Merkel
Technical Manual

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Hydraulics

General Technical Data and Materials

Hydraulics

Merkel hydraulic components are suitable for a wide range of applications in hydraulics, for both light-duty and heavy-duty applications.
Merkel offers a complete range of standard solutions and also special solutions customised for particular applications. The range includes seals, wipers and guide rings.
The latest production technology guarantees the fastest possible availability. Even in less than 24 hours with Merkel Xpress.

Requirements

Operational reliability under different extreme loads such as:

- High temperature fluctuations
- Irregular duty cycles and maintenance
- High lateral forces and deflections
- Very dirty conditions
- High system pressures and pressure peaks.

Features

- Rod seals with high pressure resistance as primary or secondary seal
- Piston seals with integrated pressure activation grooves for high operational reliability with fast pressure changes
- Wipers with static sealing edge for reliable protection against ingress of dirt
- Guides with patented profiling ensure even distribution of stress
- Sealing rings for static sealing e.g. cylinder heads with end position damping
- Friction-optimised sealing systems with low stick-slip tendency
- Heavy-duty sealing systems with high operational reliability under shock pressures, high lateral forces and extreme temperatures
- Universal sealing systems for support cylinders with good static and dynamic tightness because of additional support edge and sealing edge.

Application areas

Merkel sealing components cover a wide range in modern hydraulics and are in use wherever safety and service requirements as well as costs are important.

Use of Hydraulic Seals

Different requirements and loads in numerous applications have resulted in the development of different seal designs.
Hydraulic seals can be categorised by function and design (→ Fig. 1).
Hydraulic seals are also classified into seals with a symmetrical cross-section and seals with an asymmetrical cross-section.

Asymmetrical seals are designed so the pre-load is distributed over the entire axial width on the supporting mating area to give them a sufficiently fixed seating in the groove. The correct pre-load on the moving side is not derived until after fitting in the housing (→ Fig. 2 and → Fig. 3).

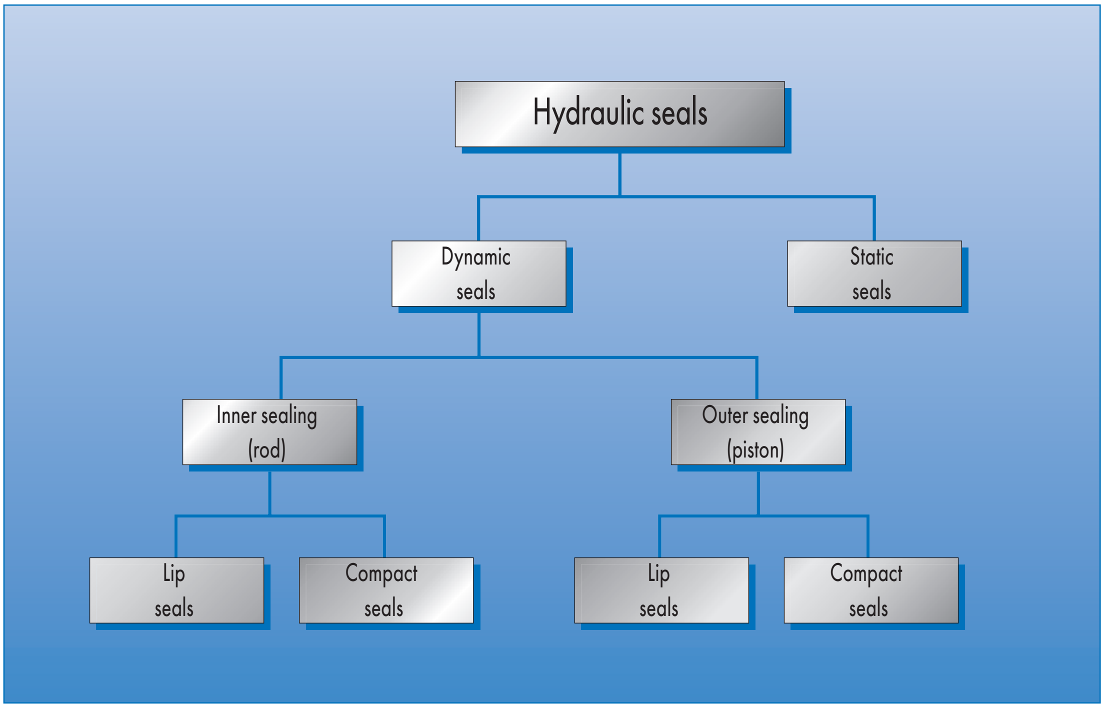


Fig. 1 Categorisation of hydraulic seals

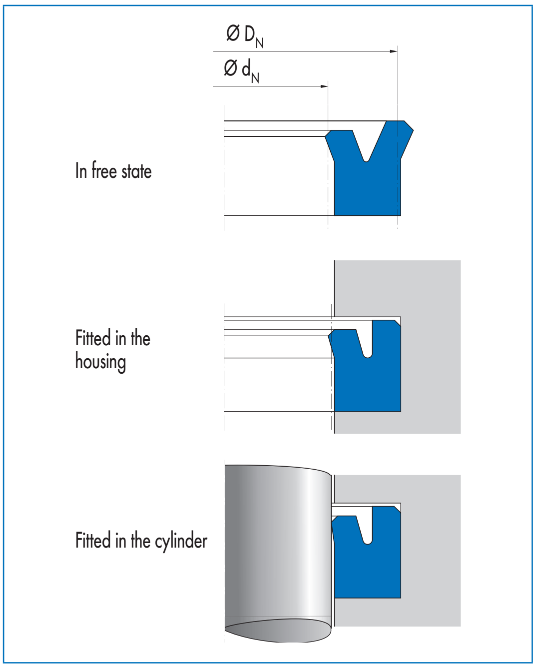


Fig. 2 Rod seal

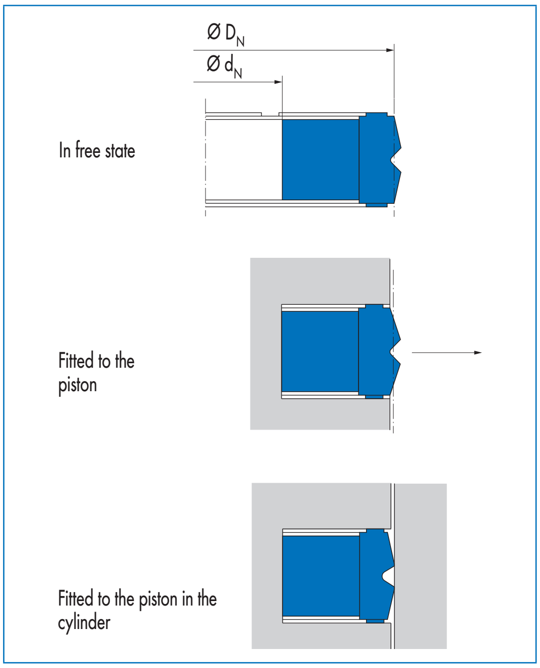


Fig. 3 Piston seal

Hydraulic seals/preselecting seals

In addition to the main requirement for a good sealing effect, the user expects the following from hydraulic seals:

- Functional reliability
- Long service life
- Easy fitting
- Compatible with hydraulic fluid at high and low temperatures
- High resistance to mechanical damage (e.g. gap extrusion)
- Low friction
- Good shape elasticity to ensure correct function, even with eccentricity between rod and housing or piston and cylinder barrel caused by operation as well as the barrel widening as a result of the operating pressure.

The weighting of the requirements for the specific application in combination with the operating conditions (pressure, temperature, sliding speed etc.) are the decisive factors affecting the selection of the seal.

With reference to the operating conditions the usage limits specified there can be exceeded in some cases. In the case of extended duty cycles, operation subject to shocks or other severe operating conditions we recommend not exceeding all values simultaneously. Our technical consultants will be pleased to proved appropriate recommendations.

Sealing Systems

Definition

Sealing components are used to retain the hydraulic medium securely inside a hydraulic system. A defined moistening of the counter surface with lubricating medium is desirable when the required service life is taken into account. A sealing component is referred to in this regard as leaky if the hydraulic medium is visible from the outside in the form of dripping leakage.

Requirements

During operation sealing components are subject to a reciprocating or rotary movement when operating pressure is applied. In addition to other influences, the selection of a sealing component is significantly influenced by the material-dependent resistance against extrusion and the equally material-dependent friction and wear characteristics. The values of the main properties of sealing effect, form stability and friction or wear work against one another and in total cannot be optimally represented by one single sealing component. An approximation of the ideal sealing component is reached with a reasonable combination of single components with appropriate properties into one sealing system.

Arrangement

Sealing systems generally consist of an arrangement of sealing components with a primary seal, a secondary seal, a wiper and guide elements (→ Fig. 4). The properties of the individual components are optimised with reference to the main requirement.
The operating pressure is applied to the primary seal. The main requirement is a high resistance against extrusion simultaneously with acceptable friction values under high pressure. Compact sealing components with a slip ring of PTFE compound are primarily used inside sealing systems. The remaining oil film is comparatively thick and without additional reduction by a secondary sealing component (depending on the operating parameters) may be visible as dripping leakage in front of the wiper edge. The lower gap pressure (<5 MPa) is applied to the secondary seal. The main requirement is therefore effective reduction of the residual oil film left by the primary seal simultaneously with acceptable friction values in the lower pressure range. With sufficient media resistance U-rings of polyurethane or compact sealing components with a slip ring of polyurethane are generally used in this case. The sealing effect is better with such sealing components compared to PTFE sealing components.

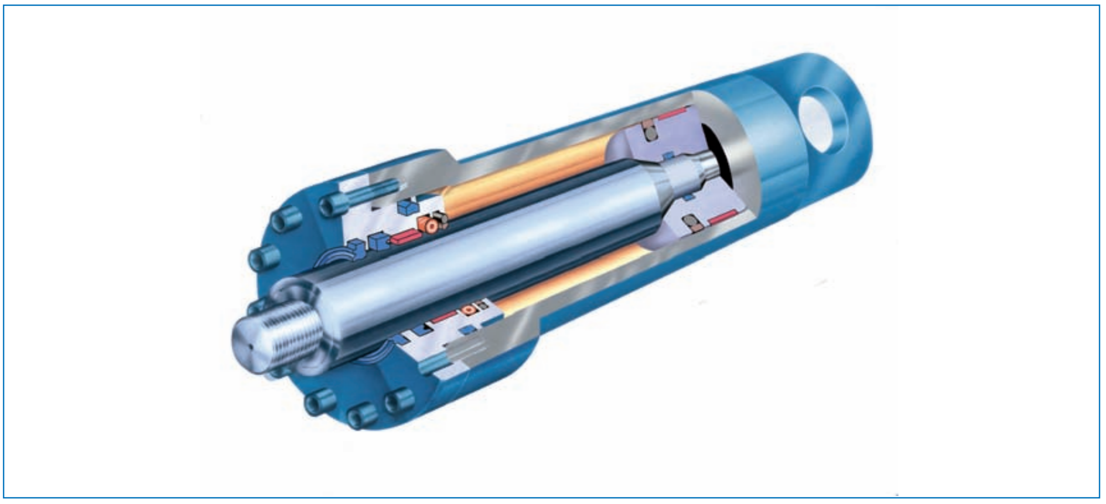


Fig. 4 Components in a sealing system

Standard sealing systems for rods 1

Typical operating conditions
Pressure: <40 MPa;
Running speed: <0,8 m/s
Temperature: −30 ... +100 °C
Media: hydraulic oil HL HLP
Leckage behaviour: +++
Operating reliability: ++++
Friction reliability: +++

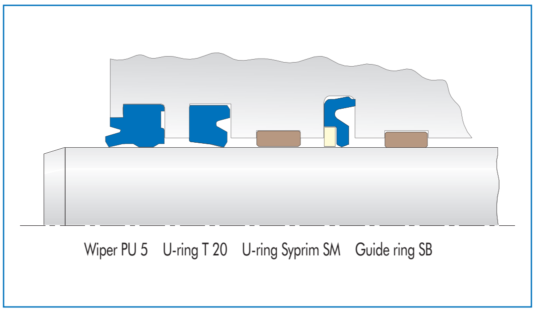


Fig. 5 Standard sealing systems for rods 1

Standard sealing systems for rods 2

Typical operating conditions
Pressure: <40 MPa;
Running speed: <1,5 m/s
Temperature: −30 ... +100 °C
Media: hydraulic oil HL, HLP
Leckage behaviour: +++
Operating reliability: ++++
Friction reliability: +++

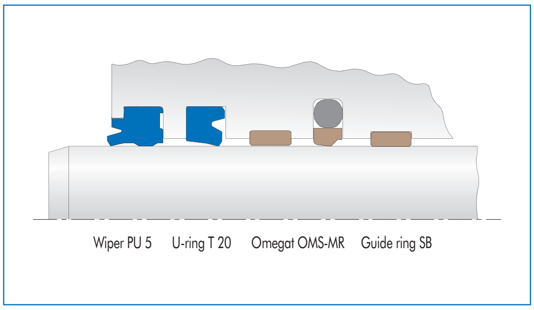


Fig. 6 Standard sealing systems for rods 2

++ good
+++ very good
++++ outstanding

Standard sealing systems for rods 3

Typical operating conditions
Pressure: <40 MPa;
Running speed: <1,5 m/s
Temperature: −30 ... +100 °C
Media: hydraulic oil HL, HLP
Leckage behaviour: ++++
Operating reliability: +++
Friction reliability: +++

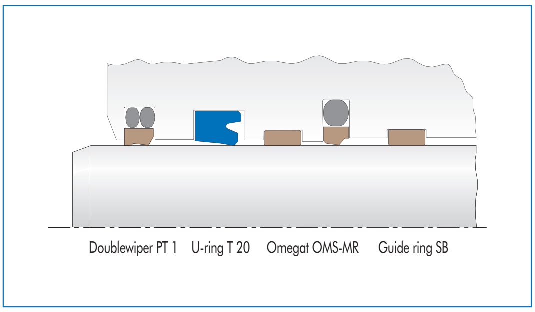


Fig. 7 Standard sealing systems for rods 3

Standard sealing systems for rods 4

If a high chemical resistance is required.
Typical operating conditions
Pressure: <40 MPa;
Running speed: <2,0 m/s
Temperature: −30 ... +100 °C
Media: hydraulic oil HL, HLP
Leckage behaviour: +++
Operating reliability: ++
Friction reliability: +++

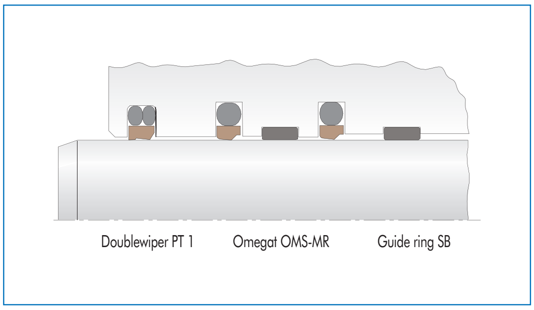


Fig. 8 Standard sealing systems for rods 4

++ good
+++ very good
++++ outstanding

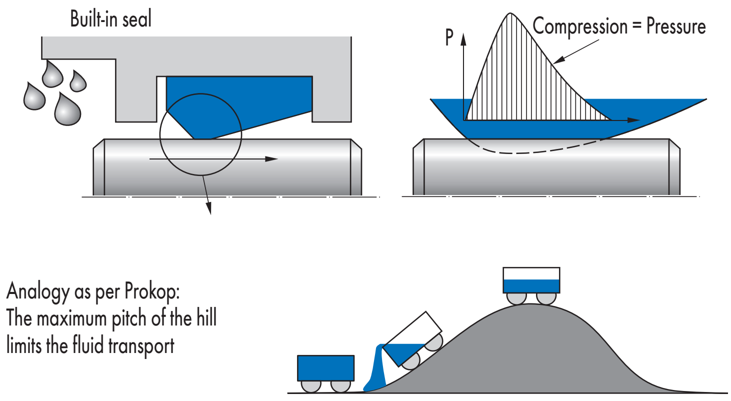


Fig. 9 Qualitative compression curve, single-acting rod seal

Depending on the requirements, wipers have different designs, such as single wiper or double wiper with extra sealing edge and are made of different materials. The outward aligned wiping edge keeps dirt from the environment outside the hydraulic system. A suitable design of the wiping edge (radius) ensures that the required lubricating film can be completely transported on the return stroke. The additional sealing edge increases the operating reliability of the sealing system when required. The use of guide elements enables a low-friction and low-wear relative movement between the moving components of the hydraulic cylinder. The transverse loads occurring during operation are absorbed in a defined manner and prevent unwanted metal contact between the piston rod or the piston body and the surrounding housing components.

Function

To reduce friction and wear solid bodies that move relative to one another must be separated by a lubricating film. The oil film left beneath the seal must be completely transported back into the hydraulic system at every cycle. Inside a sealing system all individual seals and the wiper must meet these conditions.
The formation of the hydrodynamic lubricating film is influenced by the design of the sealing edge (pressure movement), the operating pressure and the magnitude and direction (extending or retracting) of the relative movement as well as by the structure of the counter surface (wettability) and the properties of the hydraulic medium (viscosity).

The pressure curve beneath the sealing edge is in general optimised in that a high wiping effect (steep pressure rise) is set at the pressure space and a good return capacity (flat pressure rise) is set from the return side (→ Fig. 9). Independently of the geometry of the sealing edge at low pressure, high stroke speed and long stroke a comparatively greater oil volume is released beneath the sealing edge than at high pressure, lower stroke speed and short stroke. In operation the primary seal releases a thin oil film into the gap area, which is reduced even more by the secondary seal. The excess oil is collected in the space between the primary seal and the secondary seal and returned to the oil compartment during retraction. A thin oil film coating the rod escapes outside under the wiper. Normally no medium is accumulated in the space between the secondary seal and the wiper in this process. The moistening is transported back into the system while the dirt remains outside. The sealing effect of a component is described by the ratio between wiping effect and return capacity. This value is variable depending on the operating conditions and is not a constant quantity.

Guide Elements

Tasks of the guide element

The use of guide elements enables a low-friction and low-wear relative movement between the movable components of the hydraulic cylinder. The transverse loads occurring in operation are accepted in a defined manner and unwanted metal contact between the piston rod or the piston body and the surrounding housing components is prevented.

Contact conditions

As a result of the guide play and the elastic deformation of the components under load (deflection of the guide element; bending of the shaft), an angular deviation develops between the piston rod or the piston body and the counter surface (→ Fig. 10). Calculation of the transverse forces and the probability of collision on the basis of idealised contact conditions with parallel axes results in incorrect results. Excessive tension peaks in the edge area of the guide element (edge break) are not taken into consideration here nor is the distance between the metal components (metal contact), which changes with the incorrect position, and the changed force initialisation. Depending on the type of guide, the result of an idealised observation in this regard must be evaluated differently.

