SEALING SOLUTIONS FOR THE CHEMICAL INDUSTRY

FREUDENBERG
SEALING TECHNOLOGIES

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THE COMPANY

Founded in 1849, the Freudenberg Group is a global technology company that remains family-owned until today. Consisting of more than 30 market segments, it develops technically leading products for a wide range of applications in cooperation with its customers – from sealing technology through nonwovens to chemicals and medical devices.

Freudenberg Sealing Technologies is the largest business group of the Freudenberg Group, acting as a supplier, developer and service partner. As a globally leading technology specialist, Freudenberg Sealing Technologies serves sectors such as the process industry, the automotive industry, the agricultural, and mechanical engineering industries. These areas are dedicated to autonomous units. Thus, the group ensures that each segment is supported by specialized know-how carriers.

From a defined standard product range to customer-specific developments, Freudenberg Sealing Technologies offers a unique product portfolio.

Freudenberg Sealing Technologies' market sector process industry offers sealing solutions especially for the areas:

- Food and beverage industry
- Chemical industry
- Pharmaceutical industry

These segments are characterized by high demands on the sealing products and the applied materials. The seal and the material must be resistant to extreme temperature conditions, aggressive media, high pressures, and the process fluid itself. Thus, the right choice of material plays an important role. Freudenberg Sealing Technologies has developed industry-specific materials that take these factors into account and have the required approvals.

THE CHEMICAL INDUSTRY AND ITS REQUIREMENTS

The chemical industry is one of the most important economic sectors. Chemical products are needed in many industries, such as the food or automotive industries, as raw materials for further processing.

In general, the chemical industry is divided into the following areas:

- Basic chemicals
- Fine chemicals
- Specialty chemicals
- Inorganic chemicals
- Organic chemicals

Each of these areas has different requirements due to the special features of its facilities. For this reason specially developed sealing solutions are required.

The seals are essential for reliability, as they ensure that nothing harmful infiltrates into the process or leaks, to either, regardless of the process or operating conditions, the sealing point and the medium.

Freudenberg offers highly resistant sealing solutions made of plastics such as PTFE, as well as a wide range of high-quality elastomers such as perfluoroelastomers (Simriz®), EPDM or FKM, if elastomeric flexibility in less aggressive production environments is required. A wide range of thermally and chemically resistant flat gaskets is available for the numerous piping and flange connections used. Mechanical seals are equipped with universally applicable secondary seals.

When selecting the sealing product, including the design and materials, all operating conditions with the respective media and their aggregate states must be taken into account.

In manufacturing and processing, particularly extreme parameters always occur during the handling of **inorganic basic chemicals**. In addition to aggressive, sometimes toxic media and high pressures prevail. Furthermore, the seals used here must have a wide temperature resistance. Accordingly, high-quality, robust and chemically resistant materials are in demand. In order to meet the high standards of the statutory emission values in processes, the seal must make a decisive contribution.

A typical application in the field of **petrochemicals** is the so-called steam cracking. In addition to the resistance to aggressive chemicals, seals must withstand high temperatures and pressures. For example, in a convection-capable oven for heating the residues, temperatures of up to +600 °C prevail with simultaneous pressure and subsequent vapor deposition. During the subsequent cracking of the resulting gas, the temperatures continue to increase to +850 °C. The real challenge for seals consists in the strong temperature changes due to the subsequent cooling of the gas. The seal must also be able to withstand an increase in pressure during the compression of the cracking gas to about 30 bar. The absorption of the gases requires the use of chemicals, especially lye.

During the handling of **polymers** (plastics), there are usually no particularly high demands in terms of pressure and temperature resistance. Only in individual cases, for example during a reaction break-off, temperatures of up to −80 °C may occur, which makes the use of specially developed sealing solutions necessary. In addition, solvents can corrode conventional sealing materials.

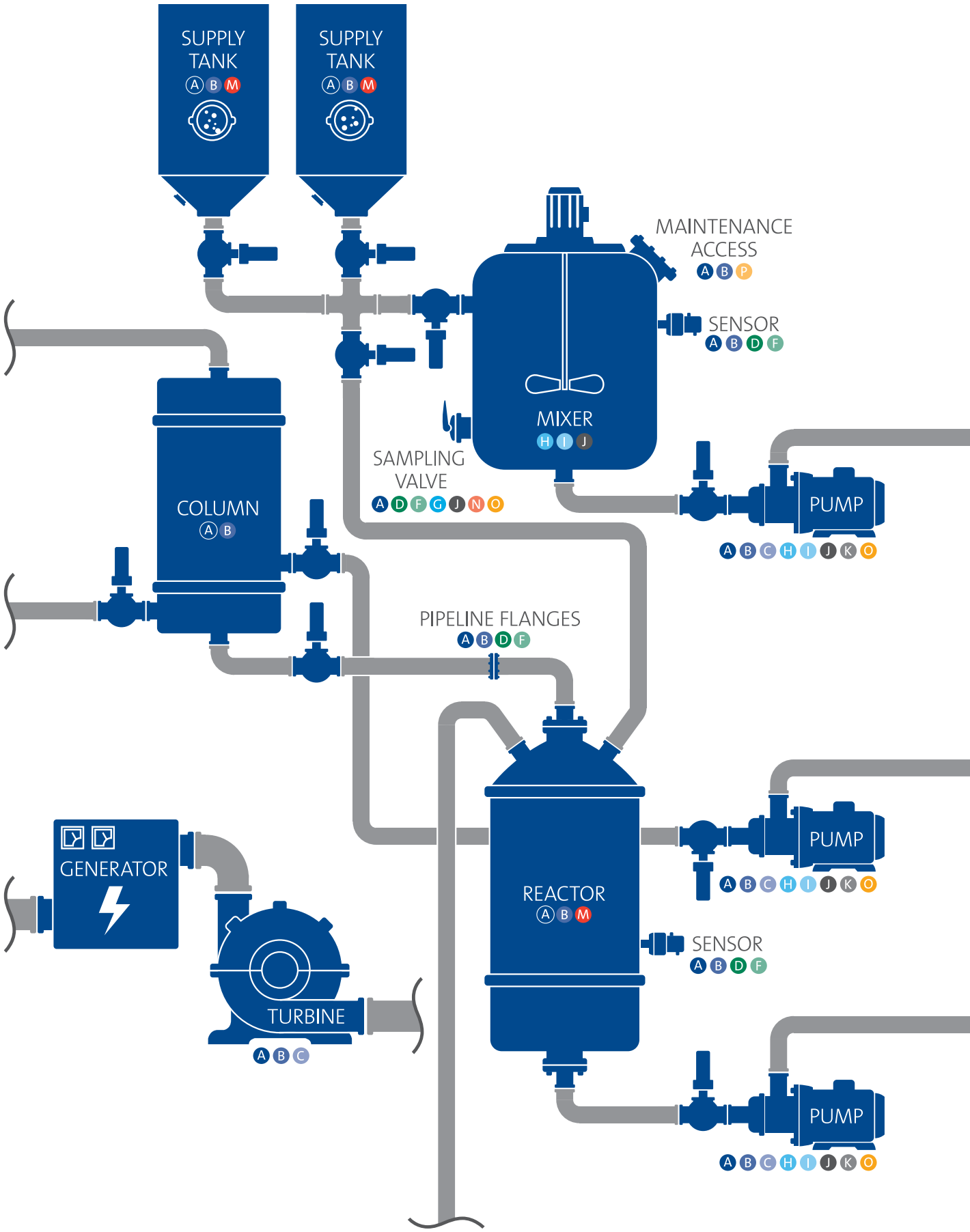
When dealing with **fine and specialty chemicals**, gaskets with particularly high temperature and chemical resistance are required. In addition to the use of aggressive and sometimes toxic media, temperatures from +300 °C down to the low-temperature range are not uncommon in crystallization processes. The material and the finished seal must be able to cope with this.

