Glossary of material codes

4. Testing and Interpretation of Test Results

Highly elastic materials are distinguished from other materials not simply by the fact that they are "elastic". The properties are different in many respects. The usual terminologies from materials testing such as hardness and tensile strength have to be interpreted differently by the engineer. New terms such as ageing resistance or deformation speed appear. There are hardly any constants; the majority of properties are greatly affected by temperature and other aspects, many are even dependent on the size and structure of the relevant test specimens or moulded parts.

Still, there are a large number of synthetic rubbers. And these have a larger number of variations in the material composition. The ability to combine the materials properties is however limited. As an example, with NBR it is not possible to combine high oil resistance with optimum low temperature behaviour.

A range of material properties are interlinked due to chemical and physical factors. If one property is changed, then other properties inevitably change as well. This can be an advantage for the respective application, but can also be a disadvantage.

Taking this aspect into consideration, unnecessary requirements should not be placed on the material when drawing up the specifications. This approach smoothes the way to a material to suit the application.

4.1 Physical properties

• Hardness

The parameter most frequently used to characterise highly elastic materials is hardness. Testing is performed using test equipment to Shore A or D and IRHD. The highly elastic materials from Simrit are usually to be tested to Shore A.

In the test laboratory the measurements are performed as per the conditions defined in DIN 53 505. Hardness according to Shore can also be measured with a handheld device. However, measurement uncertainties can often not be excluded here.

In many cases, however, useable relative or comparable values are produced if the standards are observed, and the following are adherred to during measurement:

- Insufficient sample thickness results in excessively high measured values.
- Conversely, measurements too close to the edge, e.g. on excessively small moulded parts, produced excessively low values.
- The same applies for excessively high contact pressure.
- The test specimens should be as flat as possible, not lie over a cavity. Always keep the sample and the measuring instrument parallel and observe the time for taking readings accurately..

Another method for performing measurements in the test laboratory is to determine the international rubber hardness degrees (IRHD; DIN ISO 48) by measurement of the penetration depth of a defined sphere under a defined force. With highly elastic materials the IRHD value corresponds approximately to the Shore A hardness. For materials that have a tendency to plastic deformation, the measured values (determined from the two methods) can vary significantly.

A variant of this method, exists, with correspondingly reduced sphere diameter(0,4 mm) which permits small and thin samples to be measured (so-called micro-hardness, DIN ISO 48 Method M).

It is therefore frequently used for measuring finished items. With this method there are differences due to the specimen surface (un-evenness, e.g. due to grinding, surface hardening, or friction coefficient), which can lead to even greater differences in the values.

Measured values determined on the finished items often do not correspond to the values measured on standard test specimens.

For hardness information, the measurement methods used must always be stated, e.g. hardness 80 Shore A or hardness 72 IRHD. For hardness testing on finished items, the method is to be discussed in detail between customer and supplier in the specific cases to avoid inconsistencies. ± 5 hardness grades are generally defined as the tolerance for hardness measurements and hardness figures. This relatively large range is necessary to take into account the differences between different instruments and testers as well as the inevitable production scatter.

• Tensile stress and modulus of elasticity

Like hardness, tensile stress and modulus of elasticity are also parameters for the ability of elastic materials to deform.

The tensile stress determined at 100 or 300% elongation in tensile trials as per DIN 53 504 is defined as the force necessary for the related deformation divided by the original cross-section of the test specimen. The tensile stress is often wrongly called a "modulus". The modulus of elasticity or elongation modulus is the tensile stress divided by the relative longitudinal change (elongation). It is not a constant for highly elastic materials.

Hook's law $\sigma = E\,\varepsilon$, according to which the stress σ is proportional to the elongation Â, where the modulus of elasticity E represents the constant of proportionality; applies to rubber only in a restricted deformation region that can be different from material to material. The modulus of elasticity can both increase as well as decrease with elongation →Diagram 20.1.

The modulus of elasticity is dependent on the so-called form factor, the relationship of a loaded to a free surface on the part or test specimen. Here the loaded surface is taken to be under a tensile or compression load (without mating face) and the free area, the total of all areas at which the specimen is free to elongate or compress. Both areas are to be measured in the unloaded state. Thus the form factor F for an axially loaded cylinder is

$F = d/4h$ (d = diameter, h = height).

• Other moduli

Other moduli are of significance for the deformation characteristics. Shear modulus or modulus of elasticity in shear and dynamic moduli are important for vibration processes. They are not specified in more detail here.

Test procedures are defined, e.g., in DIN 53 513, DIN 53 445 and ASTM 945 (YERZLEY testing).

• Relationships between deformation properties and their parameters

Based on the statements made above, only an approximate relationship can be expected between the individual measured parameters.

For shear modulus G and modulus of elasticity E, for highly elastic materials the following applies approximately

$G = 1/3\,E$.

Between the hardness in Shore A or IRHD and the modulus of elasticity at 5–10% compression set there is an approximate relationship that is shown graphically in →Diagram 20.3.

The hardness, however, has no general correlation with the moduli for larger deformations, even if in general a material possesses higher moduli with greater hardness.

A common feature of all deformation properties is that they are heavily dependent on temperature and time. Time-dependency means that the speed of deformation (e.g. withdrawal velocity in tensile testing or the frequency for the dynamic modulus) or the time when the measured value is taken (e.g. for hardness measuring) affect measured values.

"The" modulus of elasticity of a highly elastic material, as is occasionally requested, therefore does not exist!

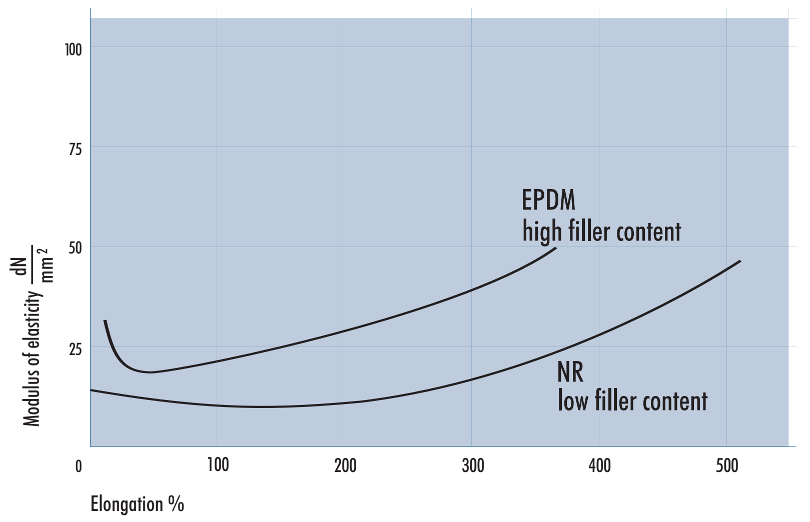

Diagram 20.1 Dependency of the modulus of elasticity on deformation (tensile test) for two different vulcanisation processes

• Tensile strength and elongation at break

These values are only of limited use for assessing possible applications and service life of parts made of elastomers, as they are only subjected to stresses or elongation that lie in the order of magnitude of the fracture values for the material in exceptional cases. Thus, on diaphragms very high values can be reached near the clamping flange that can then lead to premature failure. In instances of this type, as explained at the beginning of this section, the solution of the problem is not only to be sought in the material, but also in the design.

