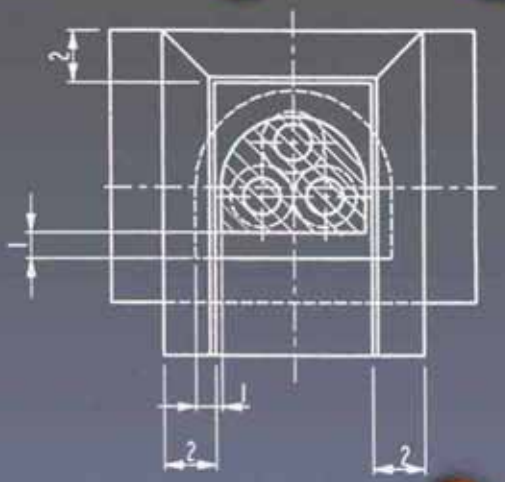
ZruElast FPM

Designing



with

Fluoroelastomers

ZruElast FPM

At the beginning of the 20th Century the only elastic material available was Natural Rubber. Today, designers can choose from more than twenty different synthetic elastomers. This great variety offers outstanding flexibility to solve the sealing problems arising from the numerous and multifaceted requirements in modern applications. A very special elastomer is fluoro rubber. In many fields, the properties of this specialty rubber are superior to those of other elastic materials. Zrunek Gummiwaren GmbH specializes in the formulation and mixture of elastomer compounds and focusses in particular on fluoroelastomer-based compound development. This class of materials made by Zrunek is referred to as ZruElast FPM.

What does ZruElast stand for?

ZruElast is a registered trade mark of Zrunek Gummiwaren GmbH. The name ZruElast represents all tested, specified and proven elastic materials made by Zrunek. For more than 50 years, our in-house laboratory has provided complete compound development and testing services. The laboratory is supervised by Dr. Ulrich Zrunek himself who is a doctorate chemist.

Unlike plastics technology, where the ready-to-process raw materials have to be purchased directly from the chemicals groups, rubber materials first have to be compounded based on a formulation. For this process, fillers, plasticizers and various other chemicals are added to and mixed with the base polymer (rubber). Only the proper combination of these raw materials results in the desired properties which are expected of the developed elastomer. Rubber formulation and compound development not only requires extensive expertise and experience, but also appropriate laboratory facilities and equipment. *Figure 1* shows the first steps of the rubber formulating procedure. This begins with mixing of the suitable raw materials in the laboratory mill. Subsequently, test pieces are vulcanized and later measured using our advanced testing and laboratory equipment. Only after the desired results and values are achieved, will the formulation be released for production and mixing-plant output.

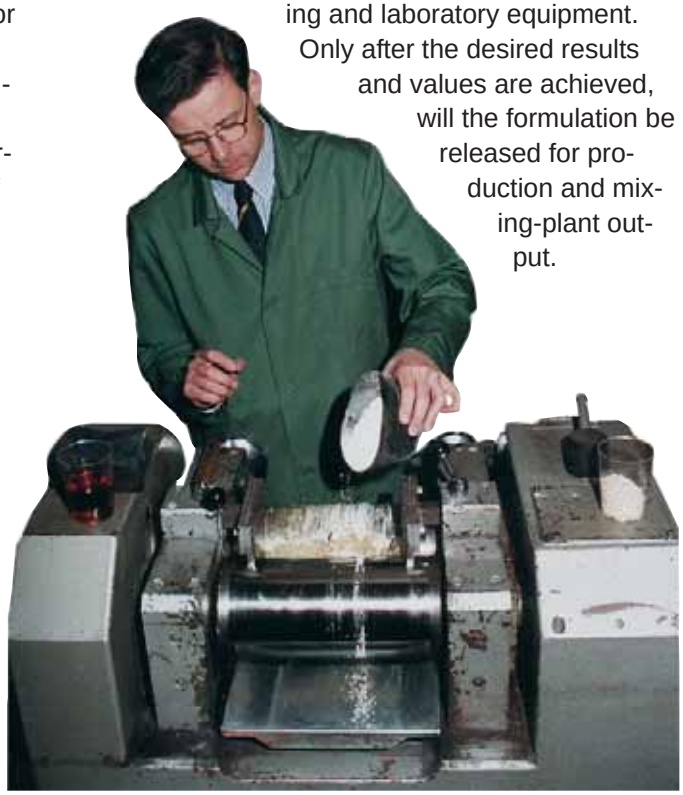


Fig.1: In-house compound development

The Difference between FPM, FKM and Viton®

The terms FPM, FKM and Viton® very often cause confusion and lead to incorrect interpre-

tations. All of these designations actually stand for one single base material:fluoro rubber.