Guide elements

Particularly when a high transverse load is expected many users install traditional flat parallel metal plain bearings. Flat parallel metal guides are subject to marked tension peaks as a result of the phase displacement position (→ Fig. 11).
The permissible value of the surface pressure is reached at a comparatively low transverse load and simultaneous minimum deflection. In the pressure zone there is insufficient lubrication. At low sliding speeds stick-slip may be experienced simultaneously with a high load on the counter surface (running-in). If the transverse load in the limit range is suddenly applied, a breakage of the edge in the region of the guide is likely.

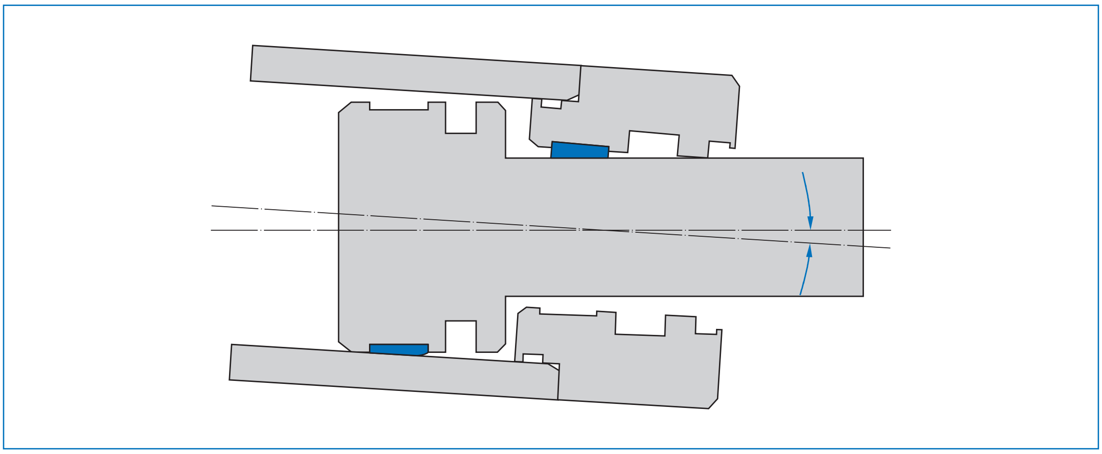


Fig. 10 Phase displacement position

The tension increase in the area of the supporting edge is reduced by the use of flat parallel guide sleeves of composite fabric materials (fabric-base laminate) (→ Fig. 12). The elastic support of the fabric-base laminate guide increases the support length of the guide ring and with it the maximum transverse load compared to the metal guide. The collision test becomes very important as a result of the elastic support of the guide sleeve. Guide sleeves are comparatively more economical.

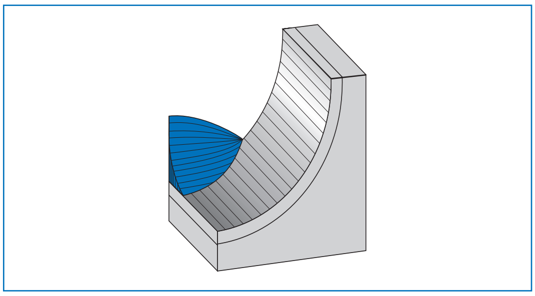


Fig. 11 Metal guide ring

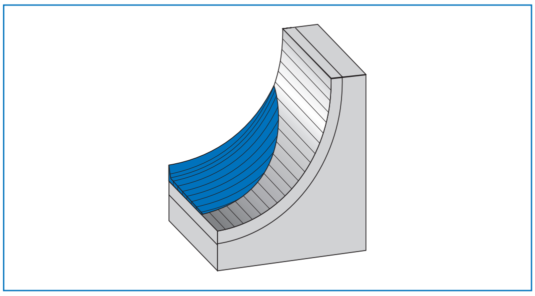


Fig. 12 Guide ring of fabric-base laminate

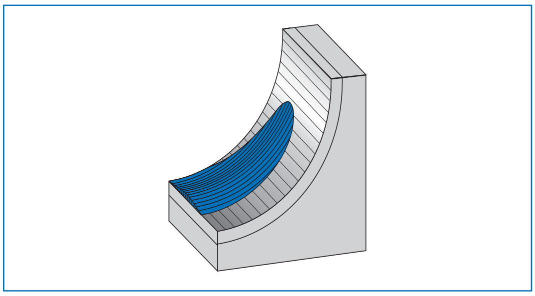


Fig. 13 Guide ring with convex profiling

The patented Guivex geometry for fabric-base laminate guide rings has been developed for reduction of the tension increase in the edge region. The zone with the highest compression, even when the phase displacement position is taken into account, is defined by the profiling approximately in the centre of the bush (→ Fig. 13). The compression is reduced on both sides and makes the ingress of the lubricating medium easier. The elastic support of the fabric-base laminate guide sleeve is simultaneously optimally used over the entire available width of the guide sleeve. Insufficient lubrication and edge breakage are virtually impossible.

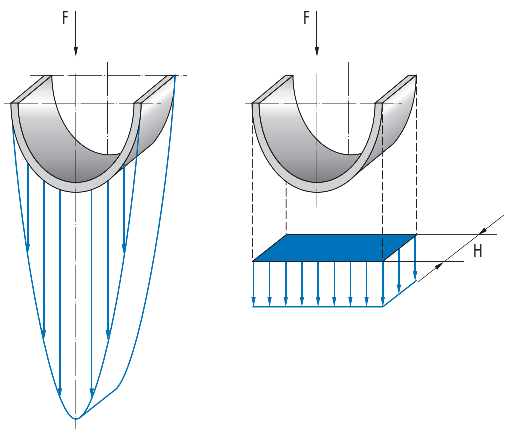
Guide belts of PTFE compound have a subordinate role as guide elements for taking up transverse loads in hydraulics. The value for the permissible surface pressure is significantly lower in comparison and with a simultaneous significant temperature dependency. The advantages of guide elements of this type become clear when comparing the costs of large orders.

Guide width

In addition to the geometric consideration (external force application, distance between mountings, angular deviation, guide play, ...) must be considered when calculating the transverse load applied in the area of the guide element and also the elastic deformation of all components involved (deflection of the guide element, bending of the piston rod, stretching of the cylinder...). A detailed scrutiny is often neglected because it can only be done with complex means such as an FE calculation.

A realistic estimate of the transverse load must pay particular attention to the limits of the mechanical loading of the metal components. In the case if long slender cylinders the permissible transverse load is limited by the bending strength of the piston rod and other factors. The classical assumption that about 10% of the hydraulic force is applied as a transverse load would in reality result in bending the piston rod in many cases.

If the magnitude of the normal force applied in the area of the guide element is defined, the minimum required guide width (H) can be specified (→ Fig. 14).



F = P x A; A = d x H; H = F / (d x P)

H = guide strip width [mm]

F = transverse load [N]

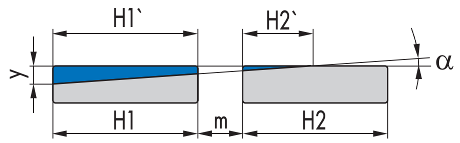
A = projected area [mm^2]

P = permissible surface pressure [N/mm^2]

d = nominal diameter of rod or piston [mm]

Fig. 14 Guide width

The permissible specific surface pressure in the specified form is a manageable calculation value with reference to the projected area and does not represent the material characteristics. In the definition of the permissible specific surface pressure the non-linear pressure curve over the contact range, the tension increase in the edge area of the guide rings and a phase displacement position are all considered. When considering the specified values of the permissible specific surface pressure (P) of the guide sleeve it must be noted in comparison that some manufacturers include extra safety factors in some cases. However, that does not bring any increase in safety into the result of the calculation, because this factor is returned to the associated equation.



H = H1 + H2   H` = H1`+ H2`

Fig. 15 Usable guide width

Metallic contacts between housing components and the counter surface are unwanted. The maximum permissible deflection (y) of the guide ring is limited by the smallest metal gap inside the sealing system, in general the metal step behind the primary seal.

Depending on the phase displacement position (α) of the piston rod and the possible deflection (y) with reference to all influencing quantities, the usable guide width is reduced compared to the geometrically total width of the guide belts (H). Only the guide width actually in contact (H') contributes to holding the load.

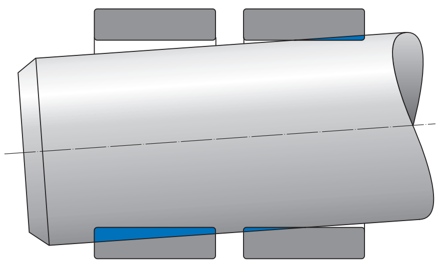


Fig. 16 Bilateral contact

In the case of large phase displacement positions, such as occur in relation to the compliance with long-slender cylinders, the guide ring may contact the counter surface on both sides of the centre axis. Here low tolerance levels favour contact on both sides. The additional contact generates a usable counteracting force but also stick-slip effects (jamming) as a result of distortion. In this case the collision check has particular significance. To select the optimum width of the guide the desired service life must also be considered. Limit values are taken into account in the calculation of the minimum required guide width and also with reference to the permissible surface pressure of the guide elements. Guide elements that are primarily traversed in the range of the maximum possible load have a service life in the lower part of the range. Whether reducing the load by selecting a wider guide is useful in some cases depends on the previously considered safety factors as well as the total loading.

Specific compression per unit area

The permissible surface pressure (dynamic) is specified at a value in the range of 17 to 25 N/mm² for the copper-tin and copper-tin-lead bronze and high-load resistant copper-zinc alloys used in the area of the metal plain bearings. High-tensile alloys with values over 25 N/mm² are only used for the edge load of non-critical applications in connection with high-tensile counter surfaces.

Guide rings of fabric-laminated materials (fabric-base laminate) have improved function compared to straight metal guides. As a result of the low tension increase in the edge area and the elastic properties of these materials a higher surface pressure can be accepted. The value of the surface pressure and the characteristics under higher operating temperatures is greatly influenced by the composition of the fabric-based laminated material. Polyester and other plastics and also natural materials such as cotton are used in the area of fine fabrics. Polyester, vinyl ester and phenolic resin and also a whole range of plastics with different properties are available for the resin matrix. While some of these compounds show significant thermoplastic characteristics, the factor of the operating temperature on the permissible surface pressure is low for others.

The values for the permissible specific surface pressure depending on the operating temperature can be found in the tables in the description of the article.
Under load guide elements show a deformation in the elastic range (reversible). The magnitude of the de- formation or deflection (y) is determined directly by the material characteristics, the thickness of the guide sleeve and the magnitude of the load. Assuming similar material characteristics, thicker guide sleeves have softer springing under identical loading. Pressure can only be applied to the guide element at the magnitude of the permissible surface pressure if the associated deflection of the guide element (→ Fig. 17) can be achieved without metal contact.

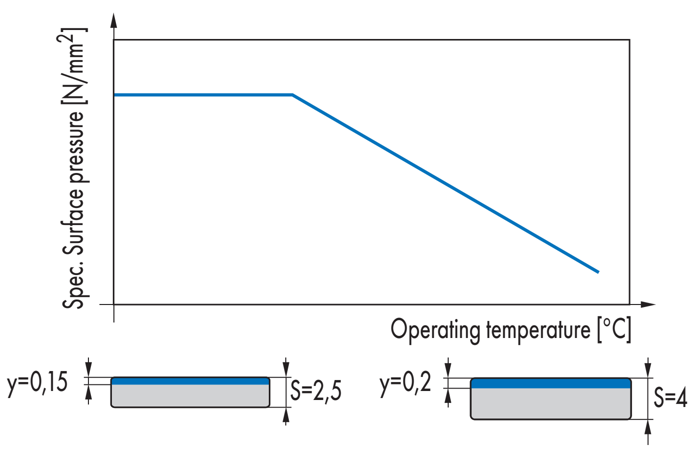


Fig. 17 Deflection at maximum surface pressure

In a sealing system the collision check is generally conducted with reference to the metal gap on the side of the primary seal away from the pressure. The minimum permissible magnitude of the sealing gap is determined by the deflection of the guide element. The maximum permissible magnitude of the sealing gap is determined by the form stability of the sealing component. General specifications for the maximum admissible gap width depending on the type of seal, the selected seal profile and the operating pressure can be found in the tables in the description of the article. There is a direct geometrical dependency between the minimum required metal gap (x3) and the maximum permissible extrusion gap (x2) (→ Fig. 18). The gap dimensions can therefore not be calculated independently of each other. As a result guide elements cannot be subjected to the maximum permissible surface pressure at every pressure stage and with all types of seals, because the minimum required metal gap is not sufficient for complete deflection.

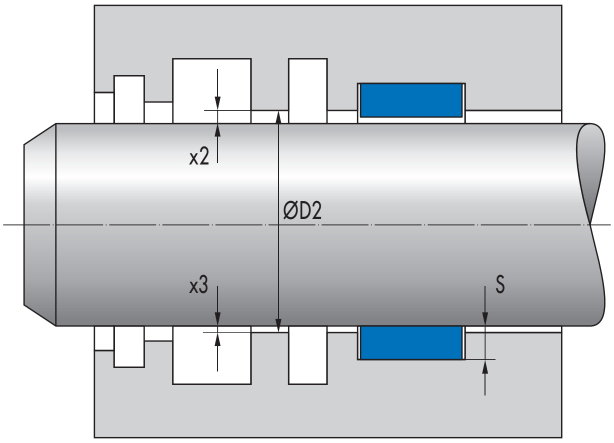


Fig. 18 Sealing gap

Sealing Mechanism and Influencing Quantities

Tightness, friction, wear

General

Hydraulic drives are used in many machines and systems because of their varied options for use. Major areas of application are:

- Machines and systems engineering
- Construction machinery
- Agricultural machinery and
- Mining machinery.

The most important component for generating the linear drive movement is the hydraulic cylinder. The function and reliability of hydraulically driven machines depends greatly on the seals installed in the hydraulic cylinder.

Static tightness

At rest all elastic hydraulic seals are tight because of the excessive initial compression p_v. The sealing pressure p is superimposed on the initial compression p_v. The compression in the sealing area p_d is therefore always greater than the sealing pressure (→ Fig. 19).

[1] $p_d = p_v + p$

Formation of the lubrication film

Under movement the sliding surface coated with fluid is pulled under the contact area of the seal. The seal acts as a wiper, but is not able to wipe away the fluid completely.

The sliding movement causes a delayed flow and the seal is lifted from the sliding surface by the hydrodynamic pressure build-up. A thin film of fluid remains on the sliding surface behind the seal.

The thickness h of the following fluid film depends on the maximum pitch of the compression curve $(^{dp}/_{dx})_{max}$ on the entry side of the fluid in the sealing gap, the dynamic viscosity η of the fluid and the relative speed v between the seal and the sliding surface.

[2] $h \sim \sqrt{\frac{\eta \cdot v}{\left(\frac{dp}{dx}\right)_{max}}}$

If the fluid film is completely returned to the pressure space on the return stroke, this is referred to as dynamic tightness.

Friction

The friction of hydraulic seals is primarily influenced by the thickness of the lubricating film between the seal and sliding surface.

Three friction states may be encountered.

- Static friction
  (dry solid-body friction)
- Dry-fluid friction
  (solid-body friction and fluid friction)
- Fluid friction
  (no solid-body contact).

The three areas can be shown in the Stribeck graph (→ Fig. 20).

The high static friction must be overcome first during approach. With increasing speed more fluid is pulled between the seal and the sliding surface and the direct contact area decreases. Then the static friction initially decreases markedly.

The range of fluid friction is reached as the speed continues to increase. The static friction increases again as the speed increases. The static friction is caused exclusively by the shear stresses τ in the fluid in the range of hydrodynamic lubrication.

[3] $\tau = \eta \cdot \frac{dv}{dh}$

Wear

The wear on hydraulic seals depends on the thickness of the lubricating film or the friction status. Most seals operate in the region of dry-fluid friction and are subject to continuous wear.