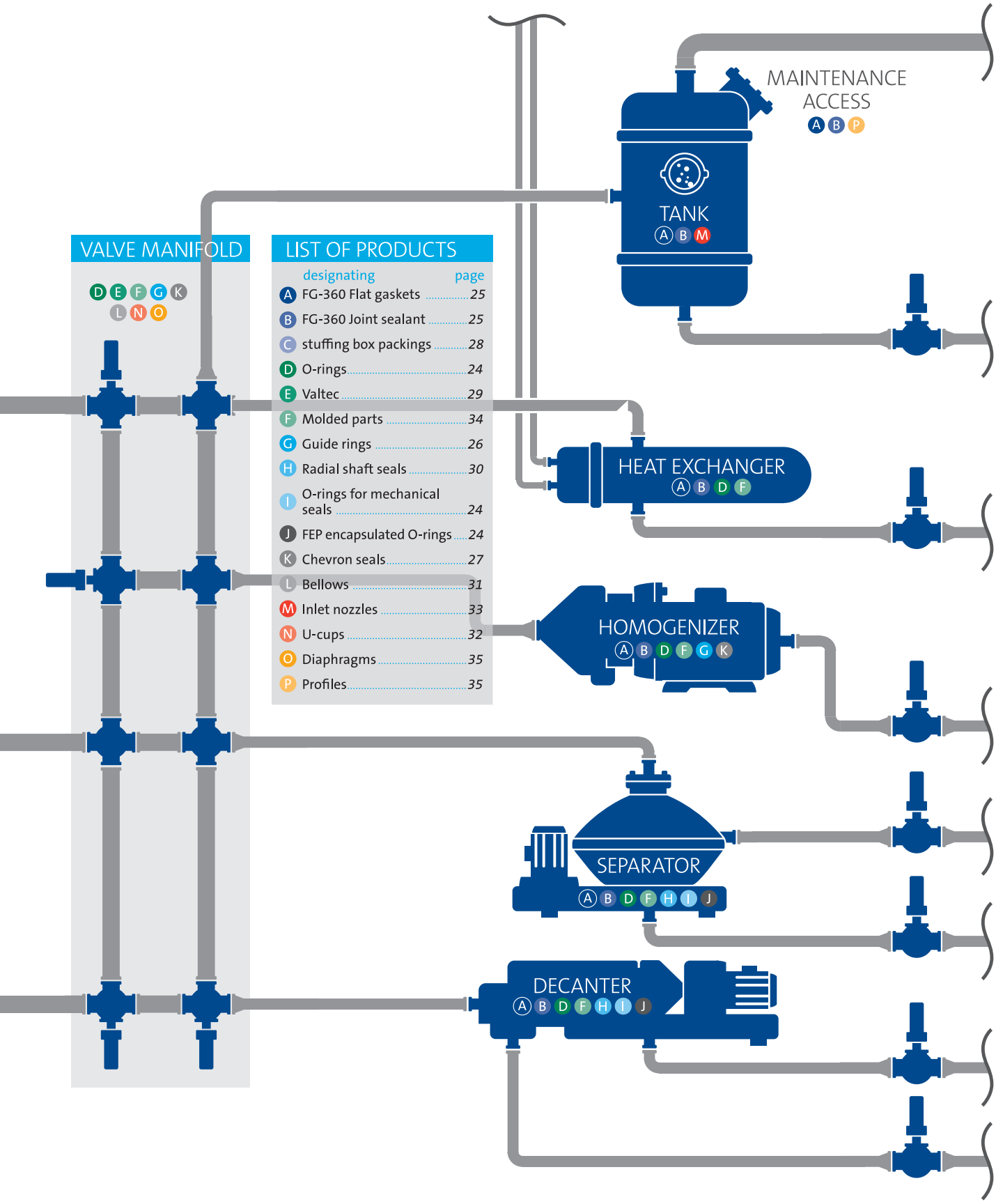
In the production of **detergents and personal care products** whose requirements are similar to those of the pharmaceutical industry, there are particularly stringent demands with regard to the purity of all process media used. In addition to the absence of dead spaces of the sealing point, the sealing materials must have the common approvals of the pharmaceutical industry and must withstand the demanding CIP/SIP cleaning media and processes.

Chemical Resistance Guide
Compatibility check of sealing materials and chemicals

www.resistanceguide.fst.com/chemical-resistance-guide

SCHEMATIC PROCESS PLANT





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OVERVIEW OF MATERIALS AND PRODUCTS

MATERIAL	NAME	COLOR	CROSS-LINKING	HARDNESS SHORE A	TEMPERATURERANGE IN AIR IN °C; STATIC	SEALING PRODUCTS
EPDM	60 EPDM 290	black	peroxidic	65 ± 5	–40 to +150	Diaphragms
	70 EPDM 291	black	peroxidic	75 ± 5	–40 to +150	• O-rings • Molded parts • Diaphragms • CNC machined
	70 EPDM 391	black	peroxidic	70 ± 5	–40 to +150	• Profiles • Cords
	85 EPDM 292	black	peroxidic	85 ± 5	–40 to +150	• O-rings • CNC machined
	85 EPDM 302	black	peroxidic	85 ± 5	–40 to +150	Diaphragms
FKM	70 FKM 576	black	bisphenolic	70 ± 5	–40 to +200 (dynamic –15)	• Diaphragms • O-rings • Molded parts
	75 FKM 461	black	bisphenolic	75 ± 5	–40 to +200 (dynamic –15)	Profiles
	75 FKM 606	black	peroxidic	75 ± 5	–40 to +230 (dynamic –15)	• Diaphragms • O-rings • Molded parts
	70 FKM 134347	black	peroxidic	70 ± 5	–40 to +200 (dynamic –30)	O-rings
	85 FKM 235447	black	peroxidic	85 ± 5	–50 to +200 (dynamic –40)	O-rings
Chem XP	75 Chem XP series	black	peroxidic	75 ± 5	–20 to +200	• O-rings • Molded parts
Simriz	70 Simriz 491	black	peroxidic	70 ± 5	–20 to +230	• O-rings • Molded parts
	75 Simriz 495	black	peroxidic	75 ± 5	–15 to +230	O-rings
	75 Simriz 497	black	peroxidic	75 ± 5	–15 to +325	O-rings
	85 Simriz 496	black	peroxidic	85 ± 5	–10 to +230	O-rings

MATERIAL	NAME	COLOR	FILLER CONTENT	TEMPERATURERANGE IN AIR IN °C; STATIC	SEALING PRODUCTS
PTFE	PTFE virginal	white	0%	–200 to +260	• O-rings • Molded parts • Guide rings/backup rings • Bellows
	PTFE bronze	brown	40%	–200 to +260	• O-rings • Molded parts • Guide rings/backup rings
	PTFE fiber glass	gray	10% - 25%	–200 to +260	• O-rings • Molded parts • Guide rings/backup rings • Rotary shaft seals
	PTFE carbon	black	25%	–200 to +260	• O-rings • Molded parts • Guide rings/backup rings • Rotary shaft seals
PA, POM, PEEK	• PA 6 • PA 66 • PA 12	• natural • gray • black	–	–40 to +110	• Molded parts • Guide rings/backup rings
	POM	natural	–	–40 to +120	• Molded parts • Guide rings/backup rings
	PEEK	natural	–	–50 to +260	• Molded parts • Guide rings/backup rings

TECHNICAL PLASTICS AND THEIR APPLICATIONS

PTFE

PTFE (polytetrafluoroethylene) shows an excellent chemical resistance. It surpasses all elastomer materials and thus makes the material the high-performance material of choice in sealing technology

The strong bonds between the carbon and fluorine atoms are due to the strong electronegativity. It is responsible for the excellent resistance to chemicals. A breakup of these bonds is only possible by means of a high energy expenditure. The thermal application range of PTFE is particularly large and lies between –200 °C and +260 °C. Thus, it is suitable for use with liquid gases. In addition, the material is particularly resistant to media such as bases, acids, alcohols, ketones, benzines, and oils. However, with strong reducing agents such as the solutions of alkali metals in liquid ammonia or very strong oxidizers at higher temperatures, PTFE is unstable. Examples include the use of sodium or elemental fluorine.

In addition to its exceptional resistance, PTFE has a static friction that resembles the dynamic friction. This leads to the effect that a transition from standstill to movement does not cause any jerking or the so-called stick-slip effect. The low friction coefficient of PTFE provides for a similarly good sliding behavior as wet ice on wet ice. The extremely low surface tension ensures that almost no material sticks to PTFE. Another advantage is caused by the memory effect of the material which is based on the long chains of molecules. When PTFE is heated, it strives to restore its original shape when cooled. However, PTFE is not suitable as an alternative for an elastomer since it has no rubbery-elastic properties.

General properties

- Low friction coefficient
- Extremely low surface tension
- Density: 2.10 to 2.30 g/cm^3
- Hardness 55 to 60 Shore D
- Thermal application range between –200 °C and +260 °C
- Temperatures above +400 °C release highly toxic pyrolysis products such as fluorophosgene (COF_2)
- Special types of PTFE can be welded

Friction coefficient of PTFE materials in different media

MATERIAL TYPE	FRICTION COEFFICIENT IN DRY RUN AT +60 °C	FRICTION COEFFICIENT WITH WATER AT +60 °C
PTFE + 25% carbon	0.24	0.10
PTFE + 15% graphite	0.24	0.11
PTFE + 10% carbon fiber	0.21	0.13
PTFE + organic fillers	0.21	0.10

Unfilled PTFE has a relatively low wear resistance and tends to cold flow. In addition, it is sensitive to high-energy radiation and difficult to glue. By adding different fillers, these properties can be positively influenced. Also, the thermal behavior in terms of conductivity and expansion can be optimized. The following table gives an overview.

Processing of PTFE

PTFE cannot be processed by injection molding. In order to produce components, different types of material can be processed into semi-finished products (tubes, rods and plates), from which the final product is manufactured in the next processing step.

Optimization of PTFE by means of fillers

FILLERS	PROPORTION	PROPERTIES	TYPICAL PRODUCTS
Graphite	up to 15%	• Good chemical resistance • Good thermal conductivity • Good wear properties • Good for soft mating surfaces	• U-cups • Rotary shaft seals
Fiber glass	up to 40%	• Good pressure resistance • Improved wear and friction behavior • Good chemical resistance	• Flat gaskets for pressure applications • Piston and rod seals
Bronze	up to 60%	• Good abrasion and pressure resistance • Good thermal conductivity • Limited chemical resistance	• Piston and rod seals for pressure applications • Bearings
Carbon	up to 30%	• Good abrasion and pressure resistance • Good thermal conductivity • Good chemical resistance • Electrically conductive	Dynamic seals
Carbon fiber	up to 30%	• Good thermal conductivity • Good wear properties • Very good for dry run	• Dynamic seals • Bearings
Organic fillers	up to 25%	• Excellent thermal and mechanical properties • Good abrasion resistance • Excellent dimensional stability • Gentle on mating surfaces	• Dynamic seals • Rotary shaft seals • Bearings

ePTFE

Expanded PTFE (ePTFE) is a specially processed variant of PTFE. Thanks to the multidimensional alignment of the polymer chains, it has improved mechanical and thermal properties.

In the chemical industry, this material is used because of its particularly good temperature and chemical resistance. Typical applications include reactors, columns, pipelines and pipe connections as well as heat exchangers and process vessels. Both in high temperatures of up to +315 °C as well as in low temperatures of up to –268 °C, the material can be used without any problems.