FPM is the international abbreviation according to DIN/ISO, whereas FKM is the short form for the fluoroelastomer category according to the American standard ASTM. Viton® is the registered trade mark of DuPont Dow- Elastomers. Zrunek uses the designation FPM for all of its fluoro-elastomer materials.

Designing with Elastomers

Elastomers are not usually materials designers are overly familiar with, nor do they deal with them day-to-day. In general, metals and their individual specifications are the materials which designers have in mind when designing and these influence their thinking at a basic level. Therefore, parts often are designed without considering that the material-specific properties of metals can meet other requirements than those of elastomers. This difference may compromise the correct selection of a suitable elastomer.

In order to select a proper elastomer it is necessary to define the specific demands of an application. This includes a full description of the conditions in use and full details concerning exposure to any chemical media, thermal resistance requirements, compression load, mechanical stresses as well as information about time-related factors.

Particular attention should be turned to the media with which the elastomer is in contact. These media should not affect the sealing material, nor should the media be affected by the seal. Furthermore, the lifetime and durability of a seal can be very critical factors. These very often are directly linked to temperature and exposure to chemical media. In addition, parameters such as specific mechanical requirements for static and dynamic applications, electrical properties, hardness, colours or flammability should be taken into consideration.

As a result of the complexity and great number of factors there is a simple rule for designers derived from practical experience:

If possible, try to cut down the design requirements to those 'absolute necessary' and try to avoid demands such as 'would like to have' or other arbitrary demands.

Advantages of ZruElast FPM

ZruElast FPM are materials based on fluoroelastomers. These materials offer one of the highest resistances to heat and chemical media of all elastomers ever developed. They withstand hundreds of fluids, from ordinary to most aggressive, over a wide temperature range. Additionally, they retain reliable and leakage free sealing force in situations where ordinary elastomers would long have failed

Fluoroelastomers do not come cheap. This is why they primarily were used only for small parts in environments where in contact with hot and corrosive fluids. Today, however, as a result of higher energy costs, stringent environmental regulations, extended warranties and increasing maintenance costs, many users have reconsidered and now think of ZruElast FPM as a cost-effective material, especially when taking into regard the complete lifetime of a product.

ZruElast FPM

The Exceptional Strengths of ZruElast FPM

Temperature Resistance

Fluoropolymers in general feature excellent heat resistance. ZruElast FPM retains its elastic properties even at a continuous operating temperature of 200° C. When talking about temperature resistance, it has to be considered for how long materials are exposed to heat or elevated temperatures. *Figure 2* shows the relation between operating temperature and hours of use. Besides the ability to withstand short blasts of more than 300° C, laboratory tests have confirmed that products made of ZruElast FPM still remained soft and elastic even after ageing in a heat cabinet over a period of three years at a temperature of 190° C. If you compare these values with the performance of other elastomers they seem even more significant. Nitrile rubber (NBR), for example, usefully serves only up to a continuous maximum temperature of 120° C.

Fig. 2: Heat resistance of ZruElast FPM in air

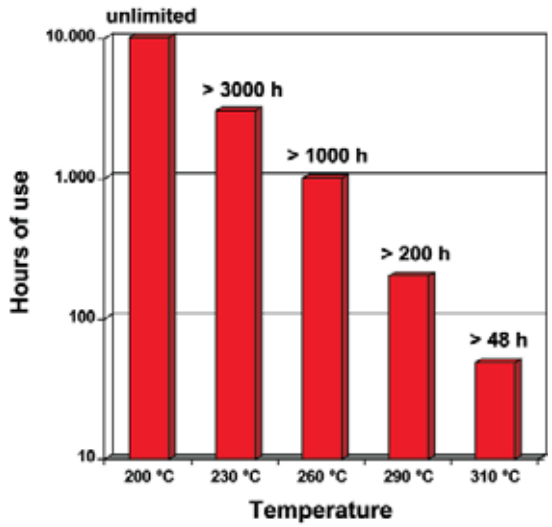


Abb. 3: Swell resistance of ZruElast FPM Examples (Compound "7575" und "7009")