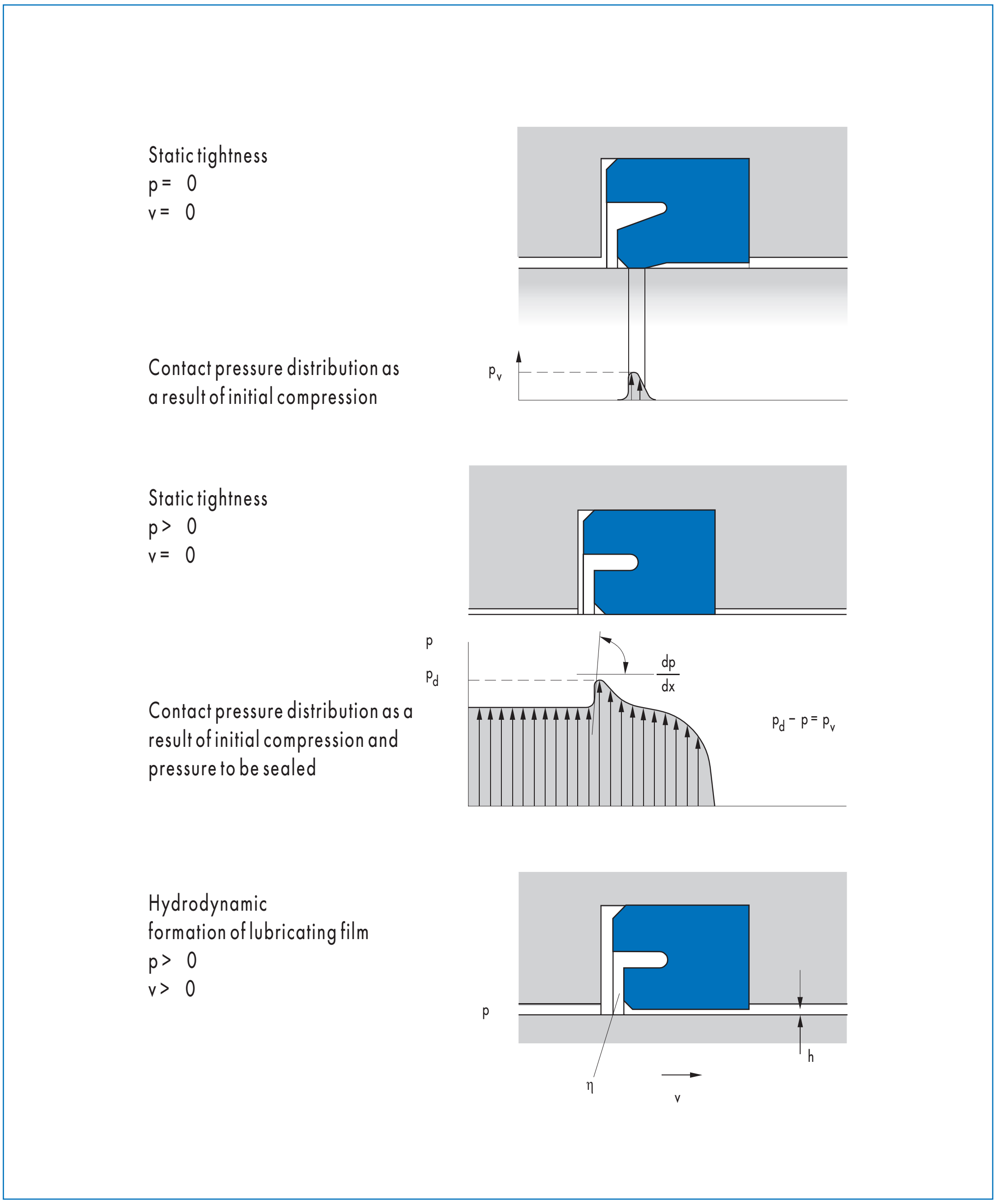


Fig. 19 Compression curve and hydrodynamic lubrication film formation

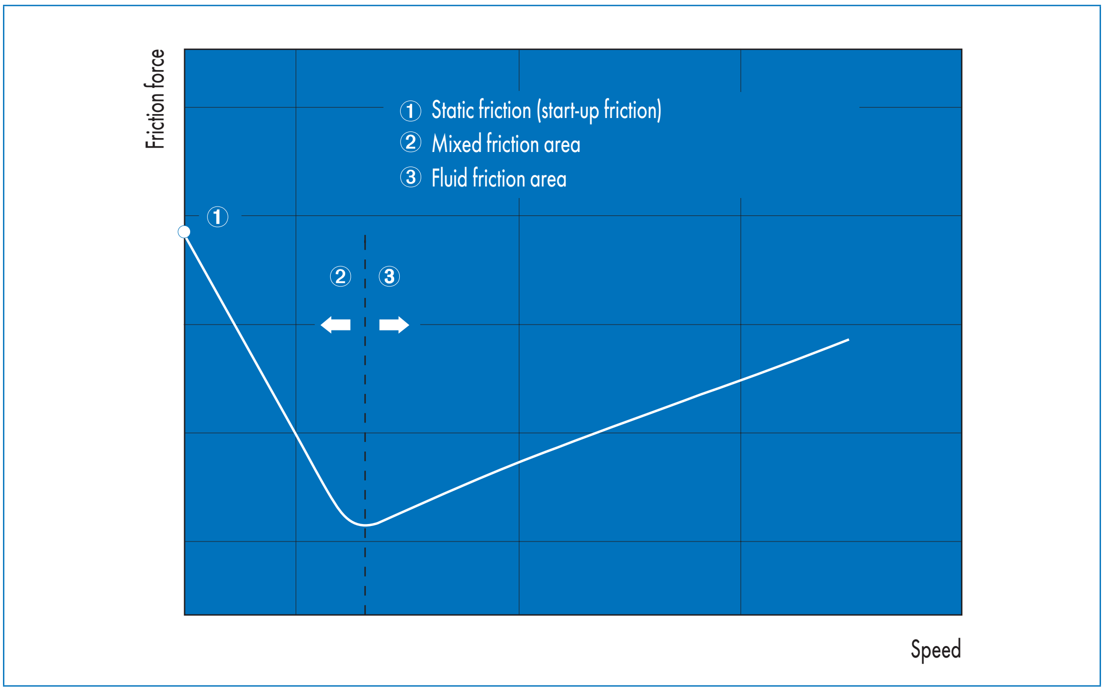


Fig. 20 Stribeck graph

Apart from the operating conditions of pressure, temperature and speed the wear depends primarily on the material properties, the surfaces of the sliding components and the lubricating properties of the hydraulic fluid. Air in the hydraulic fluid and contamination by foreign bodies also influence the wear.

Physical and chemical influences

Operating pressure

The system pressure with the size of the cylinder determines its lifting force. It is the first factor to be considered when selecting the seal and the hardness of the seal material. According to the CETOP recommendation standard cylinders are designed for the two pressure stages of 16 MPa (160 bar) and 25 MPa (250 bar). The majority of all hydraulic cylinders operates with these pressures. Higher system pressures up to 40 MPa (400 bar) are now the rule in mining and heavy-duty mobile hydraulics. with the availability of existing seal types.

During operation of the hydraulic cylinders the sealing components are under continuously changing pressure. In addition, short-term pressure peaks caused by external influences are frequently encountered, particularly in mobile hydraulics. These shock loads can reach several times the magnitude of the system pressure and place high demands on the sealing components. These loads must be taken into account when selecting the seal.

Drag pressure

When the fitting tolerances are restricted in the space between the guide and the seal the guide generates hydrodynamic pressure. The cause of this is the hydrodynamic drag flow, which depends on the dynamic viscosity of the medium, the gap width h_s the speed v and the length l of the guide (→ Fig. 21).

The pressure increase in the guide is calculated as follows

$$[4] \quad \Delta p = p_1 - p = \frac{6 \cdot \eta \cdot v \cdot l}{h_s^2}$$

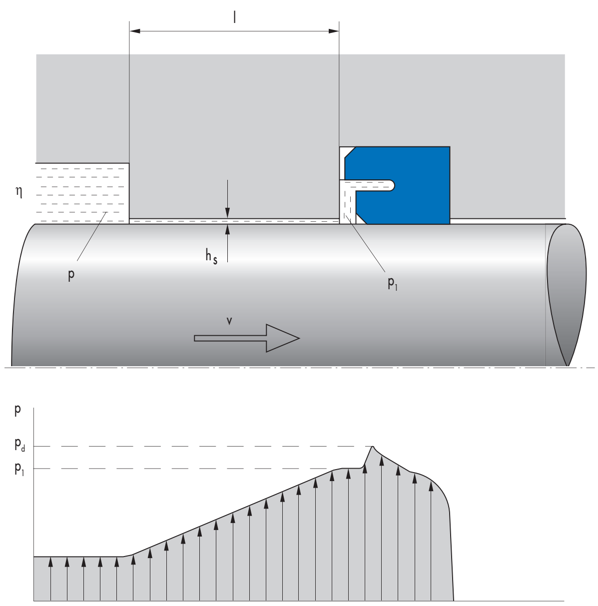


Fig. 21 Hydrodynamic drag pressure

To prevent hydrodynamic pressure build-up, return ducts are required to compensate pressure in metal guides. Otherwise the seal will be destroyed early in its life by the high pressure (→ Fig. 22). The return ducts are preferably designed as a spiral groove with a cross-section greater than the largest gap ring area (→ Fig. 23).
Axial pressure compensation holes should be avoided, because the spray effect of the fluid contributes to the destruction of the seal.

When using guide belts and guide rings of plastic return ducts are already available in the form of the joint gap (→ Fig. 23).

Speed

The speed between the seal and the moving counter surface for rubber and polyurethane materials is normally 0,1 m/s to 0,5 m/s. However, the deciding factor is the application. For example, 0,8 m/s can be approved for the Merkel U-Ring T 20 as secondary seal and the same for the Merkel Compact Seal Simko 300 at a pressure of 250 bar. Up to 5 m/s is permissible for PTFE materials.

Fig. 22 U-ring destroyed by hydrodynamic pressure build-up

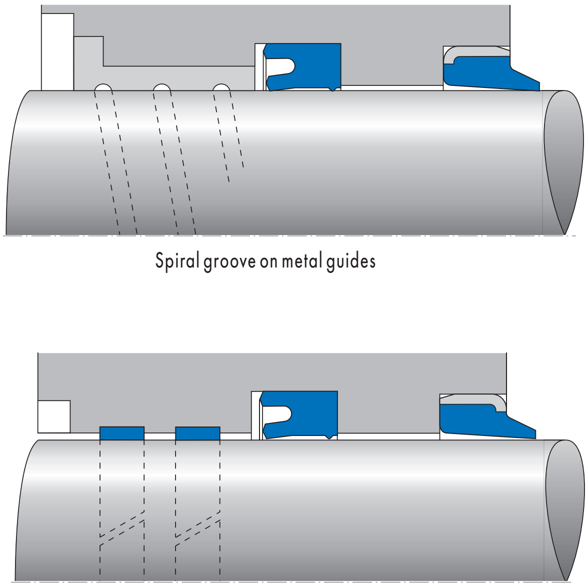


Fig. 23 Design measures for preventing drag pressure

The formation of a lubricant film and friction depend on the speed to a large degree. The friction force decreases greatly in the range of 0,05 m/s and lower. Particularly at high temperatures stick slip may occur. This juddering motion is a continuous repetition of stick and slip between seal and counter surface.
Materials with lower coefficients of friction are used to prevent this (e.g. PTFE).

Temperature

The temperature of the hydraulic medium and the ambient temperature influence the material configuration. The optimum temperature for the function of the seals and the stability of the oil is +40 °C to +50 °C. The temperature at the sealing lip is significantly higher than the oil temperature because of the friction.
The usual temperature during operation of the hydraulic cylinder is +80 °C, in extreme cases it may be up to 110 °C.

With increasing temperature the seal material becomes more elastic and loses form stability. For this reason we recommend running-in seals at lower temperatures (80 °C) if the temperature limit of 110 °C will be common for our polyurethane materials. If temperatures over 110 °C are expected, it will be necessary to use special materials (e.g. FKM, PTFE/FKM). At lower temperatures the hardness of the seal materials will be increased. The seal will lose elasticity. However, the simultaneous increase in oil viscosity will leave the functional reliability of the seals virtually uninfluenced. In the temperature range down to −40 °C cold-resistant materials based on NBR have proven reliable.
As previously noted, the temperature has a great influence on the physical properties of elastic rubber materials.
The "torsion vibration test" graph (→ Fig. 24) shows how the dynamic thrust module G depends on the temperature (thrust module measured in the torsion vibration test according to DIN 53 520). The elastic

rubber range with a virtually constant module can be recognised from right to left, then a steep rise to the transition range and finally the glass state region, in which the rubber is hard and brittle, with a virtually constant module.
When the temperature rises again the cold brittleness disappears again. This means that the freezing process is reversible. The transition from elastic rubber to the glass state region is particularly important is particularly important because in many cases it represents the limit of operation at low temperatures. This transition is not sudden but extends over a specific region, as shown in the "torsion vibration test" graph.

The region of transition from the elastic rubber region to the glass state is characterised by the glass transition temperature $T_{ü}$ (temperature of the maximum of the logarithmic damping decrement Λ). However, this value can only represent a general dimension for the low-temperature operation limit of the material, because in practical application of an elastomer component it depends completely on the type of load involved.

The same material will reach its load limit at a higher temperature under shock load than, for example, with slow elongation. The torsion vibration test can be used to distinguish among different materials, but in practice the temperature limit must be tested in operation with the various components.

Example:
Friction resulting from movements generates heat in the case of contact seals. At temperatures at which there is a danger of hardening by freezing the frictional heat may be sufficient to maintain the elasticity of the seal or to place it in a functional condition sufficiently quickly after the movement has started. The behaviour under cold conditions is therefore only ever worth testing in the form of a material comparison in connection with experience of the technical application.

Hydraulic media

In hydraulics various hydraulic fluids are used to transmit the energy from the pump to the cylinder. The most important and most frequently used Die hydraulic fluid is mineral oil.

The lubricating capacity of the oil is decisive for the wear of the moving parts. The lubricating capacity is influenced by the viscosity and additives that improve the lubrication.

Hydraulic oils are classified in viscosity classes in accordance with DIN ISO 51519 to identify the viscosity. The criterion for the categorisation is the nominal viscosity at the reference temperature of +40 °C.

The viscosity of hydraulic oils depends on the pressure and the temperature. The viscosity increases significantly from a pressure of about 20 MPa (200 bar). The viscosity doubles at approximately 40 MPa (400 bar) depending on the nominal viscosity and the temperature. Under an increasing temperature the viscosity of oils decreases very rapidly. The characteristic value for this viscosity-temperature behaviour is the viscosity index (VI). The higher the viscosity index of a hydraulic oil the less the viscosity depends on the temperature (→ Fig. 25).

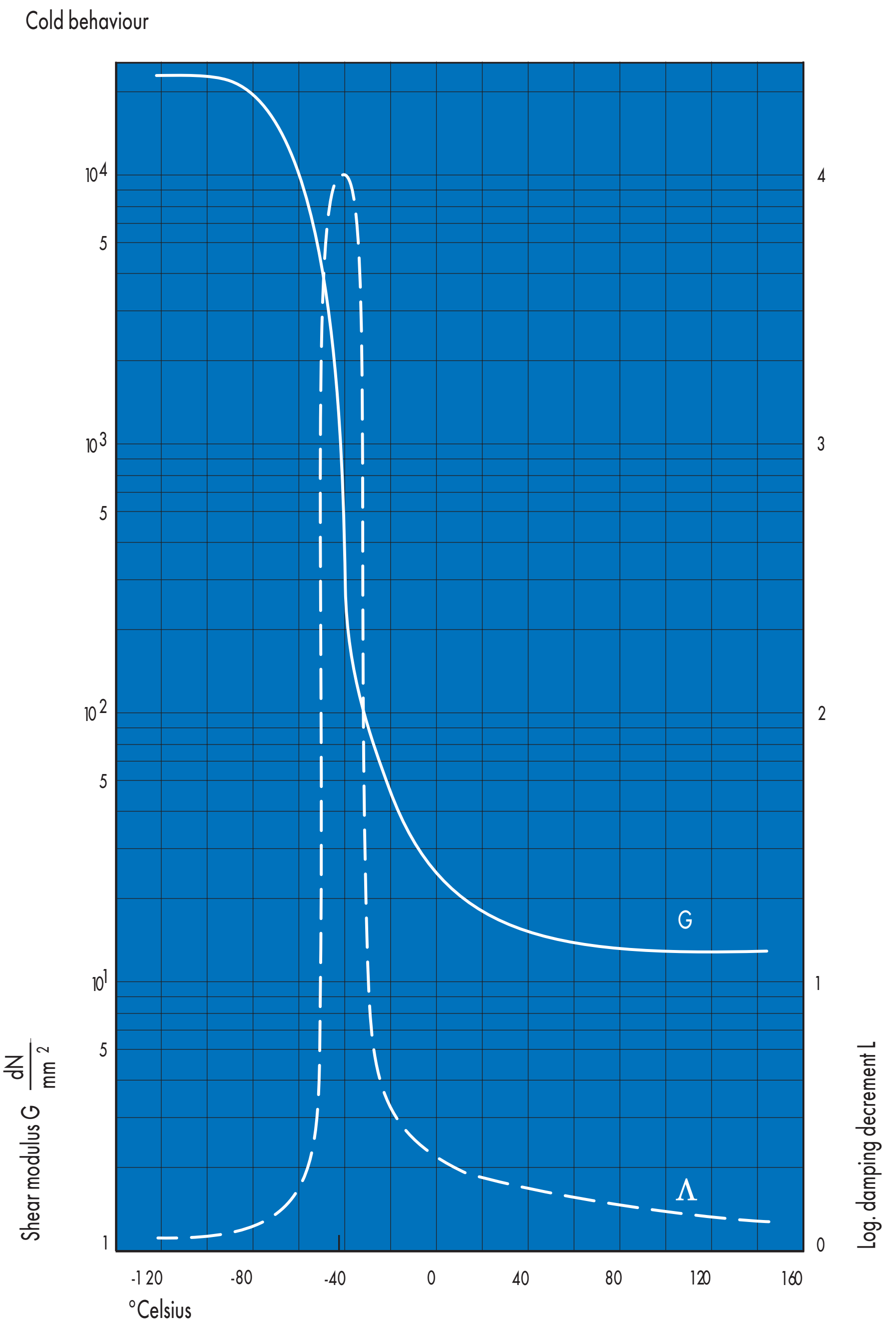


Fig. 24 Graph: torsion vibration test in accordance with DIN 53445;
dynamic shear modulus G and logarithmic decrement Λ of a Merkel material based on CR

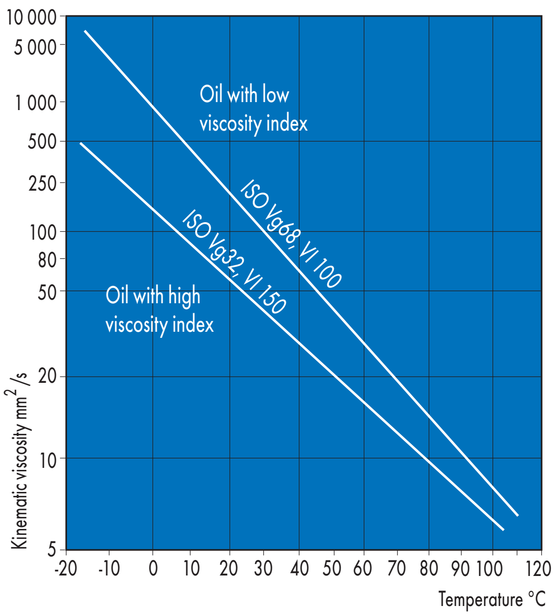


Fig. 25 Viscosity-temperature behaviour of various hydraulic oils

Hydraulic oils are classified into different groups:

- Hydraulic fluids based on mineral oils (→ Tbl. 1)
- Biologically degradable hydraulic fluids (→ Tbl. 2).

Apart from the mineral oils, in recent times so-called environmentally compatible hydraulic fluids have come into use. In this regard a distinction is made between hydraulic fluids based on vegetable oils (HETG), polyglycol fluids (HEPG) and synthetic ester fluids (HEES). The standard materials are not guaranteed to be compatible with these hydraulic fluids in all applications. Special materials such as the polyurethane material Simritan 94 AU 955 have been specially developed for use in these fluids. In some cases engine oil /HD) is used in travelling hydraulic oil systems, with the advantage that only one type of oil is required for the entire vehicle.

For specific purposes, such as in aircraft and in mining, fluids based on mineral oils cannot be used because of the danger of fire. Fire-retardant fluids are used for these applications (→ Tbl. 3).

VDMA Directive 24317 lists the properties and identification of these fluids.
DIN 24320 specifies the properties of HFA fluids. Of the fire-retardant fluids it is primarily the HFA fluids that have become established in mining. HFB and HFD fluids are only used in exceptional cases.

Contamination in oil circulation

Hydraulic oils can be contaminated by foreign bodies such as sand, metal abrasion, metal shavings and oxidation products (ageing of the oil by the action of high temperatures and oxygen). If the oil is insufficiently filtered the seal the other components in the hydraulic system may not operate correctly. Metal shavings and abrasive grains of sand will cause failure of the seal as soon as these particles enter the area beneath the sealing edge.