The values for tensile strength and elongation at break determined in accordance with DIN 53 504 are utilised for characterising material comparisons, for identification and inspection as well as for determining resistance against destructive influences (aggressive media, ageing).

• Resistance to tear propagation

Additional information is obtained by testing the resistance to tear propagation in accordance with DIN 53 507 and ISO 34-1 as the force that a defined specimen produces to oppose tear propagation compared to the sample thickness. The values found here serve as a measure of the sensitivity of elastomers to tear propagation at cuts and cracks, and do not need to be given in parallel with tensile strength. As the results of resistance to tear propagation depend heavily on the special testing conditions and particularly on the specimen shape, the ranges found on laboratory specimens for the related test methods or found in practice do not need to match. The statement of the test procedure and specimen type with the measured value is imperative, e.g. resistance to tear propagation in accordance with DIN 53 507, test specimen B or other resistance to tear propagation in accordance with DIN 53 515, shaped angled sample.

• Elasticity and damping

The elasticity is, as for ability to deform, dependent on temperature and above all on the sequence of the deformation process over time.
The testing of impact elasticity for sealing components in accordance DIN 53 512 states little about the elastic behaviour under operating conditions. It is therefore frequently more sensible to determine the return deflection or the lasting deformation under trial conditions selected in accordance with the operating conditions.

The mechanical damping is the reciprocal property of the elasticity. It can be determined using the methods given for the measurement of the dynamic modulus.

A body is elastic when it returns to its original shape again immediately after a forced deformation (e.g. steel spring). A body that retains its deformation is plastic or viscous (e.g. kneaded rubber). A viscous-elastic component is comparable to both, where the elastic portion predominates in the case of highly elastic materials. A key feature of viscous-elastic behaviour is that the original state is not reached immediately after removal of the load, but is only attained gradually according to conditions. The viscous elasticity is the actual cause of the specific physical behaviour of the highly elastic materials.
Typical viscous-elastic features are compression set, stress relaxation and creep (→Diagram 20.5 and →Diagram 20.7).

• Other physical properties

For special applications, other physical properties such as thermal expansion, friction behaviour, electrical properties and permeability to gases or liquids, amongst others, can be of significance. These issues will not be covered in further detail here.

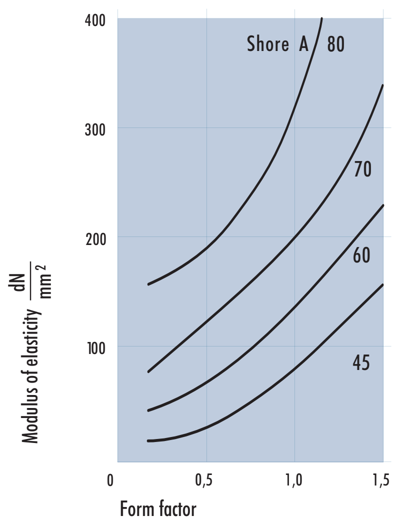

Diagram 20.2 Dependency of the modulus of elasticity on the form factor (20% compression set) for differing hardness

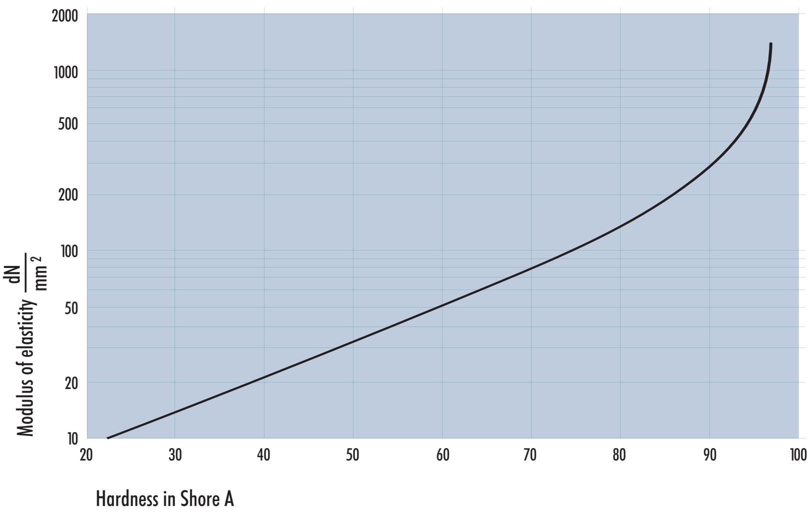

Diagram 20.3 Relationship between hardness in Shore A and modulus of elasticity at approx. 10% compression set (form factor 0,2)

• Temperature behaviour

As already mentioned several times, temperature has a significant effect on the physical properties of highly elastic materials. →Diagram 20.4 shows the dependence of the dynamic shear modulus G (shear modulus measured in torsion vibration test in accordance with DIN 53 445) on temperature. From right to left the highly elastic region can be seen with an almost constant modulus; following this is the transition region with a steep gradient, and finally there is the glass state region in which the rubber is hard and brittle, again with an almost constant modulus.
The low temperature brittleness disappears again as the temperature is raised; the freezing process is thus reversible. The transition from the highly elastic to the glass state region is especially important since in many cases it marks the low temperature limit. This transition, as can be seen in →Diagram 20.4, is not sharp but extends over a specific region.

The transition region from the highly elastic to the glass state is characterised by the glass transition temperature $T_{ü}$ (temperature of the maximum of the logarithmic damping decrement Λ). This value can however only represent a rough recommended value for the materials low temperature limit, as the type of load is very important in the practical use of an elastomeric component. The same material with sudden loading and very high deformation speed will reach its load limit at a much higher temperature than, e.g., during slow elongation. While with the aid of the torsion vibration trial a differentiation can be made between materials, the temperature limit in practice is to be tested using the appropriate components in the function.