Medium	ZruElast FPM 7575	7009
ACIDS 40 °C/70h		
Hydrochloric Acid (35 %)	A	A
Sulfuric Acid (35%)	A	A
Hydrofluric Acid (48%)	A	A
Phosphoric Acid (60%)	A	A
Glacial Acetic Acid	D	D
BASES 40 °C/70h		
Sodium Hydroxide (50%)	A	A
Ammonia (25 %)	A	A
HYDRAULICS 100 °C/70h		
Mineral Oil	A	A
Ethylene Glycol/Water	A	A
Phosphoric Ester	A	A
LUBRICANTS 175 °C/70h		
ASTM oil #3	A	A
Stauffer Blend 7700	B	A
Silicone Oil	A	A
FUELS 20 °C/70h		
ASTM Fuel C	A	A
Fuel C + Methanol (10 %)	C	B
Unleaded premium	A	A
AROMATICS 20 °C/70h		
Toluene	B	A
Xylene	B	A
ALCOHOLS 20 °C/70h		
Methanol	D	A
Ethanol	A	A
Isopropyl Alcohol	A	A
KETONES 20 °C/70h		
Acetone	D	D
Methyl-Ethyl-Ketone (MEK)	D	D
ETHER 20 °C/70h		
Ethyl Ether	D	D
Methyl-Tetrabutyl-Ether (MBTE)	D	D
Volume Swell: A: 0-10 %, B: 10-20 %, C: 20-30 %, D: 30 % or more		

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Similar in temperature performance are the materials chloroprene (CR) and chlorosulfonated polyethylene. Aged at a temperature of 200° C, products made of these materials would become brittle only after a few hours.

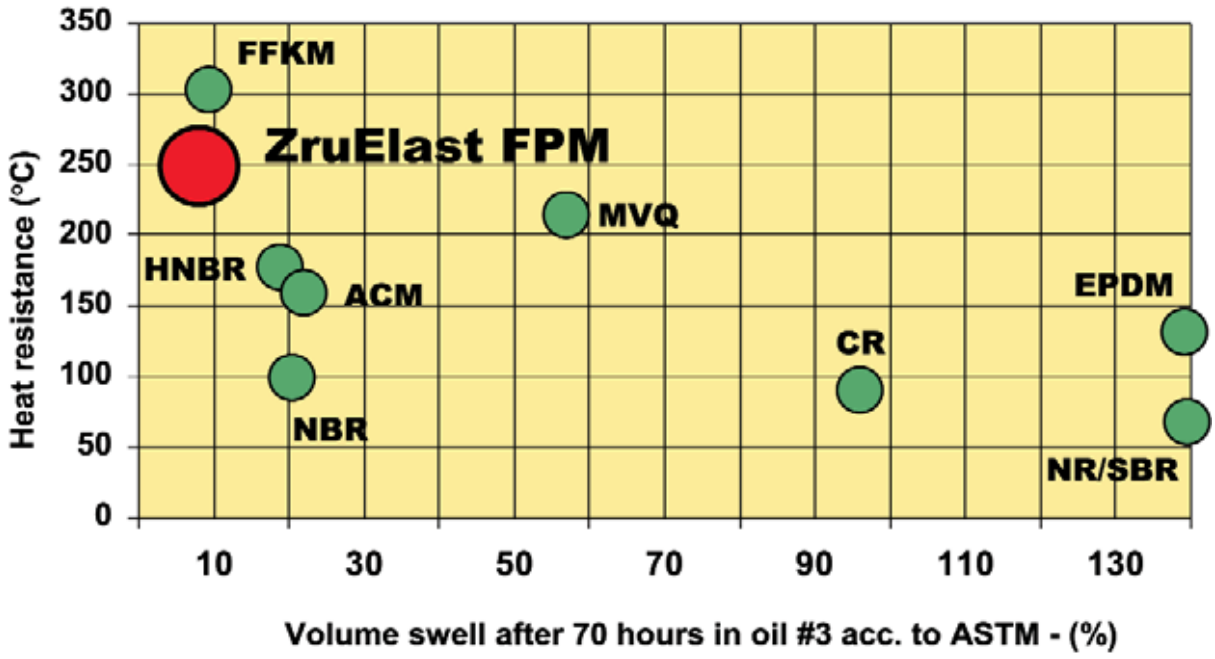
Swell Resistance

The excellent swell behaviour of fluoroelastomers has already been tested in a number of important media, for example mineral oils, fuels, acids, bases, solvents, and numerous chemicals. *Figure 3* on the previous page gives you a short overview of the outstanding volume swell resistance of ZruElast FPM. . Zrunek has compiled a chemical resistance guide which will give you extensive information about the swell behaviour of ZruElast FPM FPM in a number of chemical media. You also will find additional technical data demonstrating the relation between temperature and volume swell in several examples.