Categorisation in accordance with DIN	Categorisation of hydraulic oils in accordance with the ISO proposal	Identification/ properties	Application
H	HH	Mineral oil without active additives	is virtually never used today
H-L	HL	corrosion-prevention additives and additives for increasing ageing resistance	for lightly loaded systems
H-LP	HM	like H-L, as well as wear-reducing additives and additives for increasing loading	for heavily loaded systems
H-LPD	–	like H-LP, as well as detergent and dispersive additives	for heavily loaded systems when there is danger of water ingress during oil filling
H-V	HV	like H-LP, as well as improved viscosity-temperature behaviour	systems that are used at low or very variable temperatures

Tbl. 1 Hydraulic fluids based in mineral oil

Classification in accordance with DIN proposal	Base fluid
HEPG	Polyglycol
HETG	Vegetable oil
HEEG	Fully synthetic ester

Tbl. 2 Biologically degradable hydraulic fluids

Group	Composition/water content	Application temperature range	Kinematic viscosity at +40 °C	Application
Hydraulic fluids containing water				
HFA E	Emulsions of mineral oil in water, water content >80% (generally 95%)	−+5 ... +60 °C	0,5 ... 2 mm²/s	mining, hydraulic presses, hydrostatic drives with low operating pressures
HFA S	Synthetic oil in aqueous solution, water content >80% (generally 95%)			
HFB	Emulsions of water in mineral oil, water content >40%	−+5 ... +60 °C	non-Newtonian fluid	not in use in Germany
HFC	aqueous polymer solutions, water content >35%	−30 ... +60 °C	20 ... 70 mm²/s	Hydrostatic drives with low operating pressures
Non-aqueous hydraulic fluids				
HFD R	based on phosphoric acid ester	−30 ... +150 °C	10 ... 50 mm²/s	not approved for use in German coal mines
HFD S	Based on chlorinated hydrocarbons hydrodynamic couplings up to 150 °C			
HFD T	Mixtures of HFD R and HFD S			
HFD U	Synthetic fluids of other composition approved			

Tbl. 3 Fire-retardant fluids

Because of the large and somewhat confusing selection of media with different and varying additives, the above usage limits can only be considered recommended values. We recommend testing for individual cases

Air in oil

There are dissolved air molecules in all classes of hydraulic fluids. This air dissolved in the oil does not affect the function of the seal. Hydraulic oil can form a molecular bond to more as the pressure increases. Then when the pressure is reduced the dissolved air comes out of solution. Air bubbles form, which frequently collect in the groove spaces not filled by the seals.

If the pressure is suddenly increased, the air-oil mixture is heated so strongly that compression ignition may occur. This phenomenon, referred to as diesel effect, may destroy the seal if it occurs frequently. The seal may also be damaged by undissolved air during the movement.

The air bubbles dragged in with the oil between the seal and the counter surface expand more the closer they come to the non-pressurised side of the seal. This air-bubble erosion causes longitudinal scores in the surface of the seal. This results in further destruction of the seal by washing out and removal of surface areas by the flowing fluid (flow erosion).

The damage caused by air in the oil can be greatly reduced if the complete hydraulic system is carefully bled before operation.

Geometrical influences

Stroke

The stroke of the working cylinder is mostly between 0,1 m and 1,0 m. When the strokes are very short, only a few centimetres, and the load frequency is high, the required lubricating film will not be formed and seals of rubber materials may be subject to increased wear.

In such cases sealing components of PTFE are preferably used. If the strokes are long, in the range of several metres, there is a danger that the sealing component will be excessively heated. Distortions of the shape of the rod, different surface roughness and eccentricity occur more frequently with long strokes.

Housings

The following criteria are used to specify the housings and thus the dimensions of the seal:

- Use and load type of cylinder
- Standard seal or special seal
- Standardised housings.

The greater the load on the seal the stronger the profile. With equivalent seal diameter seals of smaller radial thickness are more likely to be damaged and to wear. The same percentage radial oversize the absolute oversize (in millimetres) of a seal with a smaller radial thickness is less than a seal with larger radial thickness.
A seal with a stronger profile is better able to bridge large eccentricities resulting from the guide play.

The dimensions listed in the catalogue are available immediately from stocks or are articles that can be delivered at short notice, which have been used successfully for years for sealing pistons and piston rods. The dimensions are marked accordingly when they match the dimensions specified by the standard.

The housings for rod and piston seals are specified in DIN ISO 5597.
DIN ISO 6547 contains the housings for piston seals with integrated guide elements.
DIN ISO 6195 governs the housing for wipers.
ISO Standard 7425 specifies compact seals, consisting of one slip ring of PTFE and an elastic compression ring.

Sealing Gap

Definition

The sealing gap is defined as the gap bordered by the counter surface and the housing on the pressurised side of the seal. Because of the different general conditions the primary and secondary seals of a sealing system considered separately with reference to the sealing gap.

$x2 = (D2_{max} – d_{min}) / 2 + xf_{max} / 2$

$x3 = (D2 – [DF_{max} – (2 * S_{min})]) / 2$

$xf_{max} = [DF_{max} – (2 * S_{min})] – d_{min}$

$D2_{max} = d_{min} + 2 \times 2 - xf_{max}$

d = shaft [mm]

DF = groove base of guide [mm]

D2 = non-pressurised side [mm]

S = thickness guide sleeves [mm]

x2 = maximum sealing gap [mm]

x3 = minimum sealing gap [mm]

xf = guide play [mm]

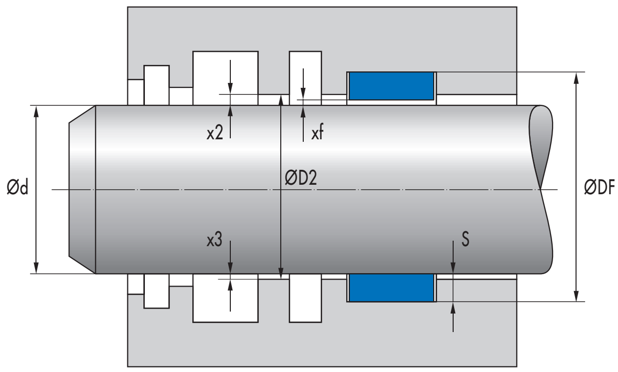


Fig. 26 Limit values of sealing gap of rod sealing system

Limit values

When considering the limit values with reference to the sealing gap the maximum adjustable sealing gap (x2) and the minimum sealing gap (x3) with one-sided mount of the piston rod or the piston body are taken into account (→ Fig. 26 and Fig. 27).

$x2 = (D2_{max} – d2_{min}) / 2 + xf_{max} / 2$

$x3 = ([dF_{min} + (2 * S_{min})] – d2_{max}) / 2$

$xf_{max} = D_{max} – [dF_{min} + (2 * S_{min})]$

$d2_{min} = D2_{max} + xf_{max} - 2 \times 2_{max}$

d = bore [mm]

DF = groove base of guide [mm]

D2 = non-pressurised side [mm]

S = thickness guide sleeves [mm]

x2 = maximum sealing gap [mm]

x3 = minimum sealing gap [mm]

xf = guide play [mm]

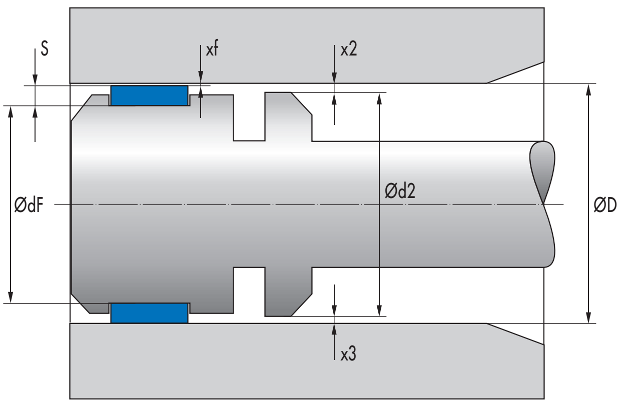


Fig. 27 Limit values of sealing gap of piston sealing system

The maximum sealing gap (x2) should be as small as possible (gap extrusion), the minimum sealing gap (x3) should be as large as possible (metal contact). Because there is a direct geometrical dependency between the minimum required metal gap (x3) and the maximum permissible extrusion gap (x2), the gap dimensions cannot be set independently of each other.

Gap extrusion

Seal materials act like a viscous fluid under the influence of the operating pressure. When the pressure is applied the sealing component is pressed closer to the metal housing and to the sealing gap. The ingress of the seal material into the sealing gap is referred to as the gap extrusion. The sealing component is damaged in the area of the metal edge of the installation space by the ingress of the seal material into the sealing gap. The repeated damage eventually causes failure of the sealing component.

When specifying the maximum gap dimension (x2) the temperature, material and geometry-dependent form stability of the sealing component and the operating and general conditions must be considered. In addition to the clear connection between the form stability of a sealing component and the operating pressure or the operating temperature, the limit values for the sealing gap are determined by the total loading, as well as other things.
The pressure applied with simultaneous relative stroke movement in the direction of the extrusion gap is more demanding than a static or quasi-static seal with reference to the power consumed by friction and shearing forces in the contact zone. A short pressure pulse is uncritical with reference to the gap extrusion, but an extended application of pressure places increased demands on the long-term form stability of the sealing component (flow).

The relevant enlargement of the sealing gap as a result of the cylinder stretching (cylinder barrel) or cylinder buckling (hollow rods) must be considered, particularly with higher operating pressures or light design. The deflection of the guide element must also be considered borderline designs with high transverse loads.
General figures for the maximum admissible gap width (x2) are listed in the tables with the article description depending on the type of seal, the selected seal profile and the operating pressure.

Metal contact

When specifying the minimum gap dimension (x3), the collision control is particularly important. The narrowest sealing gap in a sealing system is normally behind the primary seal. Collision control is therefore run primarily for this area. Where the design requires large gaps between the sealing components and also large angular deviations the collision control should be extended appropriately.

Marginal designs with high transverse loads and long slender cylinders must also be protected with reference to bending of the piston rod and the deflection of the guide element. Cylinders with short support length are tested for the required angular error.

Metal contacts between the counter surface and the installation space components cause comparatively high costs when service is required. Within the permissible limits and with reference to the operating and general conditions the dimensions and tolerances are selected to yield as large a value as possible for the sealing gap x3 and thus the greatest possible security against metal contacts. The minimum required value for x3 is determined primarily by the deflection of the guide element under load.

Counter Surface

Definition

Both sides are subject to wear at the contact and during simultaneous relative movement between the sealing components and the counter surface. To establish a stable sealing effect over the long term, the changes caused by the contact must be minor. After a short running period during which the sealing edge must not be damaged by abrasive wear, stable running characteristics must established. The system consisting of sealing components, counter surface and lubricating film must be optimised for sealing effect, friction behaviour and wear. The geometry, the material of the sealing components, the topography, the material of counter surface and the properties of the hydraulic medium all influence the operation of the system.
The factor of individual parameters on the overall system is strongly dependent on the operating conditions. While the solid-body friction is the primary factor with a low stroke speed and high operating pressure, with a high stroke speed and low operating pressure a hydrodynamic lubricating film may be built up. The influence quantities are always mutually interdependent. In an optimally set up system a thin lubricating film is released outside beneath the sealing components. The oil film must be transported completely back to the hydraulic system at every cycle. Inside sealing systems all individual seals and the wiper must meet this condition.

An absolutely sealing component that does not release a lubricating film outside is as unsuitable as an absolutely smooth counter surface (→ Fig. 28) in which there are no abrasive components and also no lubricant pockets when considering the dependencies described above. In both cases a very unfavourable friction and wear behaviour will be established.

Surface structure

The structure of the counter surface is primarily influenced by the machining process used for finishing. With reference to retaining the lubricating film it is better to generate chaotic surface structures. Dynamic effects are generated on aligned structures and in relation to the stroke movement in the area around the sealing edge. The applied lubricating film can be enlarged here and is visible as leakage. A surface generated by turning and grinding or honing cannot be accurately described geometrically. In turning the material is not sheared at the theoretical contour line, because during processing material particles are also pulled out from a depth. Geometrically undetermined cutters indentations and heights are also formed by grinding and honing (→ Fig. 29). A surface with formation of fine burrs is generated.

Fig. 28 Non-wettable surface

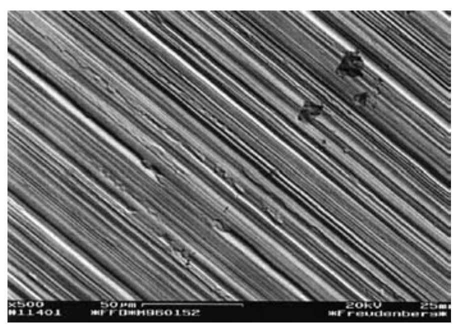


Fig. 29 Ground surface

Whether such a surface is suitable for use in contact with the sealing components cannot be sufficiently derived from the currently used surface parameters R_a, R_{max} and M_r. Depending on the general manufacturing conditions both abrasive and non-abrasive counter surfaces are created within the limit values. Processes that remove material for final machining are only suitable if the process can be managed. This requires a measured value for the abrasiveness.

When manufacturing processes for final machining are used in which material is not removed (e.g. rolling) comparatively smooth surfaces are generated, which do not normally have any abrasive components. Because it is difficult to wet a smooth surface, it is more difficult to form a lubricating film. However, such surfaces are generally suitable for a counter surface in contact with sealing components.

Hardness/coating

The counter surface and the sealing and guide elements are in contact as a result of relative movement (friction) and compression (transverse load; operating pressure). The required hardness of the counter surface depends on the height and type of loading. Slow movements with high surface load (deformation of the counter surface) and rotary movements (running-in as a result of wear) are the most demanding.

The hardness of the surface generates sufficiently wear-resistant and stable edge coatings. However, the thickness of the edge coating and the quality of the base material are very important. If it is too soft, a comparatively thin edge coating will be deformed or broken with deflection of the base material. This effect can be observed particularly with hard chrome coatings on soft substrate material. The highest compression depends on the transverse load and the operating pressure in the region of the guide element or the primary sealing component. With complete deflection of an HGW guide ring and a correspondingly high transverse load maximum compressions of p_{max}~110N/mm² are reached. In the case of the sealing components the pressure distribution depends on the geometry of the sealing edge (→ Fig. 30). An operating pressure of 30 MPa a maximum compression of pmax~50N/mm² can be expected for the Merkel Omegat OMS-MR Rod Seal.

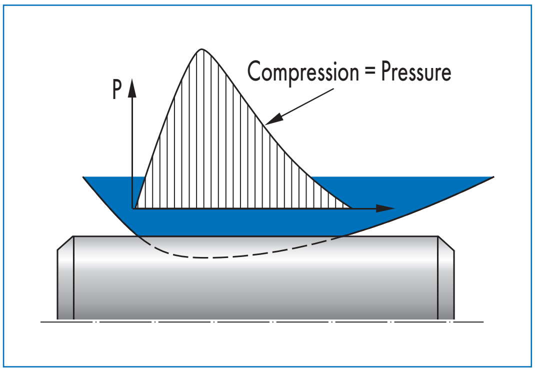


Fig. 30 Qualitative compression curve, single-acting rod seal

In the area of rod sealing systems base steel of quality Ck45N with a surface hardness of 55-60 HRC is used for cylinders under high loading. In general high-alloy, stainless steels based on CrMo or CrMoNi have proven reliable.

Piston sealing systems are under less load compared to rod sealing systems with reference to the compression curve (no pronounced sealing edge) and the lubrication. The counter surface in cylinder bores are not normally hardened. Under high loading high-alloy, stainless steels based on CrMo or CrMoNi (e.g. 42 CrMo4 + QT or 42 CrMo4V and 36 NiCrMo T + TQ) have proven reliable.

Nitrated counter surfaces

Nitration saturates the edge coating of the workpiece with nitrogen by diffusion. The result is a hard, wear-resistant and corrosion-resistant compound layer (thickness 10-20 µm). The hardness diminishes with increasing depth (diffusion coat). Depending on the process and the basic material a total penetration depth of up to 1 mm is reached. In salt-bath nitration (in a weaker form also with gas nitration) a large number of deep pores is formed in the outer compound layer. Even under a minor load (abrasive) particles tend to break out of the porous compound layer.

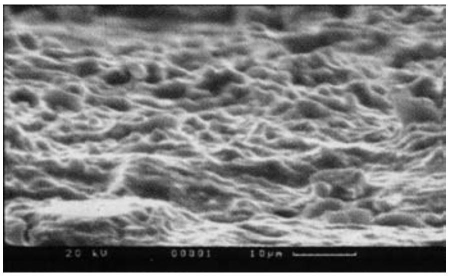


Fig. 31 Salt-bath-nitrated surface

A surface of this type cannot be used in contact with the sealing components without additional mechanical processing. Nitrated counter surfaces can be used in sealing technology without problems when they have been appropriately processed.

Chromed counter surfaces

Polished hard chrome layers (thickness 30-50 µm) do not generally have any abrasive component and, assuming a sufficiently hard substrate, are suitable for use as a counter surface in contact with the sealing components. Matt chroming forms microscopically small sharp tips, which cause heavy wear. Such surfaces must be mechanically processed before use in every case.

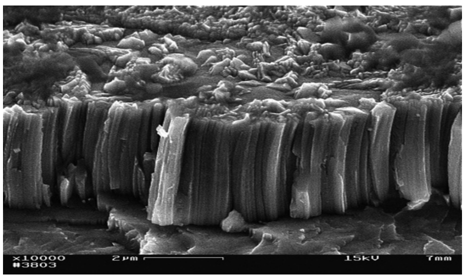


Fig. 32 Chrome-nitrated surface

Ceramic and partially ceramic counter surfaces

When using ceramic and partially ceramic surface (total thickness 300 µm) corrosion protection (saltwater resistance) and wear resistance are the primary purpose.
Ceramic counter surfaces are not smoothed in contact with the sealing components. The contact with the permanently sharp-edged crystal structure causes high wear on the sealing components. Sealing systems for ceramic counter surfaces are designed with adapted seal materials and special seal layouts and as such have a special position.

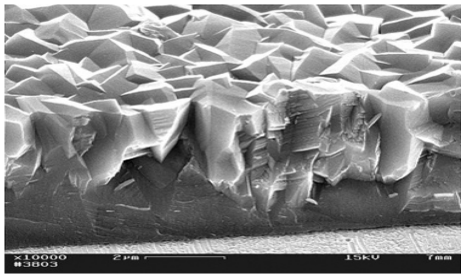


Fig. 33 Ceramic surface

In general brittle coatings would break with the elongation of the cylinder bores when pressure is applied. Therefore, in hydraulic cylinders only piston rods are coated.

Description of counter surface measurable in the laboratory

To evaluate the counter surface a suitable roughness gauge is used to measure the surface parameters R_a (average roughness), R_{max} (maximum surface roughness) and M_r (material content) and compared to the specified limit values (→ Tbl. 4).