Example:

On contact seals, heat is produced by the friction that occurs during motion. At temperatures where there already exists the risk of hardening due to freezing, the friction heat can suffice to keep the seal elastic, or quickly place the seal in a functional operating state after the start of the motion. The testing of the cold behaviour is therefore only sensible in the form of a material comparison in conjunction with experience of the engineering application. The differences between the various materials for low temperature limits, determined from torsion vibration testing on the one hand, and from practical trials on the other, in many instances correspond. If the (frequently very costly to determine) cold limit has been determined for a material in a practical trial, then a reliable prediction of the low temperature behaviour of other materials in the practical application can be made with the aid of the $T_{ü}$-values for the materials.

For the comparison of general low temperature figures, as has been agreed as per other laboratory test methods, considerations similar to those for the comparison between the low temperature limit determined in practical trials and the glass transition temperature measured in torsion vibration trials apply. Here deviations of only a few degrees may be found, but also from 30 to 40 degrees between the differing test methods. Details on the measurement methods used must always be stated with information on the general low temperature figures. The same as described above applies to the transition to the component behaviour in practice. Various common laboratory methods for characterising low temperature behaviour are briefly described in the following:

• Temperature retraction test

In this test (ASTM D 1329-79) a rod-shaped rubber specimen in an elongated state is frozen in a temperature controlled bath and the temperature T_R 10, T_R 30, ... at which the elongation of the specimen has reduced by 10, 30, ... percent measured.

• Cold brittleness temperature with impact load

The cold brittleness temperature T_S (DIN 53 546) is termed as the approximate temperature at which (after increasing the temperature of the surrounding cooling liquid) all specimens no longer break under a defined impact load.

In addition, information on the low temperature behaviour can also be gained from tests that are relatively straightforward to perform. Examples are the cold bending test using a mandrel with defined bending speed, or the Shore hardness measurement at different temperatures.

The general low temperature figure can be defined as, e.g., the temperature at which the Shore A hardness is 90 points. The curve of the compression set at low temperatures also provides information on a materials low temperature flexibility. A general low temperature figure can, for example, be defined as the temperature at which the compression set takes on a specific value, e.g. 50%.

4.2 Resistance of materials

The changes that highly elastic materials experience due to the effects of the environment and/or operating conditions are often of even greater significance than the initial values for the technological properties.
The behaviour of the materials must therefore be checked in conditions similar to practice.

• Swelling and chemical attack

Frequently, consideration of chemical resistance and of swelling behaviour is decisive for the correct selection of a suitable material when using seals. It must therefore always be known with which fluid or gaseous media the material will come into contact. Naturally, the temperatures of the media are very important.

The consequences of a chemical effect are, similar to hot air, ageing, softening or hardening, loss of strength, elongation at break and elasticity, loss of stress or creep. In addition there is a volume change due to swelling or shrinkage, depending on whether the absorption of additional substances or the removal of extractable substances dominates.

The testing of behaviour against fluids, steam and gases is performed as per DIN 53 521 in the medium to be used in the application, or in standardised testing fluids (e.g. ASTM oil No. 1, IRM 902* and IRM 903**, ASTM reference fuel A, B, C, FAM test fuels).

* replacement product for ASTM oil No. 2

** replacement product for ASTM oil No. 3

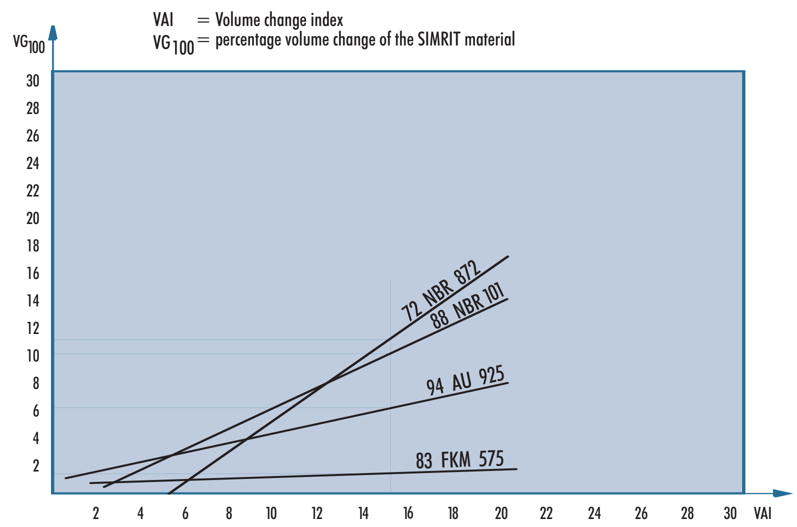

Diagram 20.5 Swelling behaviour of materials

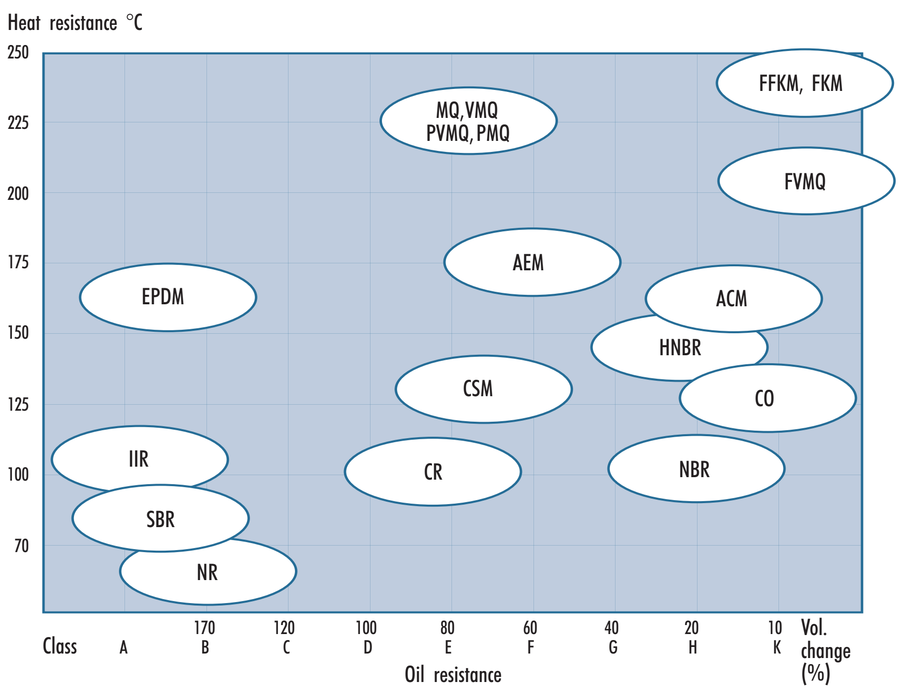

Diagram 20.6 Heat and oil resistance (in ASTM Oil No. 3) of elastomers (as per ASTM D 2000)