In sealing technology, in particular in engine construction and hydraulics, oil resistance combined with exposure to heat plays a fundamental role. *Figure 4* shows the resistance to heat and volume swell of ZruElast FPM in comparison with other common elastomers. As you can easily see, only Kalrez®, an extremely expensive perfluoroelastomer, delivers better performance. All other commercially processed elastomers neither achieve the thermal stability of ZruElast FPM nor feature the same low volume swell characteristics.

This outstanding resistance to swell combined with exposure to heat makes ZruElast FPM the most universal sealing material of all commercial elastomers.

Fig.4: Heat and oil resistance of ZruElast FPM in comparison with other elastomers



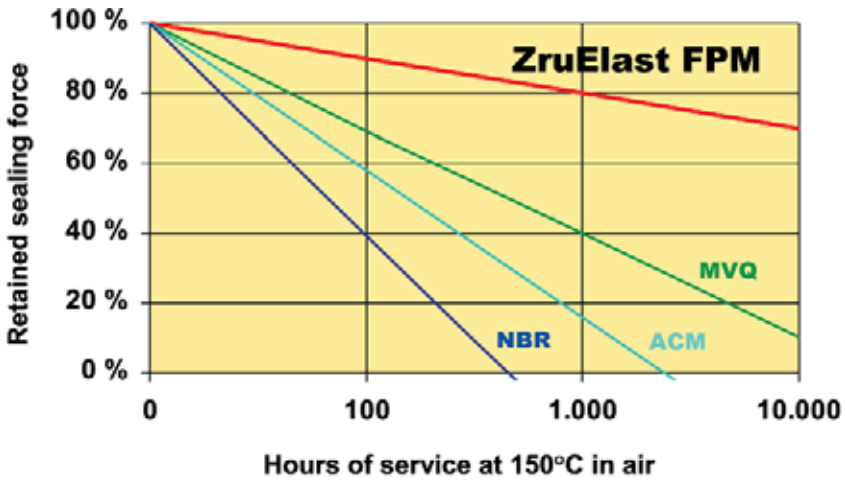
ZruElast FPM

Long-Term Retention of Sealing Force

Resistance to compression set is another very important physical property in sealing technology. The lower the compression set values, the better the sealing force and ability to recover from applied deformation. In combination with exposure to high temperatures, ZruElast FPM further shows its superior compression set properties. Without any problems values of 8% at 200° C can be achieved.

ZruElast FPM is also unbeatable when it comes to sealing force over a longer period. As illustrated in *figure 5*, all other common elastomers fail long before. After 100 hours of use in static application in air at 150° C ZruElast FPM retains 91% of its original sealing force, while silicone, acrylate and nitrile rubber with 69%, 56% and 38% show values well below. After 10,000 hours of service time at last only FPM provides sufficient sealing force (70%) These characteristics are of special importance when designing long-life, high-quality machines, where absolute product reliability is demanded, when high guarantees are required or when the risks of causing environmental damage due to seal failure or leakage become incalculable

Fig. 5: Long-term sealing force of ZruElast FPM in comparison with other elastomers



Low Temperature Resistance

Experience has shown that seals made of FPM in dynamic applications usefully serve at temperatures down to approx. -20° C. In static use they even can work at temperatures down to -40° C. Furthermore, experience has shown that the more thin-walled parts are, the lower the operating temperature at which they can work. The same effect occurs when the seal is continuously in contact with a medium that causes slight swell. This improves the low temperature flexibility and allows use at even lower temperatures.

Flame Retardance

ZruElast FPM is based upon fluorocarbon elastomers. The chemical bond of fluorine to carbon is extremely strong. Thus, under conditions of fire, its resistance to breaking and damage exceeds that of all other hydrocarbon elastomers.