Surface quality		
Surface roughness	R_{max}	R_a
Sliding surface	≤2,5 µm	0,05 ... 0,3 µm (optimum R_a = 0,2 µm)
Groove base	≤6,3 µm	≤1,6 µm
Groove flanks	≤15,0 µm	≤3,0 µm
Material content M_r >50% to max 90% at cutting depth c = Rz/2 and reference line C ref = 0%. (optimum M_r = 80%)		

Tbl. 4 Surface parameters

The material content curve or Abbott curve (→ Fig. 34) is the graphic view of the material-filled proportion of the calculated profile with reference to the cutting depth.
The material content is derived from the Abbott curve. The seal manufacturer uses different basic data.

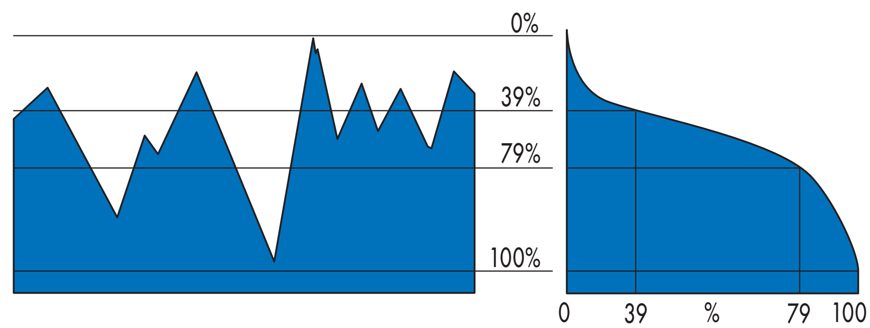


Fig. 34 Abbott graph

In the case of Merkel the entire surface including the full peak height relevant to the abrasivity and possible damage at first contact is considered starting from a reference line at C ref = 0% (→ Fig. 35). It remains unconsidered with a reference line Cref = 5% (→ Fig. 36).

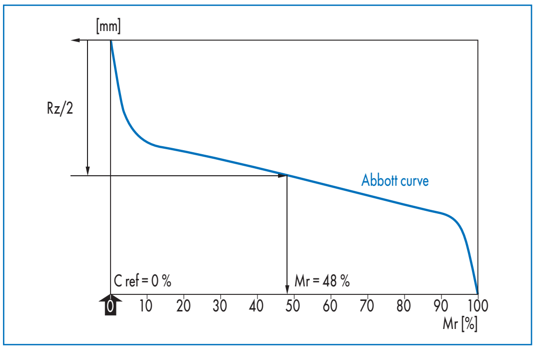


Fig. 35 Merkel material component definition

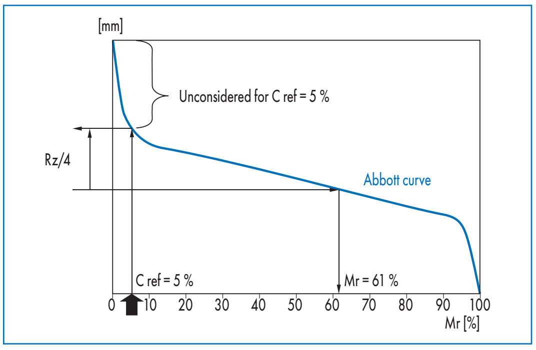


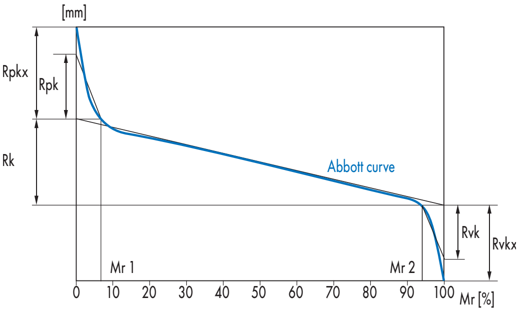
Fig. 36 Competition material component definition

Parameters such as R_a, R_{max}, Rz and the material content M_r have become established. The behaviour of the counter surface compared to the sealing components cannot yet be described with sufficient accuracy with reference to the abrasivity.

Extended laboratory description of the counter surface

The service life of the sealing component in a sealing system is determined by the contact between the counter surface and the sealing component. The contact influences by the comparatively soft sealing component (wear) and the hard counter surface (smoothing). If the sealing edge is damaged as a result of abrasive wear on the first strokes of the hydraulic cylinder, the sealing effect and the service life will be reduced accordingly. An extended laboratory examination of the counter surface is urgently required to measure abrasivity to ensure stable running characteristics over the long term.

The description of the counter surface can be refined by evaluation of additional parameters of the Abbott curve (→ Fig. 37):



Rpkx, full peak height; abrasive component.

Rpk, reduced peak height; profile peaks.

Rk, core surface roughness; supporting core; the main function area

Rvk, reduced groove depth; profile grooves; lubricant depot.

Rvkx, full groove depth; only minor influence on the sealing system.

Rpk, **Rk**, **Rvk**, **Mr1** and **Mr2** cannot be influenced any more without simultaneously influencing shape, position and dimensions.

Fig. 37 Additional parameters

Merkel has set a new direction with the definition of new surface parameters for detailed description of the counter surface for sealing components. The results are currently being applied to a wider base in collaboration with major manufacturers of injection moulding machines, presses and general cylinder manufacturing.
In the current state of knowledge at Merkel the surface parameters listed in Table 5 with the stated limit values are suitable for a complete description of the counter surface for sealing components.

Compared to the currently considered surface parameters we expect significantly improved predictability of abrasivity and long-term behaviour.
Our insights do not yet include ceramic or partial ceramic counter surfaces. Because such surfaces in contact with sealing components have a special position, we would like to exclude these surfaces from the above information.

Ideal flat	Unsuitable too fine	Suitable	Unsuitable too rough
1	2	3	4

R_a	> 0,05 µm	< 0,30 µm
R_{max}	–	< 2,50 µm
R_{pkx}	–	< 0,50 µm
R_{pk}	–	< 0,50 µm
R_k	> 0,25 µm	< 0,70 µm
R_{vk}	> 0,20 µm	< 0,65 µm
R_{vkx}	> 0,20 µm	< 2,00 µm

Tbl. 5 Limit positions of the additional parameters

Materials

Selection

The function of a sealing component is influenced by the geometry and primarily by the seal material. The influence of the specific material properties on the function of the seal in this regard depends among other factors on the nature of the relative movement between the sealing component and the counter surface (stroke, rotation, static).

As well as the chemical resistance the form stability, friction behaviour and elastic behaviour are significant influence factors. Unwanted material influences are in part compensated by additional components such as back-up rings (extrusion resistance) or preload components (initial sealing effect). A function-oriented design of the seal always considers the sealing material in use. Not every geometry can be manufactured easily with every material.

Materials

In hydraulic applications multi-component sealing components with a sliding ring of PTFE compound and an elastomer pre-load component as well as single and multi-component sealing components of elastomer (NBR, FKM) or polyurethane are primarily used. For the guide elements fabric-base laminate compounds are mostly used.

Back-up rings are manufactured of PTFE (polytetrafluoroethylene), PA (polyamide) or POM (polyoxymethylene) depending on the requirements. As well as these materials in some cases special materials such as PE (polyethylene), TPE (thermoplastic polyester-elastomer) and PEEK (polyetheretherketone) are used.

PTFE compound

Pure (virgin) PTFE has a comparatively low structure and friction strength. Even under a low load the material is deformed and begins to flow (cold flow). The addition of fillers (compounding) such as bronze, glass fibre and carbon fibre can significantly improve form stability and friction strength. Depending on the requirements other fillers such as carbon or graphite and also colour additives are also used.

PTFE is a horny, non-elastic material. The initial contact pressure of the PTFE sealing component to the counter surface required for the sealing function can only be applied by an additional contact pressure element (elastomer or spring) because of the missing elasticity. PTFE sealing components therefore always have multiple components.

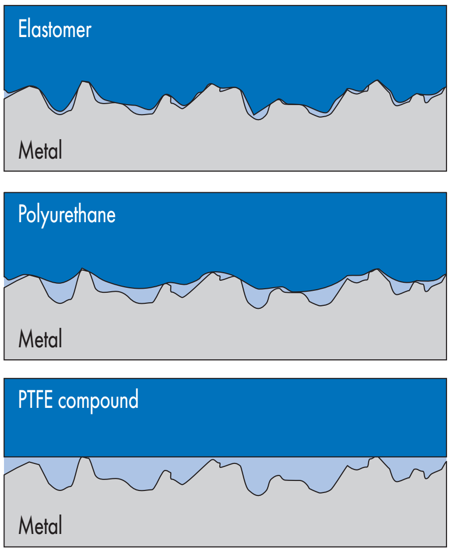


Fig. 38 Sealing edge in contact with counter surface

PTFE compounds are noted for high pressure resistance and favourable friction behaviour. A friction value (oiled) between μ = 0,02 and μ = 0,1 can be expected depending on the contact conditions.

The structure of the PTFE material causes the sealing component to slide on the higher components of the surfaces (microstructure). The sealing edge does not enter the roughness valleys (→ Fig. 38). As a result of this behaviour PTFE sealing components allow a comparatively thicker lubricating film beneath the sealing edge.

PTFE sealing components are preferably used as a primary seal in sealing systems or as a piston seal with bilateral pressure application.

Dirt adhering to the piston rod can be kept from entering the hydraulic system with suitable design of the wiping edge when using wipers of PTFE compound.

When selecting the PTFE compound amongst others the following properties are assessed with reference to the actual application:

- The influence of the hydraulic medium
- The behaviour in contact with the counter surface
- The form stability depending on the operating temperature.

PTFE bronze (PTFE B602) is the standard compound for general applications. In addition to its very smooth sliding properties the high form stability, even at high temperatures, as well as high wear resistance are particularly important.

The metal bronze and its components are not chemically neutral. In contact with water or water emulsion and in some cases also with additives in the hydraulic medium chemical reactions may be started.

The chemical reaction and also generally the results of insufficient lubrication can cause a typical damage pattern (fine strips) on the counter surface in contact with the sliding ring of a sealing component of PTFE bronze.

The restriction described is generally applicable for all PTFE bronze compounds available on the market. However, because of the compounding, which varies in detail, the results must be evaluated very differently.

If the lubrication is insufficient (poorly lubricating hydraulic medium, short stroke, stroke at high load and low stroke speed), the use of PTFE glass fibre MoS2 (PTFE GM201) has proven to be suitable. Influence by standard hydraulic media is not a factor because the glass fibres are chemically neutral.

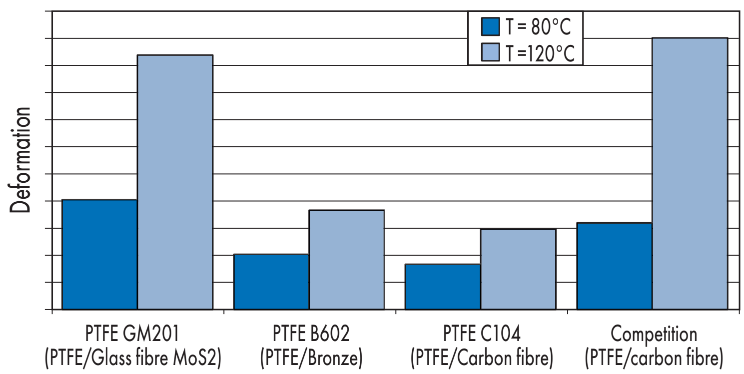


Fig. 39 Form stability of PTFE compounds in comparison

The pressure resistance of PTFE glass fibre is lower than that of PTFE bronze. In the temperature range above 100 °C there are significant differences in the form stability in comparison with PTFE bronze (→ Fig. 39).

The positive properties of PTFE bronze and PTFE glass fibre are combined in the PTFE carbon fibre compound (PTFE C104). The compound has favourable behaviour with insufficient lubrication and comparatively high form stability.

The matrix of modified PTFE is the difference in compound PTFE C104 compared to other PTFE carbon fibre compounds. The cost of the base material and the processing are higher than for PTFE bronze, PTFE glass fibre and simple PTFE carbon fibre compounds. Therefore, this compound is generally used for applications where neither PTFE bronze nor PTFE glass fibre MoS2 appear suitable.

The maximum permissible operating pressure is primarily determined by the extrusion gap and the temperature-dependent form stability of the seal material. Because the size of the extrusion gap cannot be selected as very small with reference to metal contacts, the pressure application range of the sealing component must be limited depending on the temperature.

An operating pressure of up to 40 MPa is generally permissible in the average temperature range, depending on the extrusion gap. At an operating temperature above 100 °C the operating pressure should remain limited to 26 MPa with the use of PTFE glass fibre and the simple PTFE carbon fibres.

The PTFE profile ring of a PTFE seal is machine-manufactured up to a nominal diameter of 2000 mm. It cannot be manufactured by injection moulding.

Polyurethane

Polyurethane has a high wear resistance and a comparatively high form stability. With the elastic behaviour of the material sealing components can be designed as single-piece components, i.e. without an extra pre-load component. Polyurethane under pressure behaves as a viscous fluid. At an operating pressure above 10 MPa sealing components of polyurethane are completely formed. The full contact to the counter surface makes ingress of the lubricating medium in the contact area difficult and as a consequence increases the friction wear. The use of a sealing system should be preferred to the individual seal with reference to the achievable service life.

Code	Colour
95 AU V142	dark-blue
94 AU 925	light-blue
93 AU V167	light-red
93 AU V168	light-red
95 AU V149	dark-blue
AU V206	dark-yellow
AU V204	light-yellow
92 AU 21100	white

Tbl. 6 Overview of polyurethane

Sealing components of polyurethane wipe away the hydraulic medium reliably with suitable design of the sealing edge. Assuming adequate media resistance, seals of polyurethane are used as primary and secondary seals (gap pressure up to 5 MPa) inside sealing systems. Their use as individual seals in combination with a double wiper is also widespread. With its high wear resistance polyurethane is also very suitable as a material for wipers. Sealing components of polyurethane can be manufactured by injection moulding or rotary processes to a nominal diameter of approximately 2000 mm. The qualities of polyurethane used (→ Tbl. 6) can be processed more or less easily depending on the nominal diameter and the manufacturing process. On the other hand some qualities are noted for excellent properties such as increased resistance to hydrolysis (hydrolysis = loss of structure as a result of contact with water) or improved properties in the low-temperature range.

Elastomers

Sealing, wiping and pre-load components of NBR (acrylonitrile-butadiene rubber) or FKM (fluoro elastomer) are primarily used in the area of hydraulic applications. Depending on the general conditions HNBR (hydrogenated acrylonitrile-butadiene rubber) and EPDM (ethylene-propylene-diene rubber) are also used.

Sealing components of elastomer wipe away the hydraulic medium and also fine dirt reliably with suitable design of the sealing edge. In this respect they are superior to PTFE and polyurethane. On the other hand the high sealing effect causes the elastomer to penetrate the microstructure of the counter surface (→ Fig. 38) and thus forms a very close contact between the sealing component and the counter surface. The friction and the wear are increased particularly when pressure is applied compared to PU and PTFE (→ Fig. 40).

Sealing components of elastomer tend to adhere to the counter surface after extended downtime because of this property.
Because of the low resistance to gap extrusion (form stability) seals of elastomer without additional reinforcement such as fabric inserts (Chevron seal sets) or back-up rings can only be used at low pressures up to 10 MPa.

Elastomer seals with fabric reinforcement are robust and with pressure applied have sufficient form stability. However, such sealing components are often not sufficient to meet the increased demands related to stroke speed and service life, primarily because of the unsuitable Friction behaviour.
Elastomers are mainly used as wipers and in the form of O-rings as static seals or pre-load components. Elastomers are only used as secondary seals in sealing systems if polyurethane cannot be used because of the media resistance or the operating temperature.

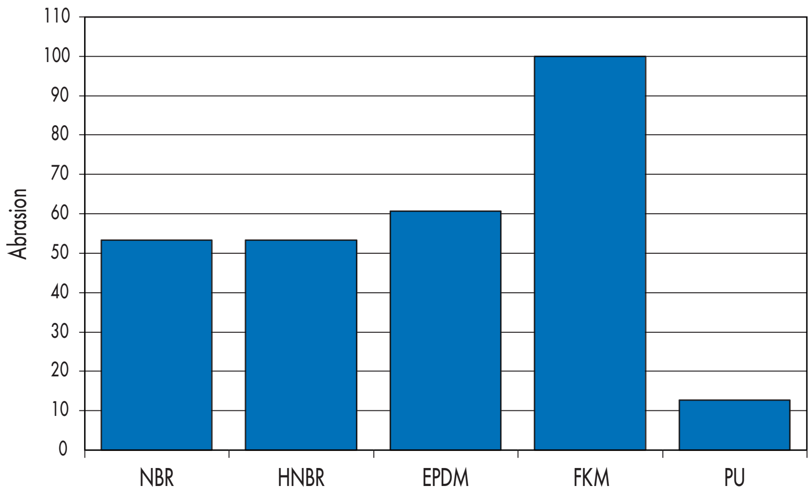


Fig. 40 Wear behaviour in comparison

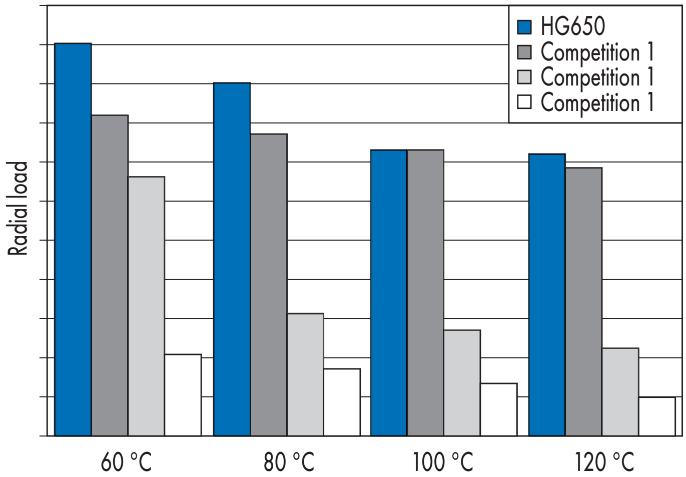


Fig. 41 Loading depending on the operating temperature

Fabric-base laminate

Fabric-base laminates consist of a fine fabric bonded with resin. Relevant properties such as the friction strength, the permissible surface load (acceptance of transverse loading) and the temperature dependency of the material behaviour are set depending on the properties of the components. Polyester and other plastics and also natural materials such as cotton are used for the fine fabric. In addition to polyester, vinyl ester and phenol resin a whole range of plastics with various properties are available for the resin matrix. While the friction resistance of the established compounds is generally at a comparatively high level, there are significant differences in the permissible surface load and the dependence on the operating temperature (→ Fig. 41).