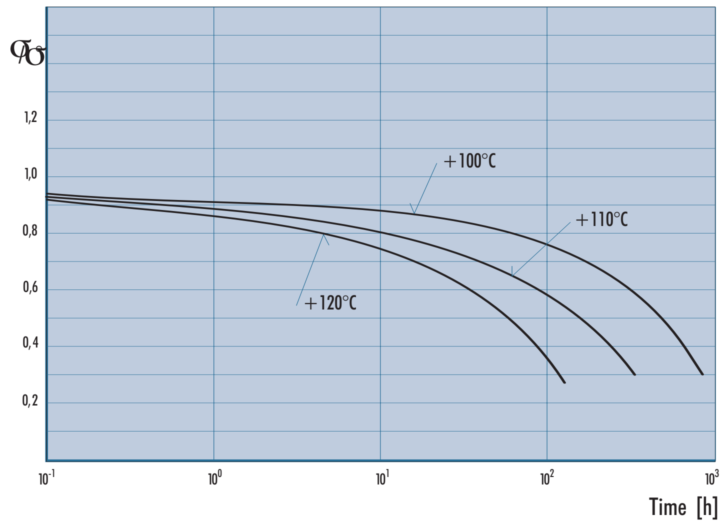

Diagram 20.7 Compression stress relaxation in an elastomeric material at various temperatures

• Volumetric change index

The regularity of the swelling effect of mineral oils on highly elastic materials can be tested on standard reference elastomers. This type of NBR standard reference elastomer (SRE) has already been proposed as test material NBR 1 and is also standardised as per DIN 53 538.
The volumetric change determined on this SRE in any mineral oil, under standard conditions, is called the volumetric change index (VAI) of the oil teste, as per a VDMA proposal.

If a rubber material is swollen up to its saturation state in any oils, there is a linear relationship between the volumetric change determined on the elastomer in these oils and the volumetric change determined on the standard reference elastomer (SRE) in the same oils under the same conditions, i.e. the VAI of these oils. If the maximum volumetric change of any elastomer in various oils is plotted on a coordinate system against the VAI values for these oils, then a straight line is obtained that characterises the swelling behaviour (QVH) of this elastomer. A straight QVH line can be determined in this way for each elastomeric material. From these straight lines the maximum volumetric change of the related elastomer can be predicted for all oils with known VAI. These QVH straight lines have already been determined for all materials from Simrit. Using this diagram, materials being considered for the respective applications can be combined with the suitable oils. The volumetric change index (VAI) is not stated by the oil manufacturers.

Example: in a mineral oil with VAI 15, the following volumetric change values are found:

Materials from Simrit	Volumetric change
83 FKM 575	1%
94 AU 925	6%
88 NBR 101	10%
72 NBR 872	15%

• Heat resistance, ageing behaviour

As with all organic-chemical products, highly elastic materials based on polymers can also be changed by the action of oxygen, water and/or other media. Important properties such as hardness, elongation and elasticity can be worsened as a result of these processes, termed ageing. The material can then become susceptible to cracking, and then fracture.

Heat accelerates the ageing processes. Also exposure to light and radiation can have a destructive effect. The higher the temperature, the lower the service life of the part. This results in different permissible maximum operating temperatures for brief loads and for continuous loads for individual materials. The respective limits depend predominantly on the base polymer.

By placing specimens in a heated cupboard (DIN 53 508), it is possible to measure ageing over a shorter test period. However, test temperature and actual operating temperature must not differ significantly.

Changes in hardness, tensile strength and elongation of break as well as in the compression set or stress relaxation are mostly used to assess ageing behaviour.

The familiar crack formation on elongated rubber parts exposed to the weather is primarily caused by the ozone present in air. The procedures for testing ozone resistance are specified in DIN 53 509

• Static constant load and constant deformation

If a part made of highly elastic material is constantly deformed for a period, then after relaxation, a certain deformation will remain. This is determined in the pressure test in accordance with DIN ISO 815 and given as a percentage of the original deformation.
This residual deformation is called compression set.

The compression set is heavily dependent on temperature and duration of the deformation. At lower temperatures the effect of viscous elasticity predominates, at higher temperatures, the ageing effect. (more information → Explanation of DIN ISO 815).

The compression set can be related in specific cases to the function of sealing components, e.g. for O-rings.

The flow behaviour, the vulcanisation state and the heat resistance affect the test value. As a result the measurement of compression stress relaxation is more suitable (DIN 53 537), since it gives a more direct measurement for the timed removal of initial contact pressure on a constantly deformed seal.

If elastic parts, instead of constant deformation, are subject to constant load, then the distortion increases with time. Here the term creep is used.

If the test temperatures for the base polymer are below the maximum permissible continuous operating temperature, compression stress relaxation and creep follow an approximately logarithmic time law, i.e. they come, seen from a practical point of view, to a stop after some time.

• Dynamic loading, fatigue and service life

Far more frequent than exceeding the stiffness or elongation limit once, is destruction of rubber parts by dynamic loading. On continually repeating deformation, the material is damaged due to internal friction resulting initially in small cracks that grow and finally lead to fracture.

Standard methods for test conditions are defined, e.g., in DIN 53 522 and 53 533.

• Resistance to wear

This important property for friction loading is also heavily dependent on the operating conditions, such as the type of lubrication, material and roughness of the mating surface, running speed, slip, contact pressure and temperature.

Wear tests should therefore only be performed with the finished product and in conditions as close as possible to practice.

5. Properties of Seal Materials

The properties of a material are primarily determined by the base polymer for the material. However they can vary widely depending on the compound composition and in this way can be matched to the related purpose.

In the following, the characteristic properties and the resulting main areas of use of the materials from Simrit are outlined. For more detailed differences between individual materials you are referred to the material tables.

5.1 General material descriptions

5.1.1 Elastomeric materials

• Acrylonitrile-butadiene rubber (NBR)

is a polymer made of butadiene and acrylonitrile. The acrylonitrile portion can be between 18 and 50% and affects the following properties of the related NBR seal materials produced from the polymer:

- resistance to swelling in mineral oils, greases and fuels
- elasticity
- low temperature flexibility
- gas permeability
- compression set

Thus an NBR material with 18% ACN content has very good low temperature flexibility down to approx. –38 °C with moderate oil and fuel resistance, An NBR material with 50% ACN content has optimum oil and fuel resistance, but on the other hand has a low temperature flexibility only down to approx. –3 °C. Elasticity and gas permeability decrease with rising ACN content and the compression set worsens.