Freudenberg has developed the material variant FG-360 for these applications. It consists of 100% pure PTFE. Due to the dense shape, fillers or binding agents can be completely dispensed with. This provides more stability and less cold flow and creep relaxation than existing expanded PTFE products. In addition, the material is resistant to UV radiation, ozone and almost all chemicals.

Even at small surface pressures and low tightening torque, the material can convince with its sealing effect. This is due to the soft, extremely compressible and yet strong material. Worn or damaged flange surfaces can easily be compensated for. Thanks to these properties, the extruded PTFE is ideally suited for plastic or glass lined flanges. It can easily be cut by hand or punched and has a low coefficient of friction. With a value of 0.2, the latter is similar to wet ice and allows easy assembly and disassembly. Since the FG-360 neither ages, embrittles nor deteriorates in its consistency, it is indefinitely durable.

FG-360 is offered in two product variants:

- **FG-360 Joint Sealant** is a sealing tape with pressure-sensitive adhesive tape on the back. It is suitable for heat exchangers, irregular flanges, tank caps, maintenance access and hand holes
- **FG-360 seal plates** are produced in 1.5 mm, 2 mm and 3 mm plate thickness. More thicknesses are available on request. The plate dimension is 1,500 mm x 1,500 mm

General properties

- Usable in the temperature range of –268 °C to +315 °C – high temperature applications or cryogenic processes
- Employable in the pressure range from vacuum up to 200 bar
- Chemically inert over the pH range from 0 to 14
- High tensile strength

PROPERTIES	1.5 MM THICKNESS	3.0 MM THICKNESS
Type	TF-0-0 DIN 28091-3	TF-0-0 DIN 28091-3
Color	white	white
Rules and Standards	TA Luft	TA Luft
Density g/cm³	0.85	0.85
Tensile strength longitudinally N/mm³	14	18
Compression	69	66.2
Resilience %	7.6	11.6
Temperature range °C	–268 to +315	–268 to +315

POM, PA, PEEK

POM – Polyoxymethylene
Polyoxymethylene (abbreviated POM, also called polyacetal) is predestined for use in the chemical industry. It has good chemical resistance to oils and bases as well as excellent sliding properties. The semi-crystalline thermoplastic material is particularly suitable for precision molded parts thanks to its high rigidity, low friction coefficient and dimensional stability. Due to its high crystallinity, POM is stiffer and stronger than other thermoplastics in a temperature range of +50 °C to +120 °C. The low tendency to creep and high creep rupture strength complete the positive properties of the material. POM should not be left in permanent contact with highly concentrated acids and chlorine.

PA – Polyamide
Polyamide is a semi-crystalline thermoplastic characterized by high toughness, strength and rigidity. In addition, PA has a good damping capacity, high wear resistance and low tendency to creep. These properties are achieved by the amide groups, which interact via hydrogen bonds. The mechanical properties can be further improved by fiber composites with glass or carbon fibers, depending on the application. In the sealing area, PA rings are preferably used as support rings for a wide variety of sealing elements.

PEEK – Polyetheretherketone
In the chemical industry, PEEK is often used in the area of high temperatures due to its high melting temperature. In addition, the material has a nearly universal chemical resistance. Like the other plastics, PEEK has high strength and rigidity. In addition, it has a low coefficient of thermal expansion and good sliding properties, as well as a low corrosion behavior. Unfilled PEEK can be modified in its mechanical properties by fillers such as glass and carbon fiber or PTFE. As a flame retardant and self-extinguishing plastic, its use is advantageous in some chemical applications. Due to its lack of elasticity, PEEK is particularly suitable for use as back-up rings for O-rings or as pressure rings for Chevron-type packing sets. In contrast to PTFE, PEEK can also be processed by injection molding.

MATERIAL	PROPERTIES	SEALING PRODUCTS
POM	• Thermal application range from –40 °C to +120 °C • Pronounced yield strength at about 8% elongation (room temperature) • Good resilience • Good friction and wear behavior • Low water absorption	• Backup rings • Guide rings
PA	• Thermal application range from –40 °C to +120 °C • Low water absorption (for example PA6 from 2.% to 3.5%) • High wear resistance • High impact resistance • Low tendency to creep	• Backup rings • Guide rings
PEEK	• Thermal application range from –50 °C to +260 °C • Excellent chemical resistance • Excellent wear resistance • Highest mechanical strength and rigidity of all plastics • Hydrolysis and hot steam resistance	• Backup rings • Guide rings

ELASTOMERS AND THEIR APPLICATIONS

FKM

Fluoroelastomers are very high performance materials with exceptional chemical and thermal resistance due to the stronger fluorocarbon bonding compared to a weaker carbon-hydrogen bond.

The degree of fluorination of a compound can be determined by a different polymerization of individual monomers, such as vinylidene fluoride (VF), hexafluoropropylene (HFP), tetrafluoroethylene (TFE), 1-hydropentafluoropropylene (HFPE) and perfluoromethylvinylether (PMVE). Co-, ter- and tetrapolymers with different structures and fluorine contents between 65% and 71% can be prepared. The use of variable proportions allows the development of a suitable material for different requirements in terms of media resistance and low-temperature flexibility.

FKM has in many cases a sufficient resistance to common organic solvents. Even in hydrocarbon mixtures, this material is unbeatable.

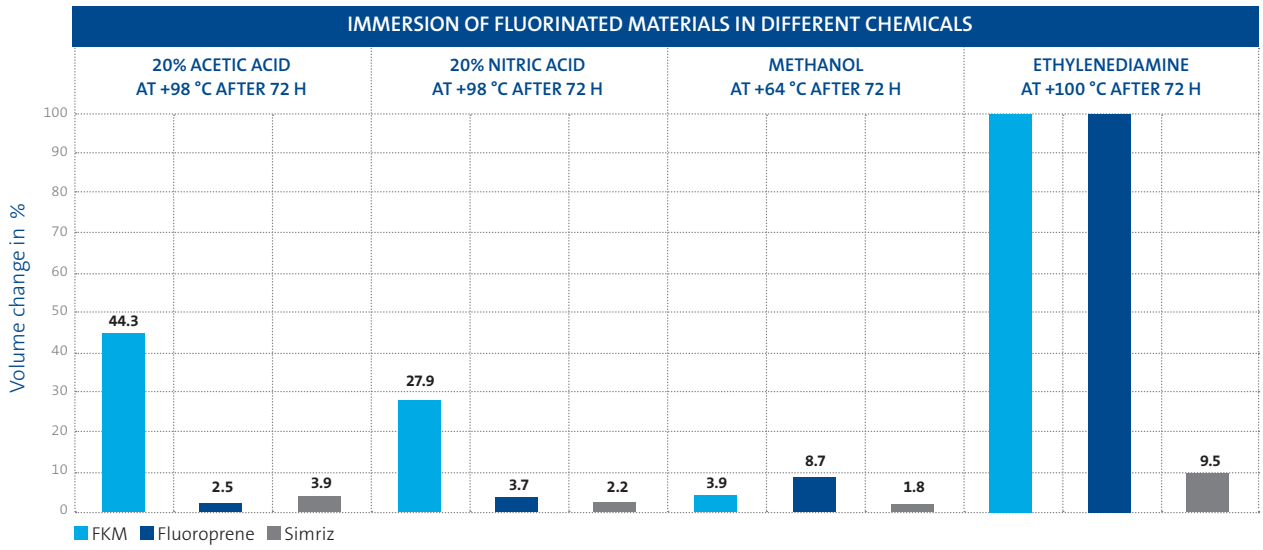
Standard materials are used in the broad spectrum of chemical applications for low-temperature applications from –20 °C up to +200 °C. For special applications in a cold environment, or for example in contact with LPG (Liquid Petroleum Gas), a temperature range from –40 °C to +200 °C is achieved with a special composition of the compound.

Special FKM compounds with higher fluorine content can even keep up with FFKM materials because of their high chemical resistance and may replace them in some applications.

General properties

- Excellent temperature resistance
- High chemical stability
- Very good ozone, weathering, aging and oxygen resistance
- Excellent resistance in mineral oils and fats
- Low gas permeability
- Very good resistance in nonpolar media
- Prone to increased swelling in polar solvents, ketones and amines
- Temperature resistance from –40 °C to +200 °C

MATERIALS	TEMPERATURE-RANGE, DYNAMIC	APPLICATION AREA	PRODUCTS
70 FKM 134347	–30 °C to +200 °C	Diluted acid, polar and nonpolar solvents, fats/oils and hydrocarbon compounds	• O-rings • Molded parts • Diaphragms
75 FKM 606	–15 °C to +200 °C	Diluted acid, polar and nonpolar solvents, fats/oils and hydrocarbon compounds	• O-rings • Molded parts • Diaphragms
85 FKM 235447	–40 °C to +200 °C	Diluted acid, polar and nonpolar solvents, fats/oils and hydrocarbon compounds	• O-rings • Molded parts • Diaphragms



CHEM XP

The chemical industry has special requirements. For this purpose, Freudenberg has developed a series of new special materials that are optimized for the different operational conditions in this industry.

In order to achieve this, particularly effective and capable components were selected to meet the high requirements of the chemical process industry. Therefore Freudenberg has developed several high-performance materials with different price-performance ratios. Thus, the customized material for the application can be chosen without leading to disproportionate costs.