Thermoplastic base materials, such as polyester, have a significant natural temperature-dependent material behaviour. At higher temperatures guide elements of these materials can only accept low transverse loads. For other compounds the influence of the operating temperature on the permissible surface pressure is only minor.

In the diameter range up to 300 mm HG517 and HG650 are currently used by the metre cut to length and above 300 mm the HG650 quality is used by the metre cut to length. Material quality HG650 represents the standard of the future over the complete dimension range. The advantage of HG650 in addition to the outstanding pressure resistance compared to competitive products is the improved handling (fitting) for small diameters (<60 mm).

Code	Colour
HG517	dark grey
HG650	Red

Tbl. 7 Overview of fabric-base laminates

Installation of Hydraulic Seals

Before installing the sealing components the compete system must be cleaned to remove machining residues, chips, dirt and other particles. Seals must not be pulled over sharp edges, threads, feather key grooves or similar when mounting. These parts must be covered during fitting (→ Fig. 42). Sharp edges must be de-burred or chamfered or radiused. Never use sharp-edged tools.
Seal, piston rod and cylinder bore must be oiled or greased before fitting. Heating the seals before installation in +80 °C to +100 °C hot oil will make the seal material more elastic and it will be easier to install the seal.

Insertion chamfers on rods and pipes

To prevent damage to sealing components when mounting, cylinder bores and piston rods must be chamfered. For the surface quality of the chamfer $R_t \leq 4$ µm is applicable.
The edge at the transition from the chamfer to the sliding surface must be rounded and polished. Product-specific information can be found in the shape descriptions.

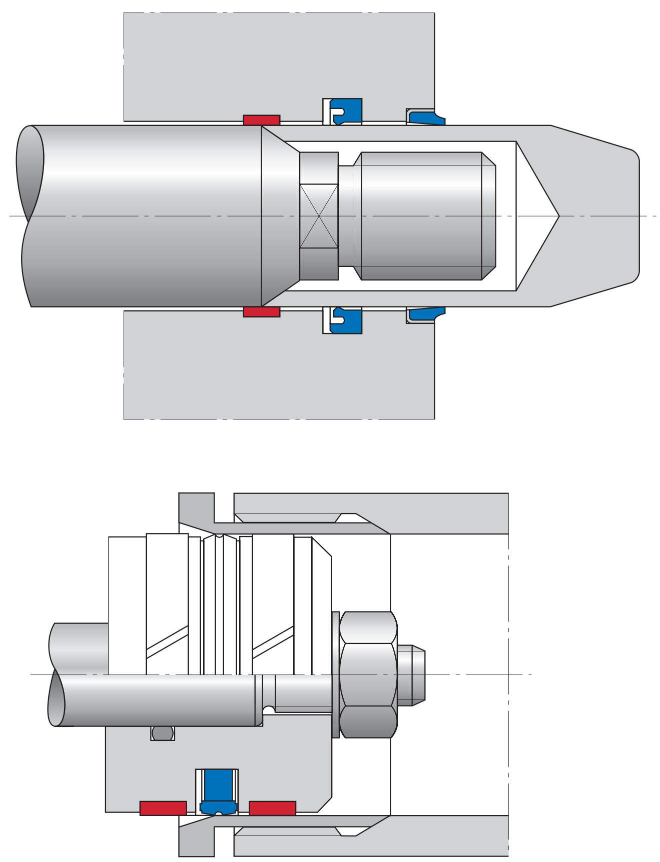


Fig. 42 Covering threads when mounting seals

Fitting of rod seals

When mounting rod seals two types of installation must be distinguished(→Fig. 43):

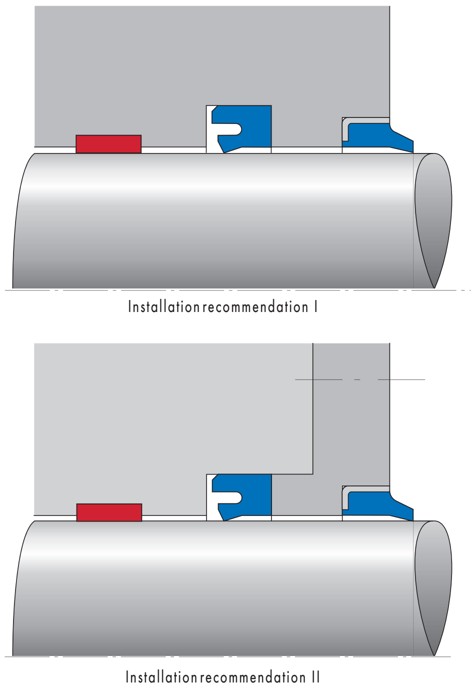


Fig. 43 Installation types of rod seals

- Snap-in fitting in an undivided installation space (installation recommendation I).
  Seals that are suitable for this type of installation are marked with h and w in the tables of dimensions.
- Fitting in a divided installation space (installation recommendation II).
  Seals that required a divided installation space are not marked in the tables of dimensions.

Assembly tools for rod seals

Snap-in fitting in undivided housings (recommended installation) can be made must easier with suitable assembly tools. The fitting tool I (order no. 00375753) can be used to snap in U-rings from 35 mm diameter (profile size 5 mm) up to a nominal diameter of 80 (profile size 10 mm) in undivided grooves. The ring is pressed into a kidney shape and pushed into the rod guide. The fitting tool is withdrawn after the seal has snapped into the groove.

Another option for snap-in fitting of rod seals is to use a suitable stopper and a rod (→ Fig. 46).

Here the seal is initially placed manually in the groove and then pushed with a rod until it snaps into the groove. Stopper and rod should be manufactured from a suitable plastic.

Fitting of groove and compact seals with back-up ring

The Merkel SM U-Ring (primary seal) with locked-in back-up ring can be snapped into a plunge-cut groove. The sealing ring is first inserted into the groove.
Then the back-up ring is installed.
Compact seals with a locked-in back-up ring can be snapped into a plunge-cut groove, depending on the diameter and profile.

Fitting of multi-part compact seals for the rod: Merkel Omegat OMS-MR

For rod diameters ≤15 mm an axially accessible housing is required. Up to rod diameter 28 mm an axially accessible housing is recommended. If this is not possible for design reasons, the seal must be selected in accordance with the smaller installation size L.
For diameter range 38 to 50 mm we also recommend using the seal in accordance with the smaller fitting size L because of the easier fitting (→ Fig. 46). The max. permissible gap widths of the type must be observed.

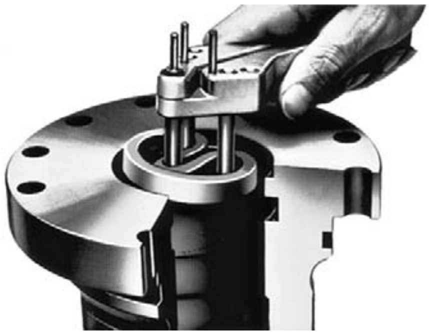


Fig. 44 Fitting tool I for rod seals

Fig. 45 Fitting tool II for rod seals

Fitting in divided housings

From a specific nominal diameter, depending on the profile size, rod seals must be installed in divided housings. The limit sizes are listed in d (→ Tbl. 8).

Rod seals in divided housings (fitting recommendation II) can be installed without special tools. For series installation we recommend using mounting sleeves and pilot shafts (→ Fig. 47).

	U-rings and single-piece compact seals						
Profile size $P = \frac{D_N - d_N}{2}$	4	5	6	7,5	10	12,5	15
Limit nominal diameters for snap-in fitting	25	30	40	50	80	100	105
Seals that are suitable for snap-in fitting are identified with h (hand) in the descriptions in the dimension lists.							

Tbl. 8 Limit dimensions for snap-in fitting (required values)

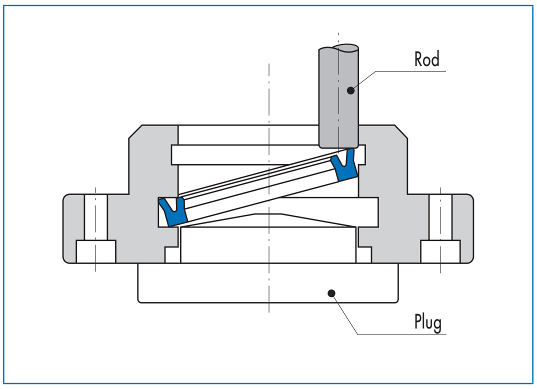


Fig. 46 Installation aid for rod seals

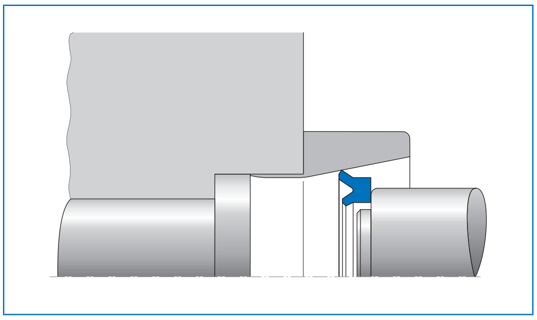


Fig. 47 Fitting of rod seals in divided housings

Fitting of piston seals

Similar to fitting of rod seals there are also two types of installation of piston seals:

- Snap-in fitting in undivided housings.
  Seals that are suitable for this type of installation are identified with h or w in the dimension tables.
- Fitting in divided housings.
  When assembled the metal parts must adhere to preclude extrusion wear on the static side.

Multi-part compact seals for pistons

Simko Piston Seals can generally be snapped in without tools. The following illustrations show the snap-in fitting without tools for the Merkel Compact Seal Simko 300 Compact Seal. First the elastic rubber contact pressure element is snapped in. Then the PUR sealing ring is placed on one side in the groove and pushed over the previously oiled piston body until it snaps completely into the groove.

Fig. 48 Snapping in the polyurethane running ring

Fig. 49 Snapping in the polyurethane running ring

Assembly tools for piston seals

The snap-in fitting is made much easier with suitable assembly tools.

Simko Piston Seals as well as U-Rings that in some cases are used as single-acting piston seals can be easily installed with the aid of simple installation tool See the following illustrations:

Fig. 50 Fully mounted seal

Fig. 51 Inserting sealing ring

Fig. 52 Inserting mounting pin

Fig. 53 Turning mounting lever

Fig. 54 Snapping in the guide back-up ring

Fitting of compact seals of the Omegat series for pistons and rods

The Merkel Omegat Compact Piston Seals (OMK-MR, OMK-S, OMK-E, OMK-ES) and the Merkel Omegat Compact Rod Seals (OMS-MR, OMS-S) are suitable for undivided housings in virtually all dimensions. Fitting requires special care.

To prevent damage to the sealing edge, which may result in leakage before commissioning, it is important to observe our installation instructions.

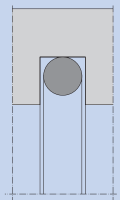
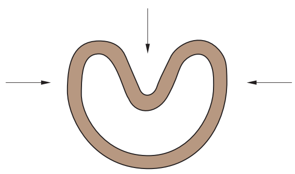
Fitting for installation

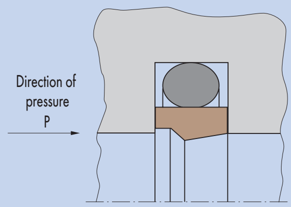
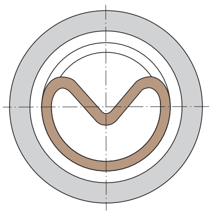
Omegat Seals consist of a high-quality pressure and wear-resistant profile ring and an O-ring as the pre-load component. Careful fitting is essential for correct function.

Before starting installation, make sure that:

- The required insertion chamfers on the piston rod and cylinder bore have been de-burred and rounded,
- Thread peaks and sharp edges are covered,
- Dust, dirt, chips and other external objects must be thoroughly removed,
- The Omegat sealing components and the components are oiled or greased (use only greases without solid additives. In this regard make sure that they are compatible with the medium.),
- The assembly tools must be of soft material and have no sharp edges.

Heating them in oil up to about 80 °C makes it much easier to stretch and deform the Omegat Profile Ring.

Omegat Rod Seal	
Fitting of Omegat Rod Seals in undivided housings is very easy (d ≤Ø15 axially accessible housing required):	
Insert O-ring into the groove without twisting it.	
Press Omegat Profile Ring into a kidney shape (attention: do not kink!).	

Omegat Rod Seal	
A fitting tool is preferred for series fitting.	
Place compressed Omegat Profile Ring on the O-ring so the sealing edge is on the pressure side.	
Insert Omegat Profile Ring in original shape in the groove.	
Then calibrate with a mandrel. The mandrel can be manufactured from PA, POM or similar material. Chamfers of 15° and minimum 30 mm long.	

Tbl. 9 Deformation of the profile ring

Ø d	L	Ø d mandrel
<50	15	Ø d – 0,10
≥ 50 ... <120	20	Ø d – 0,18
≥120 ... <200	30	Ø d – 0,25
≥200 ... <650	40	Ø d – 0,35
≥650 ... <900	50	Ø d – 0,50

Tbl. 10 Recommended diameter of mounting equipment

Recommendation:

Please use an assembly tool when d Ø>15 mm and for larger series. This deforms the profile ring less. The major design principles are shown in the drawing.

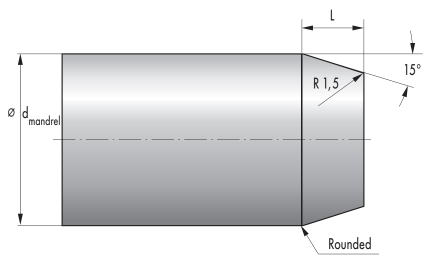


Fig. 55 Calibrating mandrel

Preferred materials: pressure mandrel – plastic
tapered sleeve – plastic

We can supply complete assembly tools on enquiry.

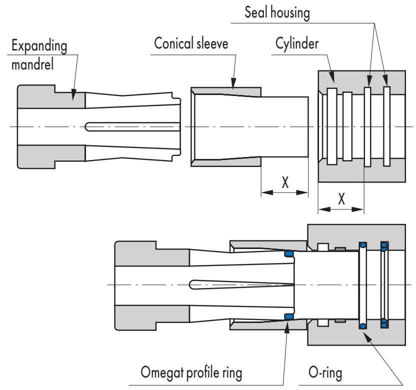
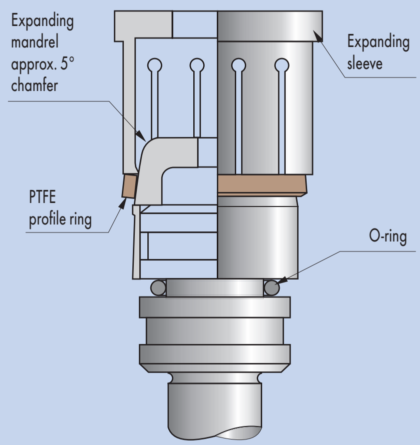


Fig. 56 Finished assembly tools (on enquiry)

<table>
<tr><th colspan="2">Omegat Piston Seal</th></tr>
<tr><td colspan="2">Omegat Piston Seals must always be fitted in single-piece pistons with a fitting tool.</td></tr>
<tr><td>Insert O-Ring into the groove without twisting it.</td><td rowspan="3">
</td></tr>
<tr><td>Stretch Omegat Profile Ring with spreader sleeve over a tapered mounting sleeve and spring into the groove,
for larger dimensions use mounting belt (order no. 24346745)
(no sharp-edged tools).</td></tr>
<tr><td>Calibrate Omegat Profile Ring on the piston diameter with a slip ring.
When using profile rings with an L-dimension ≥6,3 mm we recommend using a plastic tension belt.</td></tr>
</table>

Tbl. 11 Mounting equipment for piston seal

Fitting instructions for Merkel Compact Seal L 43

Fitting of the Merkel Compact Seal L 43 is uncomplicated and generally corresponds to the conventional compact piston seal. The assembly should be carried out in the sequence below.

Fitting of Merkel Compact Seal T 19

We recommend using installation tools for all dimensions of the size series T 19; hand installation is possible for servicing. The sequence when mounting the individual parts is as follows:

- First angled bush
- Sealing component
- Second angled bush

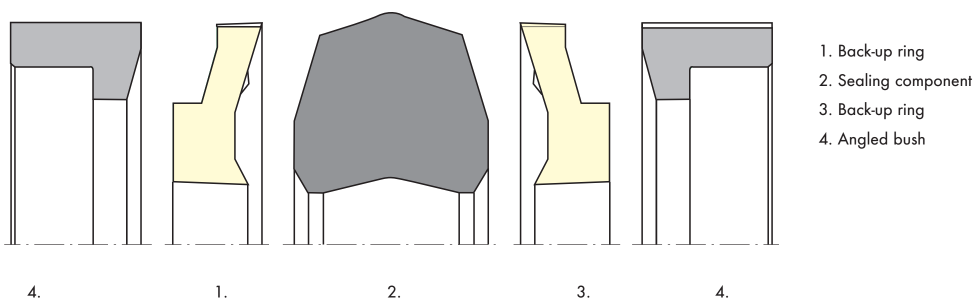


Fig. 57 Fitting of Merkel Compact Seal L 43

Installation instructions for Merkel double wiper PT 2

Double wipers of the PT 2 series can be installed in housings that are not axially accessible without tools from Ø150 mm. For installation first insert the large O-ring into the groove, insert the small O-ring into the groove of the PTFE profile ring, then the profile ring is placed in a kidney shape and snapped in. Make sure that the profile ring is not kinked and that the sealing edge is correctly aligned to the pressure direction. For smaller dimensions please use an installation tool.
Dimensions <Ø100 mm cannot be installed in a plunge-cut groove.

Installation instructions for Merkel double wiper PT 1

Double wipers of the PT 1 series with inside diameter ≥30 mm can be installed in non-axially accessible housings without fitting tools. For smaller dimensions a fitting tool is recommended.

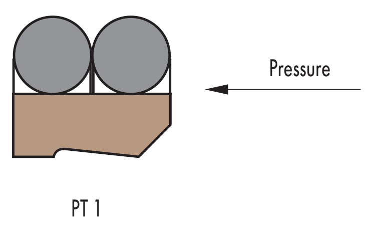


Fig. 58 Functional direction of wiper

For installation the O-rings are inserted into the groove, then the profile ring is placed in a kidney shape and snapped in. Make sure that the profile ring is not kinked and the sealing edge is correctly aligned to the pressure direction.

Fitting of Chevron Seal Sets

Instructions for Chevron Seal Set housings

Adjustable housings have the advantage of an optimal adjustment option. After a lengthy period of running and incipient wear on the seal tightening the gland can extend the service life and significantly delay a system standstill. For adjustable housings an extension of 2,5% and an adjustability of 7,5% of dimension L is recommended. Non-adjustable housings have the advantage of more cost-effective manufacture, because washers are not required. Seal Set Type B is particularly recommended for these housings. The rubber-sprung back-up rings handle the function of initial compression and continuous re-adjustment during operation. Maintenance of the seal contact area is not required.