Materials from Simrit based on this synthetic rubber are, due to their good technological properties, suitable for a large number of applications.

In particular, the proven Simmerrings, sealing components for hydraulics and pneumatics as well as O-rings are produced in large numbers from materials based on NBR. Across the world Freudenberg has the most far-reaching experience of all seal manufacturers on the use of this base elastomer.

Good swelling resistance in

aliphatic hydro-carbons, e.g. propane, butane, petrol, mineral oils (lubricating oils, hydraulic oils of groups H, H-L and H-LP) and grease with a mineral oil base, fire retardant hydraulic fluids of groups HFA, HFB and HFC, vegetable and animal oils and fats, light heating oil and diesel fuel. Some materials are particularly resistant in:

hot water up to a temperature of +100 °C (sanitary valves), inorganic acids and bases without excessively high concentration or temperature.

Medium swelling resistance in

fuels with high aromatic content (high grade fuel).

Heavy swelling in

aromatic hydro-carbons, e.g. benzene, chlorinated hydro-carbons, e.g. trichloroethylene, fire retardant hydraulic fluids of group HFD, esters, polar solvents as well as brake fluids of a glycol ether base.

Thermal applications

Depending on composition of compound between –30 °C and +100 °C, short term to 130 °C; material hardens when temperatures are higher. Low temperature flexibility reaches –55 °C using special compounds.

• Carboxylated nitrile rubber (XNBR)

are terpolymers or blends of butadiene, acrylonitrile and methacryl acid. The main properties are similar to the NBR polymers, however they have improved wear behaviour in dynamic seal applications. The low temperature flexibility is limited compared to other NBR types.

Thermal applications

approx. –25 °C to +100 °C (+130 °C also briefly).

• Hydrogenated acrylonitrile-butadiene rubber (HNBR)

is obtained from normal NBR polymers by full or partial hydration of the double-bonded butadiene components.

In this way the heat and oxidation stability increases with peroxide cross-linking.

The materials produced feature high mechanical strength and improved abrasion resistance. Media resistance same as NBR.

Thermal applications

approx. –30 °C to +150 °C.

• Acrylate rubber (ACM)

is a polymer made out of ethylene acrylate or butyl acrylate with a small amount of a monomer required for cross-linking.

Elastomers based on ACM are more heat resistant than those based on NBR or CR. Simmerrings, O-rings and moulded parts made of materials based on ACM are used in the higher temperature range and in oils with additives for which the NBR materials from Simrit are no longer adequate. However materials based on fluoro elastomer and silicone rubber are not yet necessary.

Ageing resistance and ozone resistance are very good.

Good swelling resistance in

mineral oils (engine oils, transmission oils, ATF oils), also with additives.

Heavy swelling in

aromatic and chlorinated hydro-carbons, alcohols, brake fluid of a glycol ether base, flame retardant hydraulic fluids. Hot water, steam, acids, alkalis and amines damage the material.

Thermal applications

Approx. –25 °C to +150 °C.

• Ethylene acrylate rubber (AEM)

is a polymer made of ethylene methyl acrylate with carboxyl groups. Ethylene acrylate rubber is more heat resistant than ACM and has properties between those of ACM and FKM.

Good swelling resistance in

mineral oils of a paraffin base and with additives, water and cooling fluids.

Good weathering resistance and ozone resistance.

Heavy swelling in

ATF and transmission oils, richly aromatic mineral oils, brake fluid of a glycol ether base, concentrated acids and phtal acid esters.

Thermal applications

approx. –40 °C to +150 °C.

• Silicone rubbers
Vinyl-methyl polysiloxane (VMQ)
Phenyl-vinyl-methyl polysiloxane (PVMQ)

are high polymer organosiloxanes that feature high thermal resistance, good low temperature flexibility, good dielectric properties, very good resistance to attack from oxygen and ozone and low temperature dependency of the technological properties. Permeability for gases is higher than for other elastomers at room temperature. This is to be taken into consideration, particularly for thin-walled diaphragms.

The material is broken down with the release of oxygen at higher temperatures due to de-polymerisation.

Medium swelling resistance in

mineral oils (comparable to materials of a CR base) and brake fluids of a glycol ether base.

Use possible in water up to around +100 °C.

Sufficiently resistant in aqueous salt solutions, monohydric and polyhydric alcohols.

Heavy swelling in

low molecular esters and ethers, aliphatic as well as aromatic hydro-carbons.

Concentrated acids and alkalis, water and steam at temperatures over approx. 100 °C damage the material.

Thermal applications

approx. –60 °C to +200 °C (briefly up to +230 °C). Parts can be produced from special compounds that only become brittle under –100 °C.

• Fluorosilicone rubber fluoromethyl polysiloxane (FVMQ)

is a methyl vinyl silicone rubber with groups containing fluorine. Elastomers made of this synthetic rubber are significantly more resistant to swelling in fuels, mineral and synthetic oils than those made of silicone rubber.

Thermal applications

approx. –80 °C up to +175 °C (briefly up to +200 °C).

• Fluoro elastomer (FKM)

By means of the polymerisation of vinylidene fluoride (VF) and alternatively, the use of variable proportions of hexafluoropropylene (HFP), tetrafluoroethylene (TFE), 1-hydro pentafluoropropylene (HFPE) and perfluoro (methyl vinyl ether) (FMVE), it is possible to manufacture copolymers, terpolymers or tetrapolymers with varying structure and fluorine content of 65–71%, and as a result different media resistance and low temperature flexibility. Crosslinking is performed either with diamine, bisphenols or organic peroxide.

The special significance of materials based on FKM is in their high temperature resistance and chemical stability.

Gas permeability is low. In a high vacuum elastomers from FKM have minimal weight losses.

The ozone, weathering, and light crack resistance is very good, as is flame resistance.

Amines can damage the material and require selection of suitable types as well as special compound composition.

A special elastomer group is the copolymers made of TFE and propene with a relatively low fluorine content (57%). Materials using these elastomers possess excellent resistance to hot water, steam as well as against amines or media containing amines with lower swelling resistance against mineral oils.

Good swelling resistance in

mineral oils and greases (also with the majority of additives), fuels and aliphatic as well as aromatic hydro-carbons, some fire retardant hydraulic liquids and synthetic aviation engine oils.