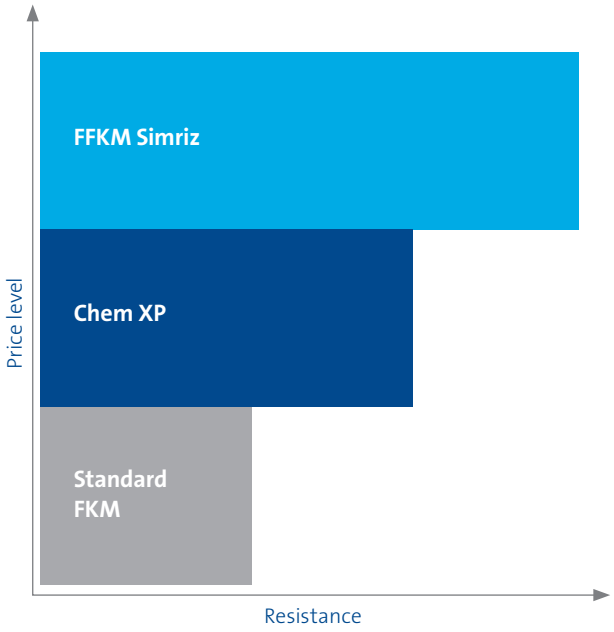
The newly developed materials differ by their chemical resistance which was examined in a comparative study (to be found on page 20–22). The benchmark shows the strength of the individual compounds, making it easier to choose the right material for a particular application.

In the broad spectrum of chemical applications for temperature ranges from –20 °C to +200 °C, these specialty compounds can be used as O-rings in mechanical seals or as molded parts for valves, for example.

In acids and bases, organic solvents as well as hydrocarbon compounds, Chem XP provides almost the same resistance as FFKM. Therefore, substitution is conceivable in many cases, especially in applications where FFKM has so far been without alternatives, but where it possibly may not be necessary. This provides an opportunity to optimize the plant components and reduce costs with this newly developed family of materials. Replacing an FKM with Chem XP increases the service life and reduces production costs due to the infrequent maintenance intervals.

General properties
- Excellent temperature resistance
- High chemical stability
- Very good UV, ozone, aging and oxygen resistance
- Excellent resistance in mineral oils and nonpolar solvents

Products / Materials
- O-rings made of 75 Chem XP on request
- Molded parts made of 75 Chem XP on request



SIMRIZ

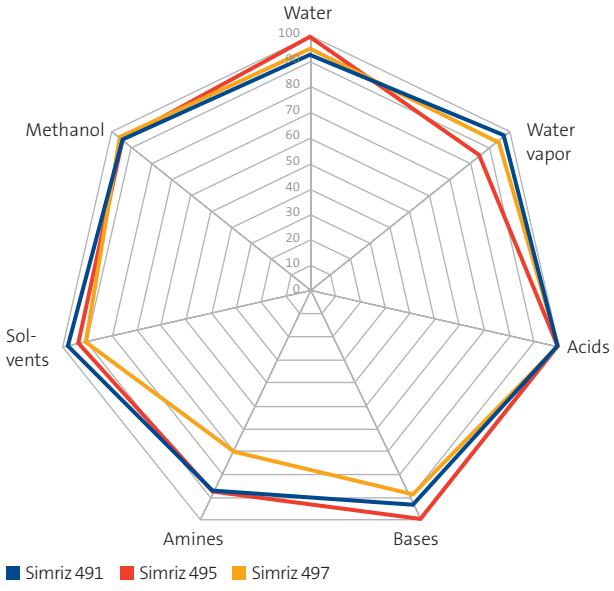
The perfluoroelastomer Simriz is considered a high-end solution for the process industry. Thanks to its broad chemical resistance and exceptional temperature resistance, it is widely used in the chemical industry.

Special monomers form the basis for Simriz and other perfluoroelastomers (FFKM). The high bonding energy between the carbon and fluorine atoms provides the excellent thermal and chemical properties which are comparable to the plastic material PTFE. However, compared to PTFE, Simriz has the rubbery-elastic properties of an elastomer. This combination of elasticity and excellent durability makes it the material of choice for particularly demanding applications. This makes Simriz universally applicable: in static and dynamic applications, at high temperatures, extreme pressures and strong fluctuations in these parameters. With Simriz, Freudenberg offers a comprehensive product range of high-quality FFKM materials. In addition to the versions for standard applications, that is available in different degrees of hardness, there is a variant for high-temperature applications.

General properties

- Broad chemical resistance in polar and nonpolar media
- Very good resistance in oxidative media, even at high concentrations and temperatures
- High temperature range of up to +230 °C, special types of up to +325 °C
- Very good elasticity

Chemical resistance



MATERIALS	UPPER TEMPERATURE LIMIT	APPLICATION AREA	PRODUCTS
70 SIMRIZ 491	Up to +230 °C	Standard	• O-rings • Molded parts
75 SIMRIZ 495	Up to +230 °C	Standard	O-rings
85 SIMRIZ 496	Up to +230 °C	High pressure, expl. decompression	O-rings
75 SIMRIZ 497	Up to +325 °C	High temperature	O-rings

EPDM

EPDM (ethylene propylene diene rubber) is the standard material for all aqueous media applications.

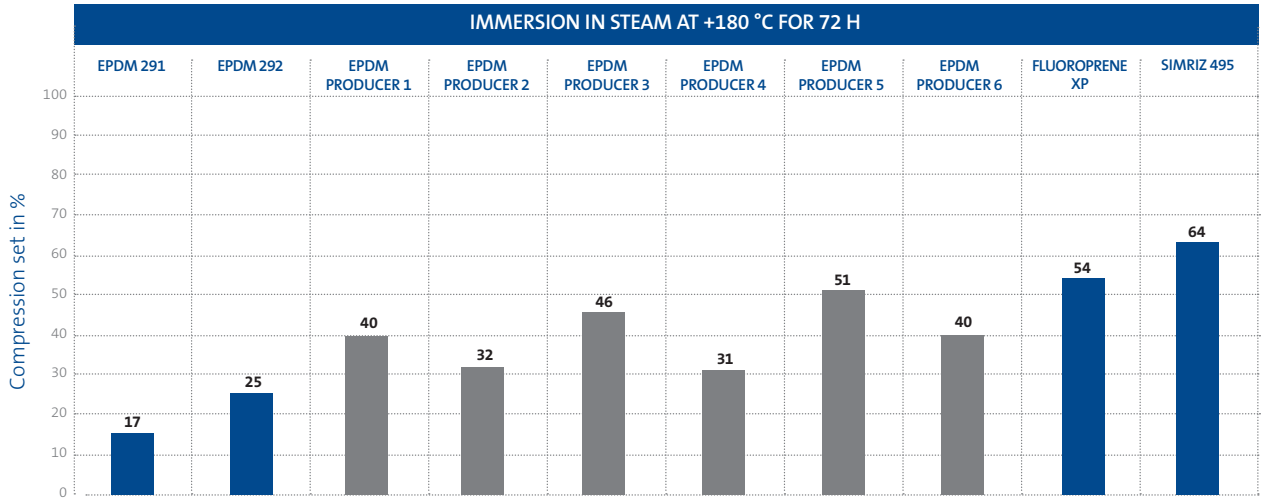
EPDM is polymerized from ethylene, propylene and a low diene content. Seals made of this material show good media resistance in hot water and steam (permanently up to +180 °C), diluted acids (hydrochloric acid, nitric acid and phosphoric acid) and alkalis (caustic soda solution and potassium hydroxide solution). They can be used very well in all polar media and therefore also in polar organic solvents such as methanol, or in coolants such as ethylene glycol. For use in products containing grease and oil, EPDM is not recommended. In nonpolar solvents, the material cannot be used either.

As shown in the graph below the EPDM materials of Freudenberg boast the best results of the compression set test at +180 °C after three days.

General properties

- Very good aging, ozone and light resistance
- Good resistance to cold and heat from approx. –50 °C to +150 °C (in air)
- Good elongation at break and tensile strength
- Very high abrasion resistance
- Very good resistance to water and polar and oxidative media
- Excellent elastic behavior

MATERIALS	TEMPERATURE-RANGE, DYNAMIC	APPLICATION AREA	PRODUCTS
70 EPDM 291/391	–40 °C to +180 °C in steam	• Polar and nonpolar solvents • Hot water and steam	• O-rings • Molded parts • Diaphragms • Profiles • Clamp seals
85 EPDM 292	–40 °C to +180 °C in steam	• Polar and nonpolar solvents • Hot water and steam	O-rings
85 EPDM 302	–40 °C to +180 °C in steam	• Polar and nonpolar solvents • Hot water and steam	Molded parts



BENCHMARK – FLUORINATED SEALING MATERIALS IN CHEMICAL APPLICATIONS

The differences in the polymer architecture of the fluorinated compounds are reflected in the durability and resistance of the different fluoroelastomers. A variety of possible variations for the design and the amount and arrangement of monomers help the developers to positively influence one or the other property. These include not only the chemical resistance, but also temperature behavior or the processability of the compound.

No FKM material is identical to another with regard to its performance. For standard FKM materials, good performance in oils or other hydrocarbon compounds is associated with low acid resistance. In this case, a different type and constellation of the monomers in the compound is required to withstand the chemical attack. Increasing the acid stability of a compound does not necessarily improve its resistance to other reactive chemicals. With FFKM, a perfluorinated elastomer that can withstand almost all highly aggressive chemicals while maintaining high heat resistance, the developers succeeded in creating a universal compound for a variety of very reactive substances. Of course, this has its price. It results from the complex synthesis of the raw polymers as well as the complicated processing of the material.

For example, many manufacturers in the market are endeavoring to offer several tailor-made solutions in the FKM segment for the different requirements of the market. These compounds are designed to meet customer needs and to reduce costs without sacrificing seal performance.

