high quality standards of today's environment. Our comprehensive business and technical development team works closely with our customers to ensure that every step of the product development process is thoroughly analyzed.

Lean Manufacturing and Six Sigma Quality

Freudenberg-NOK manufacturing is exceptionally lean, which reduces in-process inventory and waste while increasing product quality. Focusing on individual parts as opposed to batch processing allows us to isolate problems and prevent potential errors without jeopardizing an entire production run.

To learn more about Freudenberg-NOK and how we can assist with your PTFE applications, call us at 937-335-3306 or visit us at www.freudenberg-nok.com.

Since 1978, we have been committed to developing the highest quality products, allowing us to remain on the cutting edge of plastics technology. Today we are known as the experts in the design and manufacturing of PTFE products.

Diverse Manufacturing Capabilities

Freudenberg-NOK will meet or exceed your production demands with whatever application you choose. We offer a complete variety of processes to match the size, material, and quantity of parts needed with the most efficient manufacturing processes.

By developing a variety of support systems, Freudenberg-NOK can offer the following services:

- Worldwide R & D Technology Exchange
- Global integrated supply of products from factories in over 27 countries
- Over 30,000 employees serving you will ensure 100% satisfaction
- One-piece-flow lean manufacturing
- "Zero Warranty" focus



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