Also newly developed peroxide cross-linked materials have good resistance to media that have little or no compatibility with conventional FKM. This relates to, e.g.: Alcohols, hot water, steam and fuels containing alcohol.

Heavy swelling in

polar solvents and ketones, fire retardant hydraulic fluids, type: skydrol, brake fluid on glycol ether base.

Thermal applications

Approx. –20 °C to +200 °C (briefly up to +230 °C).

Special types: –35 °C to +200 °C.

By means of suitable moulding and especially material compositions developed especially for such applications, seals and moulded parts can be used even for low temperatures.

• Perfluoro elastomer Simriz (FFKM)

With the use of specially perfluorinated (i.e. completely free of hydrogen) monomers and corresponding compounding and process techniques, materials with highly elastic properties can be manufactured that come very close to PTFE in their media and thermal resistance. Seals and perfluoro elastomer are used everywhere where extreme safety standards apply, and a high maintenance and repair effort outweighs the price for the seals. Preferred fields are the chemical industry, oil production and processing industry, appliance manufacturing and power station applications, as well as for aerospace projects.

Thermal applications

–15 °C to +230 °C.

• Polyurethane (AU)

Polyurethane is a highly molecular organic material with a chemical composition that features a high number of urethane groups. Within certain temperature limits, polyurethane possesses the characteristic elastic properties of rubber. Three components determine the composition of the material:

– polyol

– diisocyanate

– chain extender.

These define the properties of the resulting polyurethane material depending on the type, quantity and reaction condition.
Polyurethane possesses the following properties:

– high mechanical strength,

– good wear resistance,

– variable modulus of elasticity in broad limits,

– good flexibility,

– broadly adjustable hardness range with good elasticity,

(polyurethane fills the gap between stretchable soft rubber

types and brittle plastics.)

– very good ozone and oxidation resistance,

– good swelling resistance in mineral oils and greases, water,

water-oil mixtures and aliphatic hydro-carbons,

– operating temperature range – 30 °C to +80 °C, high load types up to more than +100 °C in mineral oils.

Not resistant to polar solvents, chlorinated hydro-carbons, aromatics, brake fluids with a glycol base, acids and alkalis.

• Chlorobutadiene rubber (CR)

is a polymer based on chlorobutadiene. Elastomers with corresponding compound composition feature chemical resistance, good resistance to ageing, the effects of weather, ozone attack and flame resistance.

Good swelling resistance in

mineral oils with high aniline point, greases, many refrigerants and water (with special compound composition).

Medium swelling resistance in

mineral oils, low molecular aliphatic hydro-carbons (petrol, isooctane).

Heavy swelling in

aromatics, e.g. benzene. toluene, chlorinated hydro-carbons, esters, ethers and ketones.

Thermal applications

approx. –45 °C to +100 °C depending on compound composition (briefly up to 130 °C).

• Ethylene-oxide-epichlorhydrin rubber (ECO)Polyepichlorohydrine (CO)

is a polymer made of epichlorohydrin and ethylene oxide.

Materials based on this rubber feature low gas permeability, good ozone and weathering resistance.

Good swelling resistance in

mineral oils and greases, vegetable and animal oils and fats as well as aliphatic hydro-carbons such as propane, butane etc. and both petrol and water.

Heavy swelling in

aromatic and chlorinated hydro-carbons, fire retardant hydraulic fluids of group HFD.

Thermal applications

approx. –40 °C to +140 °C.

• Chlorosulphonated polyethylene (CSM)

Good swelling resistance in

hot water, steam, washing lye, oxidising media, acids, bases, polar organic media, ketones, fire retardant hydraulic fluids of group HFC and some types of group HFD, brake fluids on a glycol ether base.

Medium swelling resistance in

aliphatic hydro-carbons and greases.

Resistance in oxidizing media, inorganic and organic acids and bases.

Heavy swelling in

aromatic and chlorinated hydro-carbons and esters.

Thermal applications

approx.–20 °C to +120 °C

• Natural rubber (NR)

is a high polymer isoprene.

The vulcanisates feature high mechanical strength and elasticity as well as good low temperature behaviour. They are therefore preferred for the production of torsional vibration dampers, engine mounts, machine mountings, rubber-metal-spring components, diaphragms, moulded parts, etc.

Good swelling resistance in

acids and bases in low concentrations as well as in alcohols and water without an excessively high temperature and concentration. Brake fluids with a glycol ether base, e.g. ATE-SL at temperatures up to 70 °C.

Heavy swelling in

mineral oils and greases, fuels and aliphatic, aromatic and chlorinated hydro-carbons.

Thermal applications

approx. –60 °C to +80 °C.

Higher temperatures over a longer period can soften natural rubber after previous hardening.

• Polybutadiene rubber (BR)

is a polymer made of butadiene.

It features high elasticity, resistance to abrasion, very good hot and cold properties and light crack resistance.

It is used as a component with NR and SBR for tyres, drive belts, conveyor belts and similar

Good swelling resistance in

diluted acids and bases, in alcohols and water.

Heavy swelling in

Hydro-carbons.

Thermal applications

approx. –60 °C to +100 °C.

• Styrene-butadiene rubber (SBR)

is a polymer made of butadiene and styrene.

Materials made of SBR are preferred for the manufacture of sealing components for hydraulic brakes.

Good swelling resistance in

inorganic and organic acids and bases as well as alcohols and water, brake fluids with glycol ether base.

Heavy swelling in

mineral oils, lubricants, petrol and aliphatic, aromatic and chlorinated hydro-carbons.

Thermal applications

approx. –50 °C to +100 °C.

• Ethylene propylene diene rubber (EPDM)

is a polymer made of ethylene, propylene and a small proportion of a diene.

Ethylene propylene rubber (EPM) is a polymer made of ethylene and propylene.

Precision moulded parts and sealing components made of EPDM are preferably used in washing machines, dishwashers and water fittings. Likewise, seals made of this material are used in hydraulic systems with fire retardant fluids of groups HFC and HFD and in hydraulic brake systems.

Elastomers made of EPDM have a very good ozone, ageing and weathering resistance and therefore are very well suited to the manufacture of profile strips and sealing strips subjected to the weather.

Good swelling resistance in

hot water, steam, washing lye, oxidising media, acids, bases, polar organic media, ketones, fire retardant hydraulic fluids of group HFC and some types of group HFD, brake fluids with a glycol ether base.

Heavy swelling in

mineral oils and greases, petrol and aliphatic as well as aromatic and chlorinated hydro-carbons.