With this objective in mind, the material family Chem XP was developed. It is intended to meet the high requirements of the chemical industry and to offer improved performance in various chemicals. This new product family and other fluorinated compounds from our own range of materials as well as similar and adequate materials from the market competitors (fluorine elastomers with high fluorine content) were compared against a benchmark and tested for their performance.

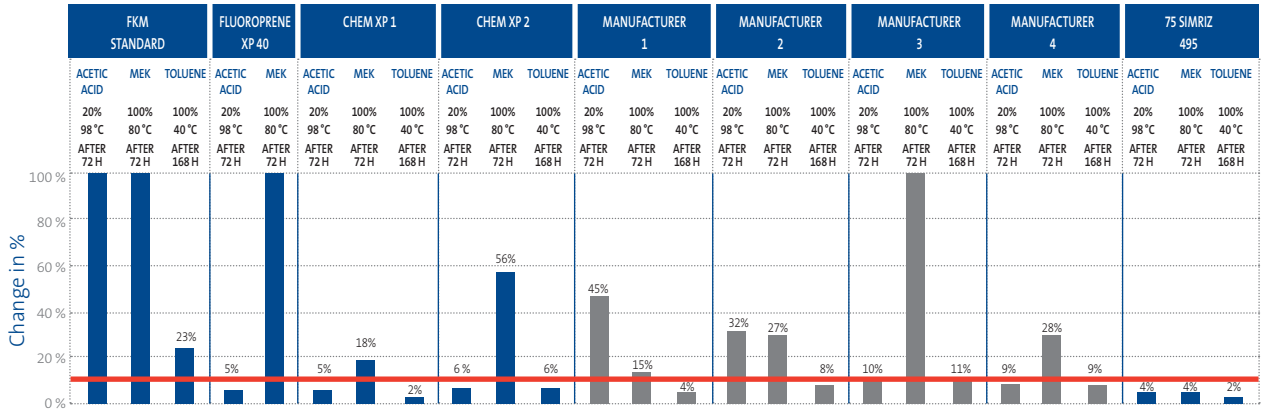
As a benchmark, three of the most critical representatives from the chemical classes relevant to the chemical industry were selected.

As representative for acids, acetic acid was selected (20% at +98 °C), while methyl ethyl ketone (MEK at +80 °C) represented the class of solvents and toluene (at +40 °C) served as a representative of the alkylbenzenes. The storage temperatures were chosen just below the boiling point. This created challenging "worst case" conditions. The storage duration was three days for acetic acid and MEK and one week for toluene.

Considering the **change in volume swelling** across all tested compounds, one notes very different behavior of the individual materials.

- The swelling values of a standard FKM material show that this material is not suitable for such critical applications.
- The material Fluoroprene® XP, which shows an excellent performance in acetic acid, fails completely in MEK.
- The compounds of the competing manufacturers show significant weaknesses in the acid as well as in MEK. Only the representative product of manufacturer 4 might be used under the conditions tested.
- Chem XP 1 gave the best results overall, which can be compared very well with the very low results of an FFKM, such as 75 Simriz 495. At temperatures below +80 °C, the material will exhibit excellent resistance. Chem XP 2 is only partially usable in MEK, but its acid resistance is very good.

Results of the volume change in acetic acid, methyl ethyl ketone (MEK) and toluene



In addition to the volume change, the change in strength is also an indicator of the performance of the materials.

A high decrease in strength (greater than 30%) is usually an indication of the chemical degradation of the crosslinking bridges or polymer chains in the elastomer matrix.

The assessment of the results in combination with the swelling values corroborates the previously made statement regarding the durability and resistance of the individual materials. Often the two parameters correlate with each other: the higher the swelling, the greater the loss of strength values. However, this does not always apply, which is why a consideration of the strength is relevant.

The strength values of a standard FKM show that all three test media have a major impact on the durability and resistance of the material. Both the change in volume and in strength classify the material as unsuitable.

With Fluoroprene XP, the excellent performance in acetic acid is confirmed, while the material cannot be used in MEK.

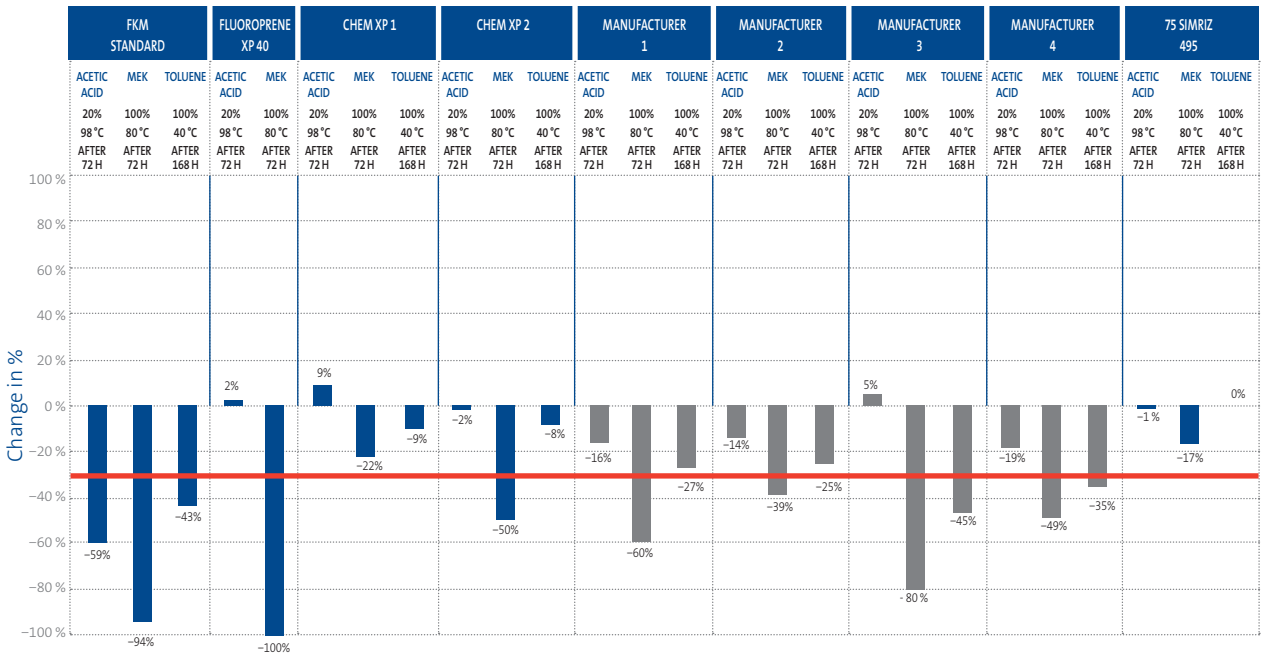
The compounds of the competitors also show clear weaknesses in MEK. The strength values are all beyond the 30% limit. Taking these results into account, the material of manufacturer 1 does not look good anymore with respect to its performance. With a loss of strength of up to 50%, it is not useable although the swelling levels are still moderate.

Chem XP 1 and 75 Simriz 495 are the winners overall. The very good resistance in acetic acid of Chem XP 2 is confirmed by the very low strength reduction.

With the new Chem XP range, it has thus been possible to generate tailor-made materials for chemically demanding applications and to further increase the family of Freudenberg elastomers for the chemical industry consisting of FKM, Fluoroprene XP and Simriz.

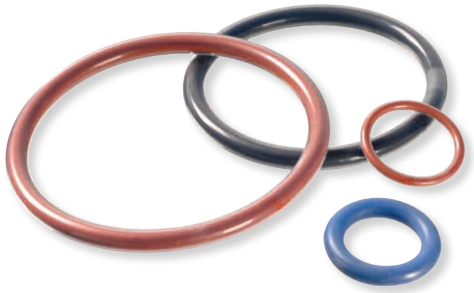
The declared objective
Every recommended material should meet the requirements of the application, but also at the best price/performance ratio.

Results of the change in strength in acetic acid, methyl ethyl ketone (MEK) and toluene



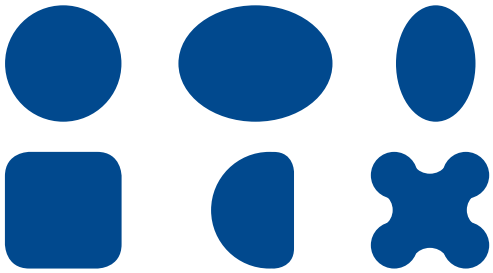
PRODUCT PORTFOLIO

O-RINGS



Thanks to its universal application possibilities, the O-ring can be found in virtually every type of industry. In the chemical industry, it is used as standard and as FEP/PFA-encapsulated version.

O-rings impress with their excellent price-performance ratio as well as their high availability. They can be made of almost any elastomer material and are very small and material-saving compared to other sealing elements. As a standard part, they can be produced in large quantities or individually in small quantities. The application areas are versatile. Typically, they are used for static and dynamic sealing in axial, radial, translational and rotating applications. Despite the simple design, they can be used reliably in a variety of installation conditions. The O-ring is available in the following cross sections:

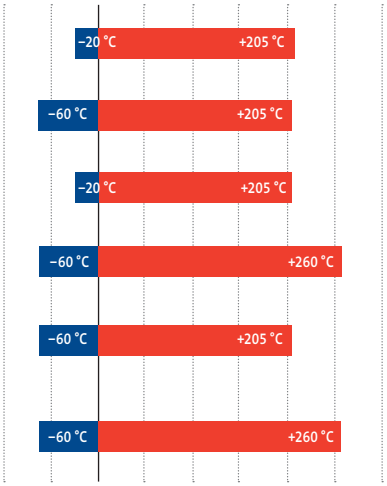


Thanks to an extensive tools kit, the O-ring is available in a variety of intermediate sizes, inch and metric dimensions. Even standardized cross-sectional dimensions from 1.0 mm to 6.99 mm can be manufactured without problems. Smaller or larger sizes are available on request. Special sizes over 500 mm usually require a new tool.