Use in Vacuum

ZruElast FPM contains no plasticizers and thus exhibits very low outgassing in use under extreme vacuum conditions. Loss of weight of only 2-3 % in vacuum applications is typical for this material. Therefore ZruElast FPM is the ideally

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suited material for seals requiring absolute pureness, lowest outgassing rates and minimal volume changes in extreme vacuums.

Weathering and Ozone Resistance

The combination of atmospheric oxygen with sunlight and ozone (weathering) is a very aggressive and corrosive effect. But in this respect ZruElast FPM also offers highest resistance. In fact, even after 20 years of daily exposure to direct sunlight no cracking or splitting was observed. Even direct exposure to ozone has no effect on ZruElast FPM. For example, after 300 hours of continuous ageing at a temperature of 60° C in an environment containing 150 ppm ozone no cracks could be observed. In comparison, parts produced from natural rubber would end up with cracked and split surfaces and become useless after just 10 minutes in the same conditions.

The extremely good weathering and ozone resistance of ZruElast FPM also is shown by the fact that UV-radiation does not have any effect on colored parts made of FPM.

Table 1: Comparison of ZruElast FPM compounds

Compound #	Moulded Part	Profile	Duro-meter	Colour	Price	Comments
7560	X	X	63		■■■	Standard compounds for all-purpose applications, such as cords, hoses, tubes, molded parts and seals
7565	X	X	67		■■	
7575	X	X	77		■	
7586	X	X	87		■	
7765	X	X	67		■■■	Standard compounds for red applications or other colored applications
7775	X	X	77		■■	
7690	X	X	90		■■	
7245	X		45		■■■■	For lowest durometers, combined with favourable compression set values
7003	X	X	77		■■■	Advanced resistance to chemicals and methanol
7010	X	X	83		■■■■	Exceptional chemical resistance
7009	X		83		■■■■■	Exceptional chemical and hot water/steam resistance

Gas Permeability

Products made of ZruElast FPM have very low gas permeability.

ZruElast FPM Compounds

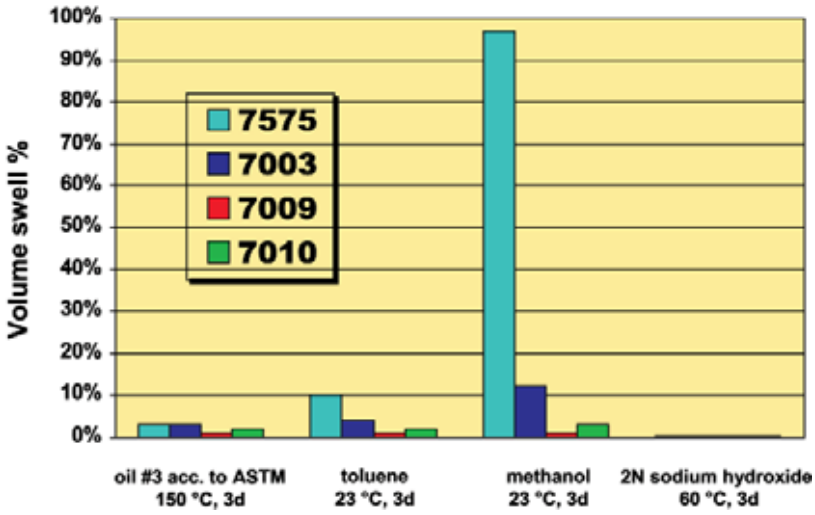
Zrunek mixes all its compounds in-house. As demonstrated before, all formulations are first developed and then get tested in our own laboratory. Over the years, a standard program of different compound types has been developed, which in the meantime has proved itself many times over. Characteristics and properties of these compounds are shown in *table 1*. Zrunek's standard program differentiates 3 categories of compounds: The first category includes the standard compound types used for the manufacturing of black all-purpose parts, eg. cords, hoses, tubes or molded parts. These materials cover a durometer range from 60-90 Shore A. Compounds of the second category are used for colored parts. The third category shows compounds which have to meet specific requirements in demanding applications. The common durometer range for FPM parts is 60 to 90 Shore A.

If you need softer seals with a lower hardness but want to retain favourable compression set values, technical realization could become difficult. Especially to meet these requirements Zrunek developed compound #7245.