For additional lubrication of seals used, special lubricants are therefore to be used.

Thermal applications

approx. –50 °C to +150 °C.

• Butyl rubber (IIR)
• Chlorobutyl rubber (CIIR)
• Brominebutyl rubber (BIIR)

are polymers made of isobutyl or chlorinated or bromine isobutyl and a low isoprene portion.

Elastomers made of IIR have a very good weather and ageing resistance.

The gas and steam permeability of this material is low.
Some materials have a very good electric isolation performance.

Good swelling resistance in

brake fluids with a glycol ether base, inorganic and organic acids and bases, hot water and steam up to 120 °C, hydraulic fluids of group HFC and some types from group HFD.

Heavy swelling in

mineral oils and greases, petrol and aliphatic as well as aromatic and chlorinated hydro-carbons.

Thermal applications

approx. –40 °C to +120 °C.

5.1.2 Thermoplastic rubbers (TPE)

The properties of TPE are between elastomers and thermoplastics.
TPE are multi-phase systems made of a hard and a soft phase. The hard segments are mounted together so that a kind of crystal structure is produced that is bonded with soft segments. A pseudo crosslinked structure is produced.

Categorisation of TPE

TPE-O	Thermoplastic rubber of an olefine base e.g. (YEPDM)
TPE-S	Thermoplastic rubber of a styrene base (YSBR)
TPE-E	Thermoplastic rubber of an ester base (YBBO)

- YEPDM (olephinic thermoplastic rubber)
  Properties comparable with EPDM, i.e. very good chemical resistance, but not oil resistant.

Products cannot be used above a temperature limit of 120 °C.

- YSBR (thermoplastic rubber containing styrene)
  Here the hard phase is styrene, the soft phase butadiene.

Properties:

The mechanical properties are comparable with SBR. Hard or soft products result from the ratio of the styrene to butadiene. Creep and loss of tensile strength occur above 60 °C. Low temperature flexibility reaches down to –40 °C. Good chemical resistance against water, diluted acids and alkalis, alcohols and ketones. In non-polar solvents, fuels and oils YSBR is not resistant.

- YBBO (copolyester TPE)

  YBBO features:

  – high tensile strength
  – high tensile modulus
  – good elongation
  – outstanding resistance to solvents
  – resistance to oxidising acids
  – aliphatic hydro-carbons
  – alkali solutions, various greases and oils.

Strongly oxidising acids and chlorinated solvents lead to pronounced swelling.

5.1.3 Thermoplastic materials

Products made of thermoplastic materials are widely used today in all sectors of technology, particularly for seals and moulded parts.

The softer grades (polyethylene, soft PVC, thermoplastic elastomers) compete in many areas with the highly elastic materials, whilst the mechanically high-quality plastics (polyamide, acetal resins) are penetrating into areas that previously were exclusively reserved for metals.

Sealing components and items made of thermoplastic materials differ according to the basic materials employed. In many cases they can be varied by the incorporation of certain additives, and can thus be matched to the purpose of the part to be manufactured. In the following some characteristic properties and the resulting primary applications are explained. Further information can be obtained from the material tables.

• Polytetrafluoroethylene (PTFE)

PTFE is a thermoplastic polymer made of tetrafluoroethylene.
This non-elastic material features a series of excellent properties:

The surface is smooth and repellent. This favours usage in all applications in which the adherence of residues is to be avoided.
PTFE is physiologically safe for operating temperatures up to +200 °C

The coefficient of friction is very low compared to most mating surface materials. Static friction and dynamic friction are nearly the same.

The electric isolation properties are extraordinarily good. They are almost independent of frequency as well as temperature and weathering effects.

The chemical resistance is better than all elastomers and other thermoplastics. Consequently, swelling resistance is good in nearly all media.

Liquid alkali metals as well as some fluorine compounds attack the material PTFE at higher pressures and temperatures.

The thermal applications are between approx. –200 °C and +260 °C.
At –200 °C. PTFE still possesses a certain elasticity; the material can therefore be used for seals and items, e.g. even for liquid gases.

To be noted on the usage of parts made of pure PTFE:

– that the material from a specific load remains deformed due to creep and cold flow,

– that the resistance to abrasion is low,

– that thermal expansion, as with most plastics, is approx. 10-x greater in comparison to metals,

– that heat conductivity is low, so that heat dissipation can become a problem for bearings and moving seals,

– that the material is not highly elastic.

For this reason designs with elastomeric seals cannot simply be switched to PTFE. For lip seals additional contact pressure by springs, or similar, must always be provided.

PTFE is filled with graphite, glass fibre, bronze and carbon to obtain special properties.

• Ethylene-tetrafluoroethylene copolymer (ETFE)

is an injectable fluoro-plastic with very good chemical and thermal properties, although they do not quite reach the values of PTFE.
Upper operating temperature around +180 °C

• Perfluorokoxy copolymer (PFA)

is also is an injectable fluoro-plastic with similar chemical and thermal properties to PTFE.

Both materials are particularly suited to the manufacture of high quality, technical moulded and injection moulded parts.

Upper operating temperature approx. +260 °C

• Polyvinyl chloride (PVC)

is today often used due to its good technological and chemical properties instead of the elastomer materials used previously.

The materials developed on a PVC base have rubber-like properties unlike the other thermoplastics mentioned here.

PVC is used as a preference for: bellows, collars, seals, coverings, covers, sleeves, caps and moulded parts for air ducting.

Thermal applications

–35 °C to +70 °C.

• Polypropylene (PP)

is resistant to hot water and washing lye, is suitable for boiling and can withstand sterilisation temperatures of +120 °C for short periods.
Preferred use is in pumps, motor vehicles and domestic appliances.

• Polyamide (PA)

significantly surpasses the previously mentioned materials with its resistance values. The high wear resistance, toughness of material structure, damping capacity and good dry-running characteristics make this material particularly suitable for machine components of various sorts (gearwheels, plain bearings, guide strips, switching cams etc.).

Upper application temperature +120 °C to +140 °C.

• Polyoxymethylene (POM) (polyacetal)

mechanically is one of the highly loadable thermoplastics. Thanks to its stiffness, hardness and resistance – linked with an excellent shape resistance, even at higher temperatures (up to approx. +80 °C) – this can in some cases replace parts made of metal die casting, brass or aluminium.

Particularly noteworthy is the low water absorption. As a result moulded parts made of polyacetal have even better dimensional accuracy even under the action of moisture. Acetal resins are attacked by acids.