Fitting

Before installation all individual parts of the seal set must be evenly greased. Mineral-oil-based greases can be used. The rod must be in the cylinder’s installation space during fitting. The individual parts of the set must be installed separately in the chamber. In this regard make sure that the seals are not reversed. Open chevron seal sets are used for repairs, e.g. in large systems, if endless seals cannot be installed.

Please note

Open chevron seals have an oversize in the circumference length to allow sufficient compression and a good sealing effect at the joint sections. An endless delivered seal set should therefore not be cut. Open chevron seals are always supplied with installed profile cords.

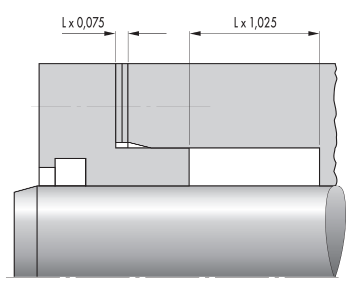


Fig. 59 DMS installation space example

General Technical Data

ISO Tolerances, Selection – in µm –

Nominal dimension range [mm]		Piston guides	Groove base for two-piece piston seals	Groove base for piston seals	Simmerring shaft		piston rods		Simmerring (housing), rod guides, wiper housing (Cylinder bores)	(Cylinder bores)	Groove base for rod seals (Cylinder bores)	(Cylinder bores)	Simmerring housing, special cases (Cylinder bores)
over	to	h8	h9	h10	h11	f7	f8	e8	H8	H9	H10	H11	f8
1,6	3	0	0	0	0	−6	−6	−14	14	25	40	60	20
		−14	−25	−40	−60	−16	−20	−28	0	0	0	0	6
3	6	0	0	0	0	−10	−10	−20	18	30	48	75	28
6	10	0	0	0	0	−13	−13	−25	22	36	58	90	35
		−22	−36	−58	−90	−28	−35	−47	0	0	0	0	13
10	14	0	0	0	0	−16	−16	−32	27	43	70	110	43
14	18	−27	−43	−70	−110	−34	−43	−59	0	0	0	0	16
18	24	0	0	0	0	−20	−20	−40	33	52	84	130	53
24	30	−33	−52	−84	−130	−41	−53	−73	0	0	0	0	20
30	40	0	0	0	0	−25	−25	−50	39	62	100	160	64
40	50	−39	−62	−100	−160	−50	−64	−89	0	0	0	0	25
50	65	0	0	0	0	−30	−30	−60	46	74	120	190	76
65	80	−46	−74	−120	−190	−60	−76	−106	0	0	0	0	30
80	100	0	0	0	0	−36	−36	−72	54	87	140	220	90
100	120	−54	−87	−140	−220	−71	−90	−126	0	0	0	0	36
120	140	0	0	0	0	−43	−43	−85	63	100	160	250	106
140	160	−63	−100	−160	−250	−83	−106	−148	0	0	0	0	43
160	180												
180	200	0	0	0	0	−50	−50	−100	72	115	185	290	122
200	225	−72	−115	−185	−290	−96	−122	−172	0	0	0	0	50
225	250												
250	280	0	0	0	0	−56	−56	−110	81	130	210	320	137
280	315	−81	−130	−210	−320	−108	−137	−191	0	0	0	0	56
315	355	0	0	0	0	−62	−62	−125	89	140	230	360	151
355	400	−89	−140	−230	−360	−119	−151	−214	0	0	0	0	62
400	450	0	0	0	0	−68	−68	−135	97	155	250	400	165
450	500	−97	−155	−250	−400	−131	−165	−232	0	0	0	0	68

Tbl. 12 Selection of ISO dimensions

Production tolerances

In the following chapter on materials will consider the technological quality of the highly elastic materials from Freudenberg, elastomers and plastomers as well as their applications with reference to their physical and chemical properties.
However, the dimensional accuracies achievable on the finished part with the above mentioned materials are also important. Designers and users very frequently aim for tolerance standards used for metal parts in mechanical engineering when they consider the tolerances required and the rules governing tolerances. However, narrow tolerances are generally not possible during the manufacture of sealing components and parts made of highly elastic materials.
The tolerances specified in DIN 7715 are generally applicable for sealing components and parts made of highly elastic materials, and assuming that there are no special requirements for specific products tolerance level M3 is considered applicable.
Deviations from the values specified in DIN 7715 must be agreed in consultation between user and manufacturer.

Permissible deviations for soft rubber parts (extract from DIN 7715 Part 2)

Dimension terms

A differentiation is to be made between two kinds of permissible dimensional deviations F and C for all moulded parts within the tolerance classes.

F: Deviations dimensions related to the mould. Dimensions that are not influenced by factors that affect shape such as compression and lateral offset between different moulded parts (high and low part, cores). See dimensions w, x and y in → Fig. 60.

C: Deviations in dimensions related to the mould closing. Dimensions that may be changed by changes in the density of the compression and the lateral offset between different moulded parts. See dimensions s, t, u and z in → Fig. 60.

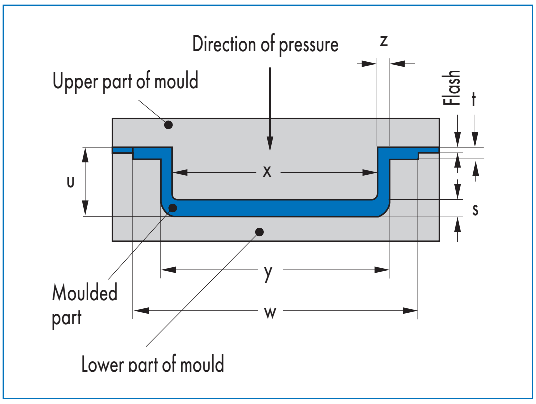


Fig. 60 Mould and moulded part

Nominal dimension range [mm]		Class M 1		Class M 2		Class M 3		Class M 4	
		F ±	c ±	F ±	c ±	F ±	c ±	F ±	c ±
over	to	Permissible deviations of dimensions in mm							
	6,3	0,10	0,10	0,15	0,20	0,25	0,40	0,50	0,50
6,3	10,0	0,10	0,15	0,20	0,20	0,30	0,50	0,70	0,70
10,0	16,0	0,15	0,20	0,20	0,25	0,40	0,60	0,80	0,80
16,0	25,0	0,20	0,20	0,25	0,35	0,50	0,80	1,00	1,00
25,0	40,0	0,20	0,25	0,35	0,40	0,60	1,00	1,30	1,30
40,0	63,0	0,25	0,35	0,40	0,50	0,80	1,30	1,60	1,60
63,0	100,0	0,35	0,40	0,50	0,70	1,00	1,60	2,00	2,00
100,0	160,0	0,40	0,50	0,70	0,80	1,30	2,00	2,50	2,50
Permissible deviations in %									
160		0,30	*)	0,50	*)	0,80	*)	1,50	1,50
*) Values only on agreement									

Tbl. 13 Extract from DIN 7715

Regardless of the values given in the tables, product-related tolerances are shown in:

DIN 3760 for rotary shaft seals

DIN ISO 3302-1 accuracy level M2 for diameter ranges of moulded diaphragms without fabric reinforcement

DIN ISO 3302-1 accuracy level M3 for diameter ranges of moulded diaphragms with fabric reinforcement and/ or metal insert

DIN 16901, Part 2 for manufactured parts made of injection moulded thermoplastics

DIN 7168 for machined parts made of PTFE or other thermoplastics

If tolerances must be less than in DIN 7168 for functional reasons, the "reduced material tolerances" given in → Tbl. 14 must be maintained. In exceptional cases consultation with us is recommended.

Nominal dimension range [mm]		Tolerance according to DIN 7168 average	Reduced working tolerances range
over	to		
	6	±0,1	0,10
6	30	±0,2	0,15
30	65	±0,3	0,20
65	120	±0,3	0,30
120	200	±0,5	0,40

Tbl. 14 Extract from DIN 7168

Nominal dimension range [mm]					Batch vulcanised parts		Hoses and discs cut from hose			
over	to	Pressed, bored and stamped parts	Flange thickness of pressed parts	Cut-outs and parts cut with a template	Diameter	Profile in cross-section and by the metre	Outside Ø ground	Outside Ø not ground	Inside diameter	Cut height
	3	±0,2[a)]	±0,10	±0,3[b)]	−0,15	±0,3[b)]	±0,1	±0,3[b)]	−0,15	±0,15
3	6	±0,2[a)]	±0,15	±0,4[b)]	−0,20	±0,4[b)]	±0,1	±0,4[b)]	−0,20	±0,20
6	10	±0,3[a)]	±0,20	±0,5[b)]	−0,25	±0,5[b)]	±0,1	±0,5[b)]	−0,25	±0,20
10	18	±0,3[a)]	–	±0,6[b)]	−0,30	±0,6[b)]	±0,2	±0,6[b)]	−0,30	±0,30
18	30	±0,4[a)]	–	±0,8[b)]	−0,40	±0,8[b)]	±0,2	±0,8[b)]	−0,40	±0,40
30	40	±0,5[a)]	–	±1,0[b)]	−0,50	±1,0[b)]	±0,2	±1,0[b)]	−0,50	±0,50
40	50	±0,5[a)]	–	±1,0	−0,80	±1,2[b)]	±0,2	±1,0[b)]	−0,50	–
50	80	±0,6[a)]	–	±1,0	−0,80	±1,2[b)]	±0,3	±1,2[b)]	−0,80	–
80	120	±0,8[a)]	–	±1,0	−1,00	±1,4[b)]	±0,3	±1,4[b)]	−1,00	–
120	180	±1,0[a)]	–	±1,2	−1,40	±1,6[b)]	±0,4	±1,6[b)]	−1,40	–
180	250	±1,3[a)]	–	±1,2	−2,00	–	–	±2,0[b)]	−2,00	–
250	315	±1,6[a)]	–	±1,5	−2,80	–	–	±2,5[b)]	−2,80	–
315	400	±2,0[a)]	–	±1,5	−3,50	–	–	±3,0[b)]	−3,50	–
400	500	±2,5[a)]	–	±2,0	−4,50	–	–	±3,5[b)]	−4,50	–
500		±0,5%[a)]	–	±0,5%	−6,00	–	–	±1,0[b)]	−6,00	–

Tbl. 15 Freudenberg tolerances derived from DIN 7715

[a)] Values corresponding to DIN 7715 accuracy level "fine"

[b)] Values corresponding to DIN 7715 accuracy level "average"

[c)] Values corresponding to DIN 7715 accuracy level "coarse"

Dimensional units – Selection –

Basic size	Basic unit	Unit character
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electrical current	Ampère	A
Temperature	Kelvin	K
Luminous intensity	candela	csd
Amount of substance	mol	mol

Tbl. 16 Base dimensions, base units

Size	Unit	Formula symbol	Units symbol
Acceleration	metres by seconds squared	b	m/s^2
Density	kilogram by cubic metre	ρ	kg/m^3
Pressure	Newton/m^2, Pascal	p	N/m^2, Pa
Energy, work	Joule	A, E	Nm = Ws
Area	square metre	A	m^2
Speed	meter by second	V	m/s
Force	Newton	F	N
Tension	Newton by square metre	σ	N/m^2, Pa
Viscosity (dynamic)	Pascal second	η	Pa S
Viscosity (kinematic)	square metre by second	μ	m^2/s
Volume	cubic metre	V	m^3
Electrical Voltage	Volt	V	W/A
Electrical resistance	Ohm	Ω	V/A
Electrical conductivity	Siemens	S	1/Ω
Inductance	Henry	H	Vs/A
Electric charge	Coulomb	C	As
Frequency	Hertz	Hz	1/s
Power	Watt	W	J/s
Luminous flux	lumen	1 m	cd sr
Illuminance	lux	1 x	1 m/m^2

Tbl. 17 Derived SI units with their own unit names

Size	Unit	Other commonly used official units
Angular momentum	N · m · s	–
Torque	Nm, J	–
Speed	2 · x · rad/s	s^{-1}
Modulus of elasticity	PA	N/mm^2, bar
Enthalpy	J	kJ
Enthalpy, specific	J/kg	kJ/kg
Entropy	J/K	kJ/K
Entropy, specific	J/kg · K	kJ/kg · K
Geometrical moment of inertia	m^4	cm^4
Force	N	kN, MN
Gas constant	J/kg · K	kJ/kg · K
Calorific value	J/kg, J/m^3	kJ/kg, kJ/m^3
Linear momentum	N · s	–
Mass moment of inertia	kg · m	g ·m, t · m^2
Moment	N · m	–
Unit conductance	W/m · K^4	–
Volume, specific	m^3/kg	–
Coefficient of heat transfer	W/m · K	–
Heat capacity	J/K	kJ/K
Heat capacity, specific	J/kg · K	kJ/kg · K
Thermal conductivity	W/m · K	–
Section modulus	m^3	cm^3

Tbl. 18 Further statutory, derived units of mechanics

Power of ten	Prefix	Prefix symbol
Decimal multiples		
10^1	deca	da
10^2	hecto	h
10^3	kilo	K
10^6	mega	M
10^9	giga	G
10^{12}	tera	T
Decimal fractions		
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Tbl. 19 Decimal multiples and decimal fractions of units

The rules allow decimal multiples and decimal fractions of units to be expressed by prefixing syllables

Conversion tables

Force: 1 Newton (N) = 1 kg m/s²				Energy, work, amount of heat: 1 Nm = 1 Joule (J) = 1 Ws					Power: Watt (W) = 1 Nm/s = 1 J/s			
	N	kp	dyn		Nm	kWh	kpm	cal		W	kW	hp
1 N	1	0,102	10^5	1 Nm	1	$0,278 \cdot 10^{-6}$	0,102	0,238	1 W	1	10^{-3}	$1,36 \cdot 10^{-3}$
1 kp	9,81	1	$9,81 \cdot 10^5$	1 kWh	$3,6 \cdot 10^6$	1	$0,367 \cdot 10^6$	$0,86 \cdot 10^6$	1 kW	10^3	1	1,36
1 dyn	10^{-5}	$1,02 \cdot 10^{-6}$	1	1 kpm	9,81	$2,72 \cdot 10^{-6}$	1	2,335	1 hp	736	0,736	1
–				1 cal	4,19	$1,17 \cdot 10^{-6}$	0,428	1	–			

Tbl. 20 Conversion factors for force, energy, work, heat and power units

Pressure, mechanical tension

1 Pascal (Pa) = 1 N/m² : 1 MPa (10^6 Pa) = 1 N/mm² = 0,102 kp/mm²							
	Pa	MPa	bar	kp/cm²	mm Hg	atm	mWs
1 Pa = 1 N/m²	1	10^{-6}	10^{-5}	$1,02 \cdot 10^{-5}$	$7,50 \cdot 10^{-3}$	$9,87 \cdot 10^{-6}$	$1,02 \cdot 10^{-4}$
1 MPa = 1 N/mm²	10^6	1	10	10,2	$7,50 \cdot 10^3$	9,87	102
1 bar	10^5	0,1	1	1,02	750	0,987	10,2
1 kp/cm² (at)	9,81 · 104	$9,81 \cdot 10^{-2}$	0,981	1	736	0,968	10
1 mm Hg (Torr)	133	$1,33 \cdot 10^{-4}$	$1,33 \cdot 10^{-3}$	$1,36 \cdot 10^{-3}$	1	$1,32 \cdot 10^{-3}$	$1,36 \cdot 10^{-2}$
1 atm	1,013 · 105	0,1013	1,013	1,033	760	1	10,33
1 mWs	9,81 · 103	$9,81 \cdot 10^{-3}$	$9,81 \cdot 10^{-2}$	0,1	73,6	$9,68 \cdot 10^{-2}$	1

Tbl. 21 Conversion factors for pressure and mechanical tension units

units no longer permitted after 31.12.1977

Materials – Basics Concepts

Freudenberg processes highly elastic materials, polyurethane, thermoplastics and duroplastics to manufacture seals and moulded components.

General information on these materials is given below, particularly an overview of the materials, their structure and possible applications as well as their limitations in use.

- Natural and synthetic rubbers
  are high polymers, that can be changed to the highly elastic state by vulcanisation.

- Rubber and vulcanised rubbers are unspecified terms, which can be used to refer to base polymer as well as to vulcanised rubber. Vulcanisate is the vulcanised rubber.

- Elastomers
  are cross-linked polymers that are capable of absorbing large reversible deformations. They have the same meaning as vulcanised rubber.

- Thermoplastics
  are not cross-linked high polymers that can be permanently deformed by the action of pressure and temperature; they have a low degree of soft elastic properties.

- Thermoplastic elastomers
  are not cross-linked high polymers. The are processed like thermoplastics and have highly elastic properties.

- Duroplastics
  are highly cross-linked polymers that have hard elastic properties at very low deformation.

The main structural features of polymer materials are explained in detail in DIN 7724.

Codes

Overview of codes for materials

Elastomers		
Chemical name for the base polymers	Code according to	
	ASTM D 1418	ISO 1629
Acrylonitrile butadiene rubber	NBR	NBR
Hydrogenated acrylonitrile-butadiene rubber	HNBR	HNBR
Chlorine butadiene rubber	CR	CR
Carboxylated nitrile rubber	XNBR	XNBR
Acrylate rubber	ACM	ACM
Ethylene-acrylate rubber	AEM	AEM
Silicone rubber		
Methyl polysiloxane	MQ	MQ
Vinyl-methyl polysiloxane	VMQ	VMQ
Phenyl-vinyl-methyl polysiloxane	PVMQ	PVMQ
Phenyl-methyl polysiloxane	PMQ	PMQ
Fluorosilicone rubber		
Fluoromethyl polysiloxane	FVMQ	FVMQ
Fluoro elastomer	FKM	FKM
Perfluoro elastomer	FFKM	FFKM
Polyurethane rubber		
Polyester-urethane rubber	AU	AU
Polyether-urethane rubber	EU	EU
Ethyleneoxide-epichlorhydrin rubber	ECO	ECO
Epichlorhydrin polymer	CO	CO
Chlorosulfonated polyethylene	CSM	CSM
Natural rubber	NR	NR
Isoprene rubber	IR	IR
Polybutadiene rubber	BR	BR
Styrene-butadiene rubber	SBR	SBR
Ethylene propylene diene rubber	EPDM	EPDM
Ethylene propylene copolymer	EPM	EPM
Butyl rubber	IIR	IIR
Chlorobutyl rubber	CIIR	CIIR
Bromobutyl rubber	BIIR	BIIR
ASTM = American Society for Testing and Materials; ISO = International Organization for Standardization; DIN = Deutsches Institut für Normung e.V.		