If the volume swell of our standard compounds caused by some specific media is too high for your applications, we also can provide special formulations to better meet your needs. A typical example is the exposure to methanol. The varying swell behaviour of different types of ZruElast FPM compounds is shown in *figure 6*. If, for example, your application requires higher resistance to swell in methanol or toluene, compound #7003 or #7010 would deliver better performance and be the compound of choice.

Table 1 shows a small selection of the extensive range of formulations provided by Zrunek. All of the compounds shown here are field-proven and currently used in industry. However, if your application demands additional requirements, Zrunek can help you, either by using one of the variety of formulations already available or by developing a new formulation in-house in order to meet your needs. If you have specific requirements, please first have a look at our guidelines listed on page 3 - "Designing with fluoroelastomers".

Fig. 6: Swell resistance - Comparison of various ZruElast FPM compounds



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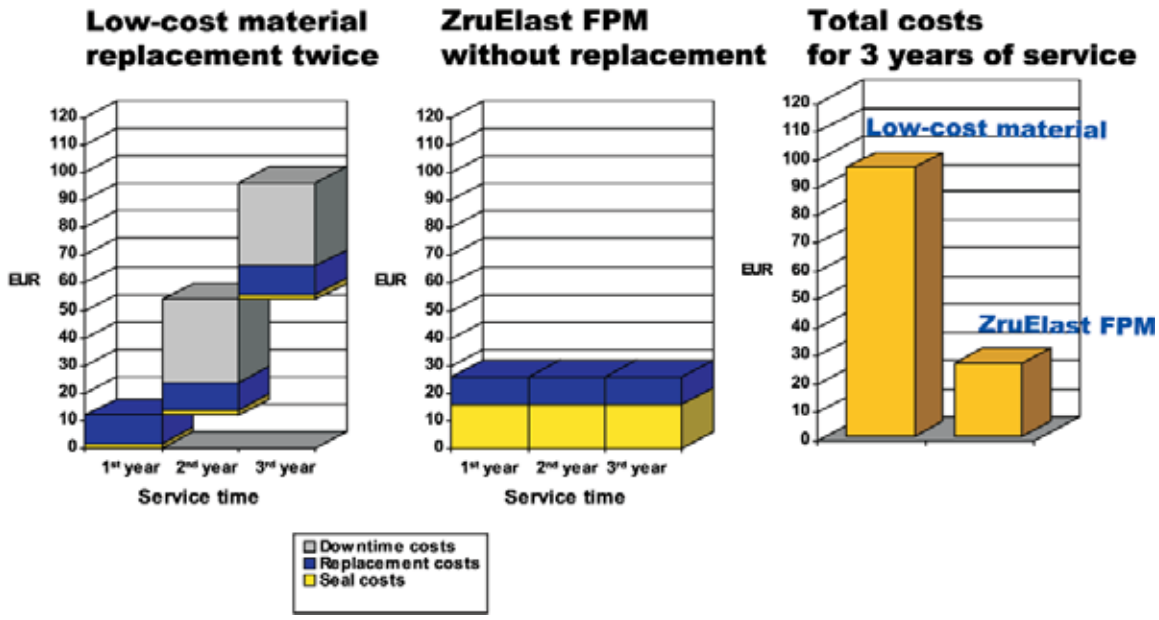
ZruElast FPM is More Expensive, but it's Worth it !

Due to the base elastomers used and their specific manufacturing process, fluoroelastomers rank among the costlier elastomers. However, this does not mean that the use of ZruElast FPM comes at a high price. Instead, considering the total costs over service time, ZruElast FPM very often is the more cost-effective solution compared with less expensive elastomers due to its extended lifetime - and this effect comes with additional safety.

The chart in *figure 7* shows how service costs can accumulate over a time period of three years using low cost sealing materials in comparison to ZruElast FPM.

As you easily can see, the price of an FPM seal is rather higher than that of a conventional seal (EUR 16,00 instead of EUR 2,00). However, even after three years of service the FPM seal remains sufficiently leakproof and its lifetime even exceeds that length of time. Within the same period conventional seals would have to be replaced at least twice. This not only causes additional costs for the seals themselves, but it also has of the disadvantage of considerable replacement and downtime costs. Therefore, the use of ZruElast FPM helps you save costs and reduces lifetime costs. After three years of use, finally, you can see a clear result: The conventional seals have caused costs of EUR 96, whereas the costs of ZruElast FPM seals add up to EUR 26,00.