In addition to the elastomer versions, it is also available as FEP/PFA-encapsulated version. This consists of an elastomer core and a seamlessly closed casing. The core is made of FKM or VMQ (silicone) and ensures the uniform prestressing at the sealing point. As a result, a comprehensive, elastic compression is achieved. The FEP- or PFA-encapsulation ensures the sealing and durability.

This variant of the O-ring can be used wherever extraordinary chemical resistance and at the same time a high degree of elasticity are required. This is especially the case when being used in extreme temperatures and chemicals. Here, the conventional O-ring can fail and lead to leakage.

Temperaturerange



FLAT GASKETS

Flat gaskets are used wherever different plant elements of a process plant are linked together. These are, for example, pipelines, fittings or pumps.

For secure sealing, the flat gasket is inserted between two flanges, which are connected by screws. For the chemical industry, the stability of the selected sealing material plays a major role in this static application. To some extent, the media flowing in the pipelines are extremely aggressive and could attack the sealing material. In the worst case, this leads to leakage, which is particularly risky when using extreme media and temperatures. The selected sealing material must therefore have a particularly high resistance to aggressive solvents and chemicals in addition to the balancing function of macro-nonplanarities. Therefore, a nearly inert material is needed. Freudenberg offers three material variants for these applications:

FG-120
Is a graphite gasket reinforced with aramide fibers and bonded with NBR. As a result, it easily withstands manifold thermal and chemical influences.

FG-180
Is a silicate-filled gasket made of modified PTFE. It convinces with universal chemical resistance, a wide temperature range and good mechanical characteristics. This material quality also fulfills the TA Luft requirements.

FG-360
Is a special form of the flat gasket. It has a unique flexibility. The material achieves this by consisting of 100% expanded PTFE (ePTFE). This material is considered particularly pure and reliably prevents cold flow. In addition, seals made of ePTFE are characterized by a high temperature cycle resistance.

In addition to the conventional flat gasket form made of FG-360, Freudenberg also offers a joint sealant. This tape is wound on a spool and can be individually cut and is self-adhesive on one side. For example, it allows to reliably and quickly seal joints, lids or frames. The FG-360 Joint Sealant has a length of 25 m and is available in different widths.

NAME	FORMAT IN MM	THICKNESS IN MM
FG-120	1,500 x 1,500	0.5 0.8
	2,000 x 1,500	1.0 1.5 2.0 3.0
FG-180	1,500 x 1,500	0.5 0.8 1.0 1.5 2.0 3.0
FG-360 Plate	1,500 x 1,500	0.5 1.5 3.0 6.0
FG-360 Joint sealant	7 x 25,000 10 x 25,000 14 x 25,000 17 x 25,000 20 x 25,000	2.5 3.0 5.0 6.0 7.0

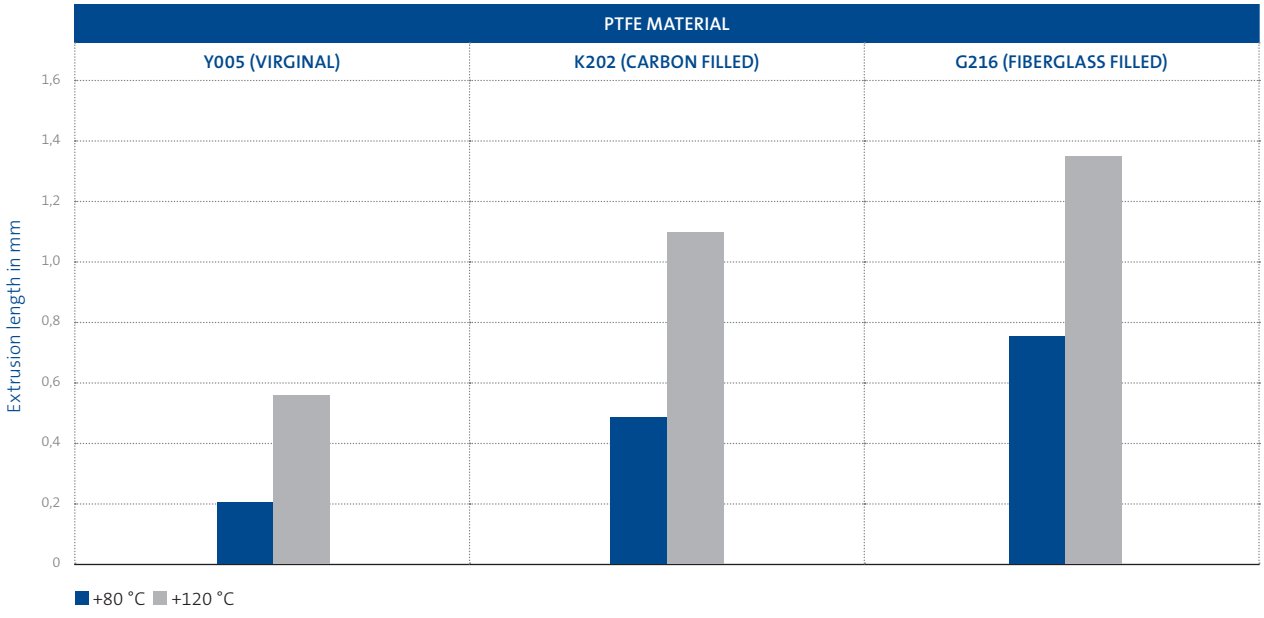
GUIDE RINGS

Guide rings are used when occurring lateral forces and deflection must be compensated. This is primarily the case in hydraulic and pneumatic applications.

In these application areas, the sealing element is used for the guidance of pistons and rods. Here it fulfills the purpose of preventing metallic contact between the sliding elements and of compensating for any deflections occurring. This requires a high compressive strength of the material with a simultaneous flexibility. PTFE guide rings show high thermal and chemical resistance. In addition, they offer excellent sliding properties and a very good friction behavior. Due to the use of PTFE, the service life and functional reliability of the seal and thus of the application as a whole is enhanced.

PTFE Y005 is a special material version for guide rings. It consists of a virginal, high-quality PTFE and a filler. This combination of materials counteracts the problem of increased wear and tear and the resulting reduced service life of ordinary PTFE materials in this application area. Thanks to its minimized extrusion length, it ensures significantly longer durability. The diagram shows a comparison of the extrusion length in mm of different PTFE variants. The Y005 version has a significantly shorter extrusion length than the other two material variants.

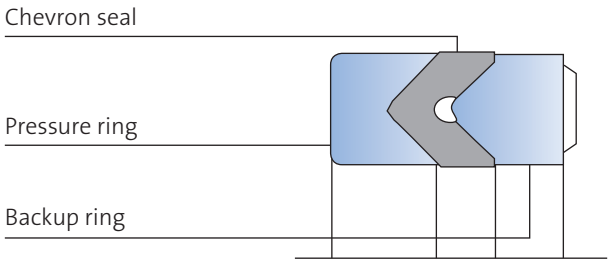
Extrusion length



CHEVRON SEALS

Chevron seals are mainly used in translational applications. They exhibit low friction and low axial preload forces. This makes the multipart gasket set a suitable alternative to stuffing box packings.

Chevron seals are usually composed of a thrust ring, multiple sleeves and a backup ring.



These sealing sets are normally used for sealing translational movements. In addition, they can be installed in applications with slow rotational movements, such as shafts at low rotational speeds. They show low friction, high pressure resistance and universal resistance to chemicals and extreme temperatures from -200 °C to +260 °C. These properties are especially in demand in applications of the chemical industry. The high compressive strength of up to 30 MPA and the variable set heights lead to a particularly large application variability in this industry.

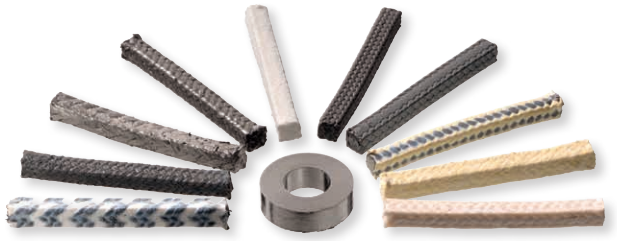
Chevron seals usually consist of PTFE and PTFE-carbon combinations. These materials can be produced as semi-finished products and are particularly economical. Tooling costs for the production of virginal PTFE and PTFE sleeves are not necessary due to the extensive tool inventory.

In addition to the standard Chevron seal sets made of PTFE, there is a modified version made of PTFE-impregnated Nomex fabric. It has significantly less cold flow and is thus suitable for applications with higher pressures of up to 700 bar. The thermal resistance of up to +260 °C is also higher than the variant made of pure PTFE.

Additional material variants of polyethylene, PEEK and Univerdit (molding compound of PTFE and graphite) are available on request.

MATERIALS	DESIGNS
PTFE	• DM 9403: stable profile for static sealing and pulsating pressures up to 300 bar • DM 9406: relatively stiff lip profile for dynamic seals and pressures up to 300 bar • DM 9409: flexible lip profile for dynamic seals and pressures up to 50 bar as well as vacuum
PTFE fabric, compression-molded	• Chevron seals made of PTFE-impregnated fabric • In individual cases: Chevron seals combination made of PTFE-impregnated fabric and virginal PTFE / PTFE compound for pressures up to 700 bar at low friction power

STUFFING BOX PACKINGS



Stuffing box packings are dynamic seals which are used where high pressure, durability and high demands on abrasiveness are required.