Application temperature –40 °C to +140 °C

• Polyphenylene oxide (PPO)

is a tough, rigid material that above all features good dimensional stability, low creep tendency and low water absorption. It possesses a high impact strength and an almost constant low loss factor.
PPO is resistant to hydrolysis but is not resistant to oil.

Various properties of polyamide, acetal resins and PPO can still be substantially improved through the use of glass fibres. As an example, the tensile strength is then in general more than doubled compared to non-reinforced material. Heat resistance is considerably improved the notch impact strength, which drops rapidly without glass fibre reinforcement with reducing temperature, remains almost unchanged.

At the same time, compression strength is increased and the cold flow tendency reduced. The linear thermal expansion is essentially lowered.
It lies in the order of magnitude of metal die casting.

Upper application temperature briefly approx. +130 °C, longer approx. +90 °C.

• Polybutyleneterephthalate (PBTP)

PBTP is a partially crystalline, thermoplastic polyester material.
In hydraulics, unfilled or filled types are used depending on load.

PBTP has the following properties:

- high stiffness and hardness
- good sliding behaviour
- very low water absorption (= high dimensional stability)
- operating temperature range –30 °C to +120 °C (shape resistance)

Resistant against all lubricants containing mineral oils used in hydraulics, and all hydraulic fluids, diluted alkalis, acids and alcohol.

Not resistant to strong alkalis and acids.

• High load thermoplastic polycondensates "high tech, engineering plastics"

These products are mostly still very expensive due to complex manufacturing. They are only used for moulded parts if other plastics are certain to fail; metal properties would however cause problems, particularly in the electrical industry.

All materials have good resistance properties and a high temperature resistance (+140 °C to +200 °C).

Special features of the individual materials:

Polyethersulfone (PESU)

- resistant to water
- not resistant in brake fluids

Polysulphone (PPSO)

- cannot be used in boiling water
- certain solvents, esters, ketones, aromatics, chlorinated hydro-carbons damage the material due to the formation of stress cracks.

Polyphenylenesulphide (PPS)

- significantly more chemically resistant than other products
- due to crystallinity not tough and sensitive to notching

Polytherketone (PEEK)

- very good resistance to chemicals
- of universal application
- strengthened types can be used up to +180 °C

Polyetherrimide (PEI)

- amorphous and transparent
- ketones and chlorinated hydro-carbons attack this material.

5.1.4 Thermosets

Materials that neither soften or melt in heat. When ardened they are also more stable than plastics that are not cross-linked.

The most important product groups are:

- phenol formaldehyde materials (PF)
- unsaturated polyester (UP)
- polyimide (PI).

• Phenol formaldehyde (PF)

Resin-type condensation products - novolak - or resol resin are produced from the reaction of phenol with formaldehyde.

DIN-type masses differ due to various filler substances and reinforcing materials. The mechanical and technical properties are extremely useful.

Tempered parts can briefly bear a load up to +300 °C.

Other general properties:

– operating temperature –30 °C to +120 °C

– hard and very solid

– low tendency to creep

– fire retardant

– notch sensitivity

– not for use with foodstuffs

– resistant to organic solvents, weak acids and alkalis, salt solutions.

• Unsaturated polyester resins (UP)

Reaction products from

– unsaturated di-carbon acid ester,

– diol,

– di-carbon acids and styrene.

They are available as injection moulding materials, bulk moulding compounds (BMC) or, as web material, sheet moulding compounds (SMC).

Processing by pressing and injection moulding.

Properties:

Unlike phenol resins

– lower shrinkage

– lower water absorption

– better colouring

– lower price

– suitable for contact with foodstuffs

– good notch and impact sensitivity.

• Polyimide (PI)

Initial material is bis-maleinimide. From this duroplastic polyimides with a different molecular composition are produced by polymerisation.
A common feature of these heterocyclical polymers is the imide-ring with in the main chain. Polyimide parts feature high temperature resistance up to over +260 °C, briefly even over +300 °C, with mechanical properties largely retained. The materials also have good sliding and wear properties that can be further improved by the addition of suitable additives. The electrical properties and the resistance to radiation of polyimides are excellent. The materials are largely resistant to solvents, greases, fuels, oils and diluted acids. Strong acids, alkalis and hot water attack polyimides.

5.1.5 Seals and moulded parts made of Simriz

Perfluoro elastomers (FFKM) provide the widest range of chemical and thermal resistance and compatibility among elastomeric sealing materials. Freudenberg produces seals made of the all-round perfluoro elastomer Simriz.

These sealing materials

– come very close to the resistance of pure PTFE,

– have in addition the great advantage of high elasticity,

– also feature a much longer service life compared to conventional elastomers.

The universal applicability

of these perfluoro elastomers is based on their resistance to aggressive media and their suitability for use in extraordinarily wide temperature ranges. Simriz provide reliable sealing of

– chlorinated and high-polar organic solvents, e.g. chloroform, di-chloromethane, alcohols, lower aldehydes, ketones, ester and ether, N-methyl-pyrrolidone, cellosolve, nitrated hydro-carbons, amines, amides

– aromates such as benzene, toluene or xylene.

Simriz is also particularly suitable for the sealing of:

– strong inorganic acids and alkalis such as sulphuric acid, hydrochloric acid, nitric acid and their compounds plus caustic soda and caustic potash or ammonia,

– strong organic acids and bases, e.g. formic acid or ethylene diamine. Simriz seals produce best results also in relation to temperature operating limits. They remain

– cold-flexible down to –12 °C and

–.can be used up to +300 °C without problems.

Reliable solutions for many sectors

Simriz seals are particularly suitable for all sealing tasks with high chemical and/or thermal loads. Simriz seals are ideal for:

– analysis technology,

– usage in plant and domestic appliances,

– aerospace,

– mechanical engineering and systems,

– mineral oil processing,

– medical technology,

– pharmaceutical industry,

– pumps,

– process technology,

– packaging machines.

You can tell us what shape your seal should have. We will deliver it.

Seals and moulded parts made of Simriz are manufactured by us in the standard sizes of the ISC O-ring range, or specially to suit your requirements. We will exactly match ISC O-rings, ISC O-rings in special shapes or moulded parts made of Simriz to your task or requirements.

Solutions even for complex requirements

High pressure, cyclical temperatures, static or dynamic loads, chemical and abrasive attack by the fluid to be sealed form a requirement matrix for the seal; this matrix can be extraordinarily complex. To be able to guarantee safe and reliable sealing, even in these cases, we will work together with you on individual solutions. High temperature and FDA materials on enquiry. Our specialists will gladly meet your challenges.

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