Fig. 7: Total cost over a service time period of 3 years - Seals made of low cost materials in comparison with sealings made of ZruElast FPM



The example and calculation in *table 2* shows why ZruElast FPM might be the more cost-effective alternative (*Figure 7*).

Table 2: Service costs of an ordinary seal made of low-cost material in comparison with costs for the same seal made of ZruElast FPM for a time period of 3 years

Sealing costs for 3 years				
	Ordinary seal		Seal made of ZruElast FPM	
Replacements	2 x		no replacement necessary	
Sealing costs	3 x 2,00 =	6,00 EUR	1 x 16,00 =	16,00 EUR
Installation costs	1 x 10,00 =	10,00 EUR	1 x 10,00 =	10,00 EUR
Replacement costs	2 x 10,00 =	20,00 EUR	no replacement necessary	
Downtime costs	2 x 30,00 =	60,00 EUR	no downtime	
Total costs		96,00 EUR		26,00 EUR

Beware of Low-Cost Fluoroelastomer Blends!

ZruElast FPM guarantees that you will get 100% virgin fluoroelastomers. Unfortunately, there are numerous low cost fluoroelastomer blends on the market, which at first glance seem to be a good deal because of their lower price. These prices can only be offered because the materials are blends of FPM and hydrocarbon elastomers, such as EPDM, nitrile or acrylate rubbers. This 'filling and stretching' can of course result in large risks for the end-user. Ordinary rubbers are often blended with other elastomers in order to specifically upgrade certain properties and gain better performance. FPM, however, cannot be blended without significantly degrading just these properties, such as excellent resistance to heat, chemicals or compression set. As a result you would only end up with unnecessarily expensive blends of hydrocarbon rubbers.

It may be the case that some rubbers show good resistance to certain media, for example, acrylate rubber exhibits low swell in mineral oils. But compared to vulcanizates based on 100% FPM, blends of FPM can in no way achieve the same excellent performance, in particular when regarding resistance to swell at elevated temperatures, resistance to other common chemical media or long-term functionality and sealing performance.

This very clearly is illustrated in both charts below (*figures 8 and 9*). In each case the different blends perform much more poorly than ZruElast FPM. With regard to resistance to compression set the superior performance of ZruElast FPM becomes even more significant.

It may be true that blends of FPM are cheaper considering the price/kg. But compared to ZruElast FPM which is based on 100% fluoroelastomers they are definitely the more costly alternative with respect to total lifetime costs.

Fig. 8: Swell resistance of ZruElast FPM in comparison with blends of FPM

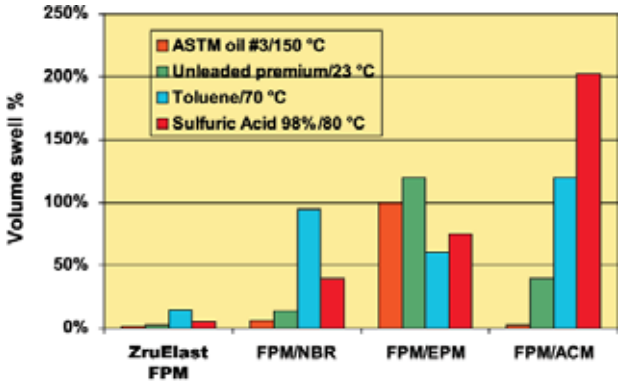
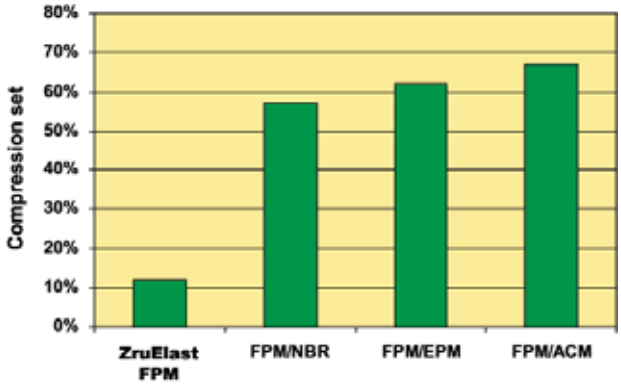


Fig. 9: Compression set of ZruElast FPM in comparison with blends of FPM



What is Viton®?