In applications for pumps with moderately rotating shafts, the stuffing box packing has proven itself. It offers an excellent sealing effect while maintaining constant elasticity. Stuffing box packings are firmly pressed in the installation space and reliably seal even with constant changes in temperature and pressure.

In the chemical industry, stuffing box packings can be found in many applications. They are particularly suitable here for use in concentrated acids and alkalis, solvents or at very high temperatures. The special program, such as the PTFE-impregnated Valtec nonwoven packing, which also meets the requirements of VDI 2440 (TA-Luft), leaves nothing to be desired.

SEALING PRODUCTS	PRESSURE [MPA]			SPEED [M/S]		TEMPERATURE [°C]	PH VALUE
	CENTRIFUGAL PUMPS	PLUNGER PUMPS	FITTINGS	CENTRIFUGAL PUMPS	PLUNGER PUMPS		
Ramilon 4586	4	100*		13	2	–40 to +120	5 to 11
Arostat 6204			20			–50 to +250	1 to 13
Arolan II 6215	2,5		10	26		–50 to +280	1 to 13
Arochem S 6216	2,5	25*		25	2	–50 to +280	1 to 13
Unistat 6303		80*	25		2	–200 to +280	0 to 14
Unichem 6313	1,5			8		–100 to +250	0 to 14
Unival 6323	2,5		25	20		–100 to +280	0 to 14
Alchem 6375		50*	25		2	–200 to +280	0 to 14
Grafiflex 6501			100			–200 to +450[1] –200 to +700[2] –200 to +2.500[3]	0 to 14
Grafiflex cover seal			100			–200 to +450[1] –200 to +700[2] –200 to +2.550[3]	0 to 14
Carbosteam 6550			30			–30 to +400[1] –30 to +550[2]	0 to 14
G-Spezial 6560			45			–200 to +450[1] –200 to +550[2]	1 to 14
G-Spezial S 6565	2,5		25	25		–200 to +450[1] –200 to +650[2]	0 to 14
Uniflex 6588	2,5			25		–50 to +280	1 to 13
Kombilon 6742	2,5			20		–100 to +280	0 to 14
Univerdit 7000	2,5*		16*	6		–30 to +250	0 to 14

[1] most media and air [2] steam [3] inert gas * chambered installation

VALTEC

Valtec packing sets have some special features compared to standard stuffing box packings. They have been developed by Freudenberg and are optimized for the lowest leakage according to the requirements of the TA Luft and VDI 2440.

In the temperature range from –200 °C to +280 °C, the base materials of the packings are nonwovens which have been impregnated with PTFE. Stripes are cut from the nonwovens, wound upright and grouted. The structure of the resulting packing rings is much more gas-tight and more homogeneous than in braided packings.

At temperatures above +280 °C, graphite-based seals must be used. The special design of Valtec HT+ 7290 achieves elasticity, so that it is possible to work without disk springs at up to 40 bar.

By means of a reinforcement with the wire, the standard materials can be used for high pressure applications with disk springs at up to 325 bar.

Material versions

- **PRDF 7200:** Nomex nonwoven with PTFE impregnation
- **PRDF 7210:** Carbon fiber nonwoven with PTFE / graphite impregnation
- **PRDF 7205:** Wire-reinforced Nomex nonwoven with PTFE impregnation
- **PRDF 7215:** Wire-reinforced carbon fiber nonwoven with PTFE / graphite impregnation

DESIGN	APPLICATION CONDITIONS		TEST CONDITIONS		
	Temperature (°C)	Pressure (bar)	Temperature (°C)	Pressure (bar)	Leak rate according to TA Luft and VDI 2440 (mbar*l/(s*m)
Valtec 7250 without disk springs	–200 to +280	≤ 30	+250	30	$6{,}5*10^{-5}$
Valtec 7255 without disk springs	–200 to +280	≤ 40	+250	40	$6{,}6*10^{-5}$
Valtec7260 LL with disk springs	–200 to +280	≤ 250	+250	40	$1{,}2*10^{-5}$
Valtec HP 7240 with disk springs	–200 to +280	≤ 325	+80	325	$6{,}3*10^{-6}$
Valtev HT+ 7290 without disk springs	–200 to +400	≤ 40	+400	40	$4{,}9*10^{-3}$
Valtec HT+ 7295 LL with disk springs	–200 to +400	≤ 300	–	–	–

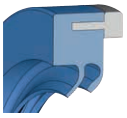
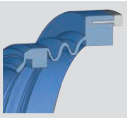
RADIAL SHAFT SEALS

Radial shaft seals are primarily designed for use with rotating motions and seal components that are moving against each other. Depending on the design, they are designed for axially accessible or closed installation spaces.

Radial shaft seals are used to seal media on rotating shafts. The patented sealing design of the Freudenberg Simmerring® features low friction torque, good dry running properties and easy assembly. This leads to a particularly high functional reliability and reliable sealing performance. Thanks to their high variability in terms of design, dimensions and material, they can be used in many applications.

Crucial for the selection of the appropriate seal are the operating conditions, which vary depending on the application. Peripheral speed, temperature, pressure and contamination from the outside play a role here. In addition, one must check against which media the product must be sealed.

A wide range of PTFE compounds optimally meets the requirements for wear resistance, friction coefficients or thermal conductivity. The excellent chemical and thermal resistance of PTFE makes the HTS II shaft seals a reliable sealing solution. The resulting increase in performance limits and the extended operating life lead to a significant increase in productivity of the units used. In addition, solutions made of elastomeric materials such as FKM or Fluoroprene XP are possible.

DESIGN	FEATURES	CROSS SECTION
HTS II 9535	With standard lip for conventional applications	
HTS II 9536 SL	• With additional dust lip for use in heavily contaminated environments. This prevents foreign bodies from getting under the sealing lip • Even with changing pressure-vacuum operation, this design offers maximum process reliability	
HTS II 9538 DL	With double sealing lip for high safety requirements	
WADB 9461	• Extremely short rotary shaft seal for confined spaces • Only in combination with secondary seal made of FKM or virginal PTFE on media contact side	
HTS II 9541 with angular momentum	With dynamic return capacity for high fluid level applications or increased tightness requirements	
HTS II EWS	• For use with increased shaft runout • With integrated flexible bellows element • Operating limits up to 1 m/s and 3 bar	

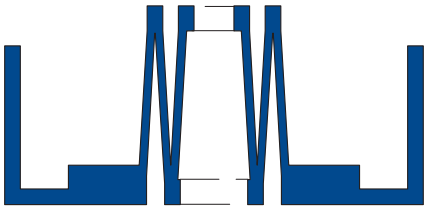
PTFE BELLOWS

Bellows serve as an elastic protective part and as connection between moving apparatus and machine parts. They are used wherever telescoping components must be protected against environmental influences.

Particularly in the chemical industry, the range of applications of PTFE bellows is large. Consisting of two connection parts and a movable bellow, they are used wherever machine parts have to be protected against aggressive media. In doing so, the sealing element especially fulfills the following three functions:

- Protection of axially and, with some reservations, radially movable rods, joints and other machine components
- Compensation of movements and displacements due to expansions, axial offset, misalignments and vibrations
- Design-dependent delivery and pumping effect of gases and liquids in connection with check valves

Bellow Type 9000



Bellow Type 9002

Depending on the operational conditions and the type of application, different materials are available:

- **Virginal PTFE:** thanks to its high chemical resistance and long lifetime, it has a particularly wide range of applications in the chemical industry
- **Modified PTFE:** low-pore material design
- **Filled PTFE:** reinforced with glass or carbon fiber to protect the most exposed areas of the bellows

DESIGN	DESIGNS
FBA-9000	Use at pressures from 0.05 to 0.2 MPa and temperatures from –120 °C to +200 °C
FBA-9002	Use at pressures from 0.025 to 0.6 MPa and temperatures from –120 °C to +200 °C
FV-SERIES	Individual solutions for pump and valve bellows
FBAX-9001	Variant of FBA-9000 on request, as well as a variety of individual designs

U-CUPS

U-cups are unilaterally pressurizable seals with a universal chemical resistance. They are mainly used in valve constructions in the general chemistry and petrochemicals industry.

U-cups consist of a PTFE sealing element and a spring. They are used to seal rotating and translational movements. The metallic spring of the seal serves as a leading element of the sealing lips and prevents the loss of the preload caused by the thermal expansion of the PTFE. It thus ensures the permanently elastic properties of the seal. The contact pressure can be adjusted to the operational conditions by three different springs:

- **V-spring:** long spring deflection and soft spring characteristic for low friction; for dynamic and static sealing and as a rotary seal
- **U-spring:** long spring deflection and higher spring rate for sealing of high pressures
- **O-spring:** high spring force with short spring deflection to seal extreme pressures

In addition to a small installation space, U-cups have further decisive advantages. They are suitable for applications with high pressures and vacuum and are available as an optimized version for static individual cases, lifting, turning and pivoting movements. Good dry and emergency running properties are achieved by selecting the suitable PTFE variant. No occurrence of the stick-slip effect and a good aging resistance complete the picture.

The following material variants are carried in the product line as standard materials:

- PTFE virginal modified
- PTFE with glass fiber
- PTFE with carbon
- PTFE with carbon fiber
- PTFE with glass and molybdenum
- PTFE with Ekonol
- UH MW PE (polyethylene)

Function and types of lip seals

DESIGN		COVER/FLANGE	TURN AND SWIVEL MOVEMENTS	SWIVEL JOINTS	PINS AND/OR STEMS
V-Spring	NRVA-9490	●	●	●	●
	NRVR-9494	●	●	●	
	NRVR-9493	●	●	●	
	NRVD-9489		●		●
	NRVI-9492	●	●	●	●
O-Spring	NRRA-9474	●	●	●	●
	NRRR-9459	●	●	●	
	NRRR-9485	●	●	●	
	NRRI-9442	●	●	●	●
U-Spring	NRVR-9487	●	●	●	
	NRVR-9486	●	●	●	
	NRRR-9499	●	●	●	

● = very suitable ● = suitable

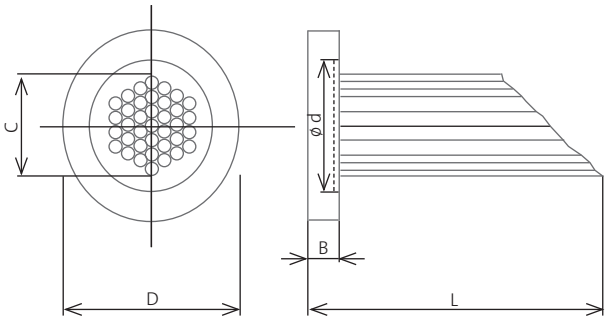
PTFE INLET NOZZLES

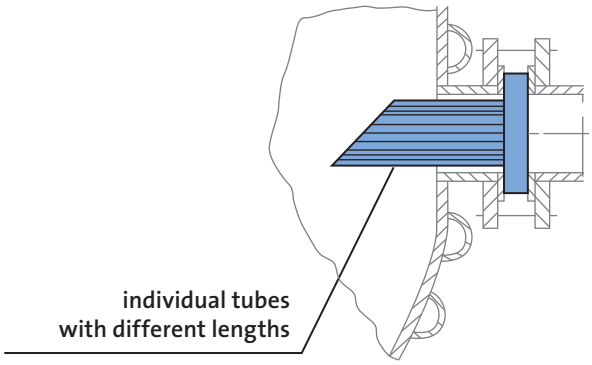
In the chemical industry, inlet nozzles are used for gentle introduction of steam and other media. This enables a uniform media distribution with simultaneous noise reduction.

PTFE inlet nozzles consist of individual tubes of different length and are mainly used in tanks and reactors. They distribute inflowing media into different sub-streams and prevent a concentrated impact of the jet. Due to the mobility of the individual tubes, the flow of the medium is introduced over a large area and at the same time well distributed.

In the chemical industry, inlet nozzles are used to introduce saturated steam into organic sulfonic acids with diatomaceous earth content, for example. The steam is introduced at a rate of 1,500 kg/h and a pressure of 0.5-0.6 MPa. The prevailing temperature in this process is +156 °C. PTFE inlet nozzles replace a costly tantalum dip tube in this case and reduce the noise from 91 dB(A) to 78 dB(A).

PTFE inlet nozzles are made entirely of fluoroplastic PTFE and thus have a particularly good resistance to high temperatures and aggressive chemicals. With the exception of molten alkali metals and fluorine, the inlet nozzle is suitable for all media and thus has a universal chemical resistance. The pressure at the introduction can be up to 1 MPa.





DN	ø D	B	C	ø d	L	A*
15	48	15	15	20	150	60
20	58	15	25	30	150	120
25	68	30	30	35	200	135
32	80	30	40	45	200	260
40	90	30	48	53	300	465
50	105	35	60	65	300	765
65	125	35	72	77	300	1,145
80	140	35	85	90	300	1,595
100	160	35	110	115	400	2,725

* In certain cases, such as when using the nozzle in short feed pipes/adapters, for example, particularly long tubes are necessary. Here, a PTFE sleeve for the tube bundle is used for better positioning. It also prevents possible damage to the adapter and the tubes.

CUSTOMER-SPECIFIC PARTS

MOLDED PARTS

Special requirements call for special solutions. Molded parts are sealing solutions that are not included in the standard product range due to their geometry and application. They are specially designed to meet the needs of the customer.

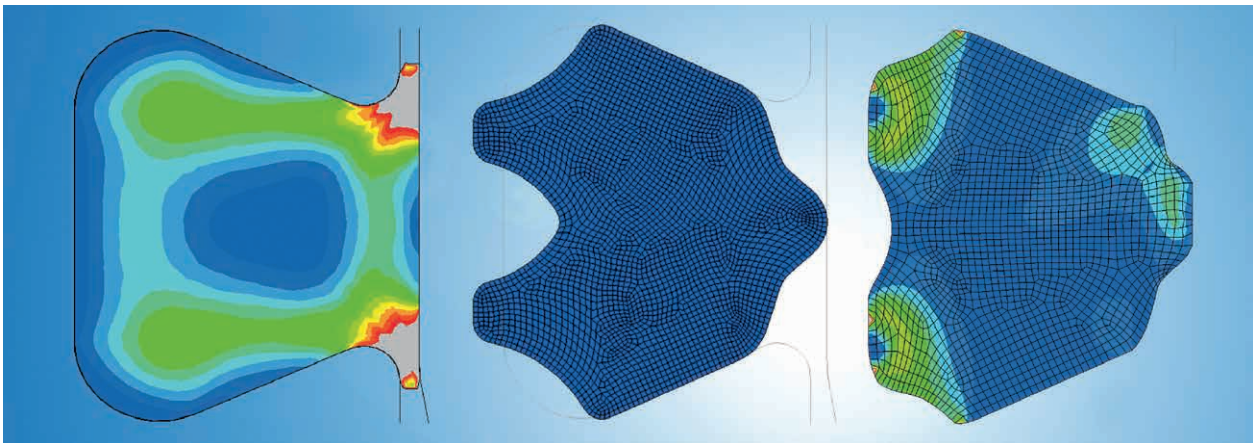
For complex applications, standard seals can often only be used to a limited extent. In order to achieve an optimum sealing function for these applications, individually developed molded parts are necessary. This can be done either by modifying a standard component or by designing an individual, customer-specific solution. Development has practically no limits in this area. Seal manufacturer and customer work together intensively in this process right from the start. In order to guarantee a high degree of system security, the seal manufacturer is often already involved in the development of the application or machine. To avoid repeated redevelopment and modification of the prototype in the development process, the deformation and the applied load can be calculated in advance. This is tested by means of FEA (Finite Element Analysis) before the construction of a sample tool and by taking into account temperature and swelling. In addition, it is possible to test the functionality prior to use in the process medium by means of innovative simulation processes and proprietary testing procedures.

The experts at Freudenberg have world-leading sealing expertise and a focused industry and application know-how at their disposal. Combined with the high level of material and design experience, precision molded parts can be developed together. In addition, the continuous testing in the development process ensures the high quality standard of the molded part. Depending on the requirements which the molded part has to satisfy and the application in which it will be installed, it must have different functions. These can be, for example, the following:

- Pressureless sealing by means of restoring force
- Self-reinforcing sealing function under pressure
- Throttle function against the applied pressure
- Sealing against media permeation

The dimensions vary depending on the application area and the design and can range from a few millimeters up to one meter.

Mechanical performance calculation by FEA-Example



Initial situation: +100 °C, 10 bar | New design | New design: +100 °C, 10 bar

DIAPHRAGMS

Diaphragms made of elastomeric materials are flexible sealing elements that separate two component spaces. Since diaphragms are tight but at the same time movable, the spaces separated by them can make volume changes. Three basic functions can be achieved in this way: regulating or switching, pumping and disconnecting.

There are a variety of designs that can be attributed to a few basic forms:
- Flat diaphragms
- Plate-shaped diaphragms
- Beaded diaphragms
- Roller diaphragms

Different applications call for different materials, which must be selected according to mechanical, chemical and thermal stresses. If the elastomer alone is not capable of dealing with the stresses and the application of pressure, then the diaphragm can be equipped with a fabric insert or cover. Metal inserts and film overlays are also possible options.

As elastomers, a wide range of products is available, from AU (polyurethane) to EPDM, FKM, NBR and VMQ (silicone). These are often provided with a film overlay made of PTFE for use in aggressive media of the chemical industry. Pure PTFE diaphragms are also available. Due to the shape-cutting manufacturing, they can be produced economically and in small quantities. In addition to the standard FKM, there is a newly developed highly fluorinated FKM available, which qualifies for chlorine applications, for example. In addition, Simriz – the perfluoroelastomer from Freudenberg – can also be processed into diaphragms.

The dimensions vary greatly according to the design, from a few millimeters to one meter (and even larger on request).

PROFILES

O-rings or molded parts can sometimes not be used at large sealing points, or only at great expense. In this case, profiles, cords or hoses can be the right choice.

With an endless, extruded round cord with O-ring profile, maintenance access holes or large container lids can be equipped with suitable seals, for example. The cross-sectional diameters range from 1 to 40 mm, with the pieces of cord up to 2,000 mm being available without self-curvature.

Furthermore, other profiles can be extruded too. More than 3,500 different profile nozzles are available for this. Even customer-specific designs can be produced because the tooling costs are low compared to molded parts.

FKM materials with different crosslinking systems and degrees of hardness from 70 to 85 Shore are available as elastomers. They can be used to produce sealing products made from sheets and extruded goods, as well as pierced rings. Furthermore, there are EPDM compounds from which simple profiles, sheets and plates can be pressed. Some compounds are vulcanizable at the joint to form a homogeneous product with higher tensile strength and longevity compared to a product bonded at the joint.

In addition to the customer-specific parts, profiles, cords and hoses are also available in standard dimensions.

Availabe standard dimensions:
- Cord diameter from 1 to 40 mm
- Hoses up to 20 mm inside diameter

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