Since 1957 fluoroelastomers have occupied an important position in industry. Many people would think of Viton® the registered trade mark of DuPont Dow Elastomers, which was the first company to develop a fluoroelastomer and introduce it to the market. Just like the brand name Perbunan® has become a well-established term for nitrile rubber, Viton® has turned out to be a well-known brand name for fluoroelastomers. However, there are also other companies which have been successfully manufacturing and supplying fluoroelastomers for several decades, such as Dyneon with Dyneon®, Solvay with Tecnoflon® and Daikin Industries with Dai-El®. All these companies have in common that they invest high amounts in research and development and offer a remarkable selection of high-performance fluoroelastomers.

The end-user has to be aware of the fact that the brand name Viton® (like other brand names, too) does not stand for a certain material specification, but rather is a name for all types of fluoro rubbers which are made by DuPont Dow Elastomers. The various types of fluoroelastomers differ in fluorine content, swell behaviour, resistance to compression set or processing. It is the task of the manufacturer to specify the correct type of rubber to meet the operating requirements of your application and to develop and formulate an appropriate type of fluoroelastomer compound.

ZruElast FPM

Are other Fluoroelastomers Inferior?

No, because all fluoroelastomers produced by the above mentioned manufacturers are specified in accordance with the globally accepted ASTM D 2000 standard and HK classification. In this standard, elastomers are classified according to their heat and oil resistance. 'H' designates that after thermal stress of 70 hours at 250° C changes of the mechanical parameters of the elastomer range within the following values:

maximum tensile strength change: ± 30%
elongation at break decreases less than 50%
maximum hardness change : ± 15

'K' stands for best swell resistance in test oil #3 according to ASTM D 471 after 70 hours (volume swell less than 10%), achieved by FPM. *Table 3* demonstrates the special importance of classification according to 'HK'.

This outstanding performance can only be exceeded by that of perfluoroelastomers.

Table 3: Classification according to ASTM D 2000 standard

Type	Heat-test temperature	Class	Volume swell max.
A	70 °C	A	
B	100 °C	B	140 %
C	125 °C	C	120 %
D	150 °C	D	100 %
E	175 °C	E	80 %
F	200 °C	F	60 %
G	225 °C	G	40 %
H	250 °C	H	30 %
J	275 °C	J	20 %
		K	10 %

Looking at the properties and parameters demonstrated above you can easily recognize that fluoroelastomers are materials which are based on defined specifications and that of course these are followed by all manufacturers.

DuPont Dow Elastomers was actually the first company to introduce fluoroelastomers under the trade name Viton® However, fluoroelastomers manufactured by other companies, such as Dyneon, Solvay or Daikin Industries, perform just as well. In fact, the opposite may be true - competition has pushed these companies forward to develop and introduce some rather interesting and perhaps even higher quality products. Additionally, when regarding standard products, considerable price differences can be observed for the same product performance. When already buying a high-priced material why spend extra money for a brand name?

Why is FPM Important for Zrunek?

Zrunek has fundamental experience and expertise in elastomer materials which goes back more than 50 years. The company was founded in 1947 by Dipl.Ing. Eduard Zrunek, the former managing director of the 'Matador' Semperit Company. Today the company is run by the third generation, Dr. Ulrich Zrunek. Naturally, over the years, we have been continuously engaged in new developments in the field of elastomer technology. And this is particularly true with a view towards ever higher performing materials, such as fluoroelastomers. Especially the manufacture of fluoroelastomers suits the production capabilities of Zrunek. Our production line is ideally suited for small and medium runs, as well as customized

solutions to your specific needs. Our capabilities extend from custom compound development in our own laboratory and in-house mixing-plant facilities, which guarantee flexibility and consistent product quality, to advanced machinery including presses, injection moulding machines and extruders to ensure a broad spectrum of manufacturing options.

A major part of our budget for research and development is spent on tasks concerning the extrusion and processing of FPM. As a result of these activities, Zrunek has become the leading expert in the field of fluoroelastomer extrusion, as well as the largest processing manufacturer of fluoro rubber in Austria.

Certified According to ISO 9001

Nowadays it goes without saying that a company which manufactures such basic and high-quality components throughout industry has established a quality control system that is in compliance with the ISO 9001 standard.

In addition to the technical competence based on the company's long standing expertise and experience, we can also provide our customers with high levels of security and reliability through our advanced quality control system.

Satisfaction makes customers

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