Tbl. 22 Overview of codes for materials

Thermoplastics		
Chemical name of the base materials	Code according to	
	DIN 7728, Part 1, ISO 1043.1	ASTM D 1600
Polytetrafluoroethylene	PTFE	PTFE
Ethylene tetrafluoroethylene copolymer	E/TFE	E/TFE
Perfluoroalkoxy copolymer	PFA	PFA
Polyvinyl chloride	PVC	PVC
Acrylonitrile-butadiene styrene	ABS	ABS
Styrene acrylonitrile	SAN	SAN
Polypropylene	PP	PP
Polyamide	PA	PA
Polyoxymethylene (polyacetal)	POM	POM
Polyphenylene oxide	PPO	PPO
Polysulphone	PSU	PSU
Polyetherblockamide	PEBA	PEBA
Polyether ketone	PEEK	PEEK
Polyetherimide	PEI	PEI

Tbl. 23 Codes for thermoplastics

Thermoplastic rubbers	
Chemical name for the base polymers	ASTM code
	D 1418
Block polymer of styrene and butadiene	YSBR
Polyetherester	YBPO
Thermoplastic polyolefin	TPO

Tbl. 24 Codes for thermoplastic rubbers

Duroplastics		
Chemical name for the materials	Code according to	
	DIN ISO 1043.1	ASTM D 1600
Unsaturated polyester	UP	UP
Phenol formaldehyde	PF	PF
Urea formaldehyde	UF	UF
Glass fibre reinforced, unsaturated polyester resin	UP-GF	–

Tbl. 25 Codes for duroplastics

Freudenberg material codes

Materials from Freudenberg are named using codes and prefixed or suffixed code numbers, e.g. 72 NBR 902.
The prefix number describes the hardness of the material in Shore A.
The group of letters identifies the base polymer as per DIN/ISO 1629.
The number after the group of letters is an internal Freudenberg compound code number.

Summary of some trade names for elastomers and plastics

Elastomers	
Chemical name	Trade names
Acrylonitrile-butadiene rubber (NBR)	Perbunan, Hycar, Chemigum, Breon, Butakon, Europrene N, Butacril, Krynac, Paracril, Nipol, Nitriflex
Chlorine butadiene rubber (CR)	Neoprene, Baypren, Butaclor, Denka Chloroprene
Acrylate rubber (ACM)	Cyanacryl, Europrene AR, Noxtite PA, Nipol AR
Ethylene acrylate (AEM)	Vamac
Silicone rubber (VMQ, FVMQ and PVMQ)	Silopren, Silastic, Silicone, Rhodorsil
Fluoro elastomer (FKM)	Viton, Fluorel, Tecnoflon, Dai El, Noxtite
Perfluoro elastomer (FFKM)	Kalrez, Simriz, Chemraz
Polyurethane (AU and EU)	Vulkollan, Urepan, Desmopan, Adipren, Estane, Elastothane, Pellethane, Simputhan
Ethyleneoxide-epichlorhydrin rubber (ECO)	Epichlomer, Hydrin, Gechron
Styrene-butadiene rubber (SBR)	Buna Hüls, Buna SB, Europrene, Cariflex S, Solprene, Carom
Ethylene propylene diene rubber (EPDM)	Dutral, Keltan, Vistalon, Nordel, Epsyn, Buna AP, Royalene, Polysar EPDM
Butyl rubber (IIR)	Enjay Butyl, Esso Butyl, Polysar Butyl
Chlorosulfonated polyethylene (CSM)	Hypalon

Tbl. 26 Elastomers (trade names)

Plastics for seal applications	
Chemical name	Trade names
Acrylonitrile-butadiene styrene (ABS)	Cycolac, Novodur, Terluran
Acetal resin polyoxymethylene (POM)	Delrin, Hostaform C, Ultraform
Polyamide (PA)	Durethan, Dymetrol, Nylon, Rilsan, Ultramid, Vestamid
Polybutyleneterephthalate (PBTP)	Crastin, Pocan, Ultradur, Vestodur
Polyethylene (PE)	Alathon, Baylon, Hostalen, Lupolen
Polycarbonate (PC)	Lexan, Makrolon
Polyphenylene oxide (PPO)	Noryl
Polypropylene (PP)	Hostalen PP, Novolen
Polystyrene (PS)	Hostyren, Lustrex, Vestyron
Polytetrafluoroethylene (PTFE)	Algoflon, Fluon, Halon, Hostaflon, Teflon
Ethylene tetrafluoroethylene copolymer (ETFE)	Tefzel
Polyvinyl chloride (PVC)	Breon, Hostalit, Plaskon
Perfluoroalkoxy copolymer (PFA)	Teflon-PFA
Phenolic resin hard fabric	Ferrozell, Pertinax

Tbl. 27 Plastics for seal applications (trade names)

Classification according to ASTM D 2000/SAE J 200

This classification system is intended to assist the user in selecting the required materials from Freudenberg. It also enables the materials to be specified by using simple qualitative characteristics for Shore hardness, strength values, temperature and swelling behaviour, etc.

The following example illustrates the classification of the material 72 NBR 872 using this classification system. For detailed information on this system see the Annual Book of ASTM Standards "Rubber" Volume 09.01 and 09.02.
The ASTM classification for the individual Freudenberg materials can be found in the tables.

72 NBR 872 = M2 BG 714 B14 B34 EA14 EF11 EF21 EO14 EO34 F17		
Basic requirements		
M 2 BG 714		
M	=	values in SI units
2	=	quality
B	=	type (specified by heat resistance)
G	=	class (specified by resistance to swelling)
7	=	hardness as per Shore A = 70 ± 5
14	=	tensile strength = 14 MPa
Supplementary requirements		
B 14		
B	=	compression set
1	=	test duration 22 hours, solid test specimens
4	=	test temperature 100 °C
B 34		
B	=	compression set
3	=	test duration 22 hours, laminated test specimens
4	=	test temperature 100 °C
EA 14		
EA 1	=	swelling in distilled water, test duration 70 hours
4	=	test temperature 100 °C
EF 11		
EF 1	=	swelling in reference fuel A (isooctane), test duration 70 hours
1	=	test temperature 23 °C
EF 21		
EF 2	=	swelling in reference fuel B (isooctane): toluene/70:30), test duration 70 hours
1	=	test temperature 23 °C
EO 14		
EO 1	=	swelling in ASTM oil no. 1, test duration 70 hours
4	=	test temperature 100 °C
EO 34		
EO 3	=	swelling in IRM 903*, test duration 70 hours
4	=	test temperature 100 °C
F 17		
F 1	=	test of low temperature resistance method A, test duration 3 min.
7	=	test temperature −40 °C
* replacement product for ASTM oil No. 3		

Tbl. 28 Classification of a material from Freudenberg by example of 72 NBR 872

Testing and Interpretation Test Results

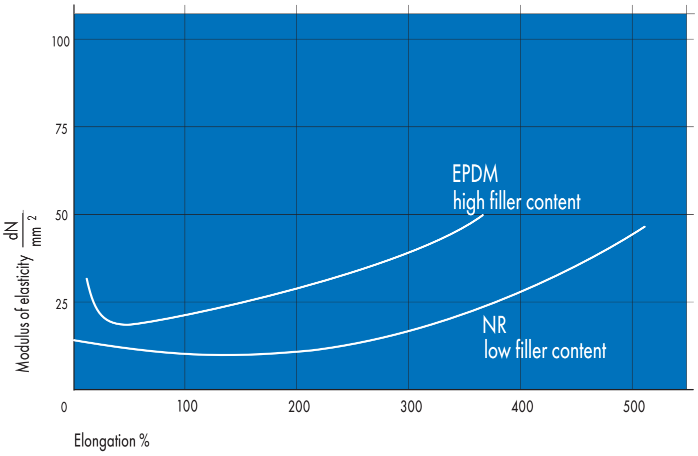
Highly elastic materials differ from other material not simply by the fact that they are "elastic". The properties are different in many aspects. The usual terminology from materials testing such as hardness or tensile strength must be interpreted differently by the engineer. New terms such as ageing resistance or deformation speed appear. There are virtually no constants; most properties are highly dependent on the temperature and other external factors, some are even dependent on the size and structure of the relevant test specimens or moulded parts.
There is a large number of synthetic rubbers. And these have a yet larger number of variations in the material composition. However, there are limits to how material properties can be combined. As an example, with NBR it is not possible to combine high oil resistance with optimum low temperature behaviour.
A range of material properties is interlinked due to chemical and physical reasons. If one property is changed, then other properties inevitably change as well. This may be an advantage for the specific application, but it may also have disadvantages. Taking this aspect into consideration, unnecessary requirements should not be placed on the material when drawing up specifications. This approach smoothes the way to a material to suit the requested application.

Physical properties

Hardness

The most common parameter 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 Freudenberg are generally tested to Shore A.
In the test laboratory the measurements are performed under the conditions specified by 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, usable relative or comparable values can be obtained if the standards are observe, and the following is heeded during measurements:

Higher measured values will be obtained if the sample is not thick enough.
The same applies if the contact pressure is too high. Conversely, measurements too close to the edge, e.g. on moulded parts that are too small, yield excessively low values.
The test specimens should be as flat as possible and not lie with a cavity. Always keep the sample and the measuring instrument parallel and observe the time for taking readings accurately.
Another measurement method in the test laboratory is to determine the international rubber hardness degrees (IRHD; DIN ISO 48) by means of the measurement of the penetration depth of a defined sphere under a defined force. With highly elastic materials the IRHD value is approximately equal to the Shore A hardness. Measured values determined by the two methods may be very different for materials that tend to be subject to plastic deformation.
A variant of this method with correspondingly reduced sphere diameter (0,4 mm) makes it possible to measure small and thin samples (referred to as micro-hardness, DIN ISO 48 Method M). This method is frequently used for measuring manufactured components. With this method there are, in addition to the above mentioned differences due to the various measurement processes, effects due to also additional influences resulting from the differences of the specimen surface caused the various measurement processes (unevenness, e.g. by grinding, curves because of the geometry of the component, surface hardening, coefficient of friction), which can result in even greater differences in values. Measured values derived from finished components generally do not conform to the values measured on the standard test specimens. When stating the hardness the measurement method must always be included, e.g. hardness 80 Shore A or hardness 72 IRHD.
When testing the hardness of finished components the method must always be precisely defined by the supplier and the customer to prevent inaccuracy.
The tolerance for hardness measurements and hardness figures is generally ±5 degrees of hardness. This apparently relatively large range is necessary to take into account differences in various devices and testers and also the unavoidable production scatter.



Graph 1 Dependency of the modulus of elasticity on deformation (tensile trials) for two different vulcanisation processes

Tensile stress and modulus of elasticity

Like the hardness, tensile stress and modulus of elasticity are parameters for the deformability of elastic materials. The tensile stress measured in tensile trials in accordance with DIN 53504 at 100 or 300% elongation is defined as the force required for the related deformation divided by the original cross-section of the test specimen. The tensile stress is frequently incorrectly described as "modulus". The modulus of elasticity or elongation modulus is the tensile stress divided by the relative change in length (elongation). It is not a constant for highly elastic materials. Hooke's law $\sigma = E \cdot \varepsilon$, according to which the tension σ is proportional to the elongation ε, where the modulus of elasticity E represents the proportionality constant, is applicable to rubber only in a very limited deformation range, which can be different from material to material. The modulus of elasticity can increase and decrease with the elongation → Graph 1.

The modulus of elasticity depends on the so called form factor, the ratio of loaded to unloaded surface on the component or test specimen. In this regard the loaded surface is considered to be an area under tension or compression (without the mating surface) and the unloaded area is the total of all areas where the specimen can freely stretch or compress. Both areas are measured in unloaded status. Thus the form factor F for an axially loaded cylinder is

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

Additional modules

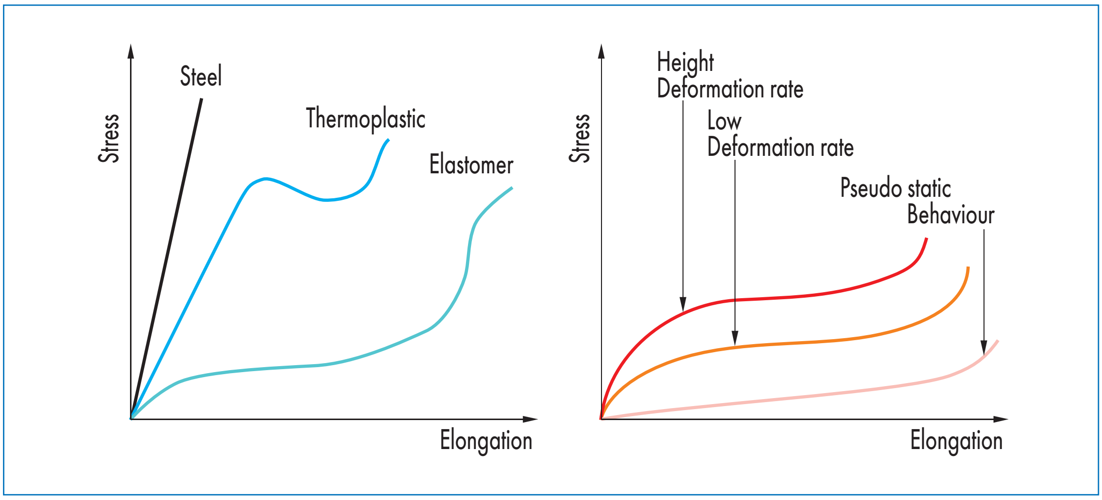
Other modules are also significant for the deformation properties. Shear modulus or modulus of elasticity in shear and dynamic moduli are important for vibration processes. They will not be described in more detail here.
Test procedures are defined in publications such as DIN 53513, DIN EN ISO 6721 and ASTM D 945 (YERZLEY testing).

Relationships between deformation properties and their parameters

Based on the prior statements, only an approximate relationship can be expected between the individual measurement parameters. The following approximation is applicable for shear modulus G and modulus of elasticity E, for highly elastic materials

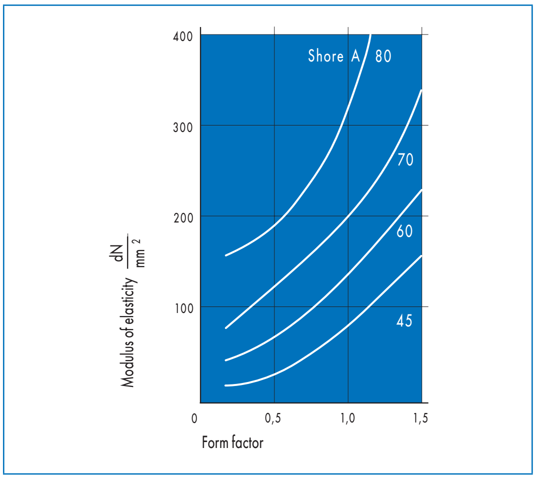
G = 1/3 E.

The approximate relationship applies between the hardness in Shore A or IRHD and the modulus of elasticity at 5–10% compression, which is shown graphically in → Graph 4 .



Graph 2 Tension-elongation graph.
Left: comparison of steel, thermoplastic, elastomer
Right: behaviour of elastomers at different deformation speeds.

However, the hardness is not generally related with the moduli for larger deformations, even if in general a material with greater hardness has higher moduli at the same time.
The common factor in all deformation properties is that they are highly dependent on temperature and time. Time-dependency means that the speed of deformation (e.g. withdrawl velocity in tensile trials or the frequency for the dynamic modulus) or the time at which the measured value is read (e.g. measurement of hardness) affect the measured values.



Graph 3 Dependency of the modulus of elasticity on the form factor (20% compression) at various hardness

There is no such thing as "the" modulus of elasticity of a highly elastic material, which is occasionally requested!

Tensile strength and elongation at break

These values are only limited qualitative characteristics for assessing possible application options and service life of elastomer components, because only in exceptional cases are they subject to tensions or elongations that come close to the fracture values of the material. For example, in diaphragms the elongation near the clamping flange can reach very high values, which can lead to premature failure. In such cases the solution of the problem is not only to be found in the material but also in the design, as shown at the beginning of this chapter.
The values for tensile strength and elongation at break determined in accordance with DIN 53504 are used to compare the characteristics of materials, for identification and operation inspection as well as for determining the 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 ISO 34-1 as the force that is applied to a defined specimen for tear propagation based on the

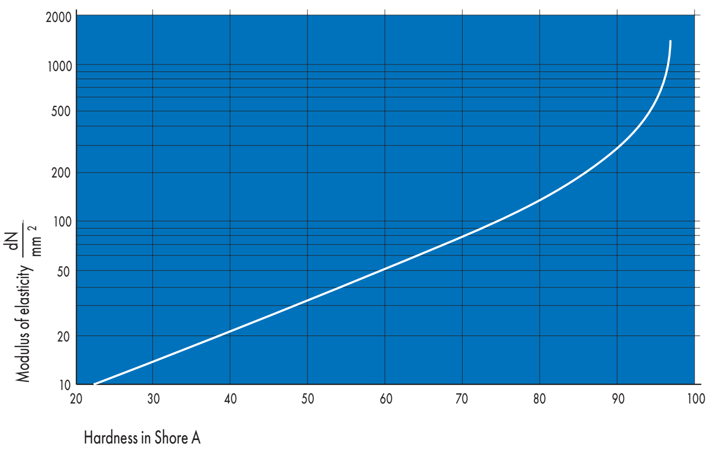
thickness of the sample. The values found here are to be used as a scale for the sensitivity of elastomers to tear propagation of cuts or cracks and are not required along with the tensile strength.
Because the results of the tear propagation test depend strongly on the specific test conditions and particularly on the shape of the specimen, the sequence used in the laboratory on the laboratory specimens for the various test methods does not need to match the sequence in practice. The test procedures and specimen shape must be given with the derived measured values.

Elasticity and damping

The elasticity is, like the deformability, dependent on the temperature and particularly on the time sequence of the deformation process. The testing of impact elasticity for sealing components in accordance with DIN 53512 does not tell the user much about the elastic behaviour under operating conditions. It is frequently more useful to measure the spring back or the lasting deformation under test conditions, which can be selected in accordance with the operating conditions.
The mechanical damping is the reciprocal property to the elasticity. It can be determined using the method given for the measurement of the dynamic modulus.
A body is elastic if it resumes its original shape immediately after a forced deformation (e.g. steel spring). A body that retains its deformation is plastic or viscous (e.g. plasticine). A viscous-elastic component is comparable to both, where the elastic predominates in the case of highly elastic materials. A key feature of viscous-elastic behaviour is that the spring back to the original status does not occur immediately on release, but it is only attained gradually depending on the conditions. This is also significant for sealing components and can be specified by appropriate laboratory tests. The viscoelasticity is the actual cause for the specific physical behaviour of the highly elastic materials. Typical viscous-elastic characteristics are compression set, tensile relaxation and creep (→ Graph 7 and → Graph 9).

Other physical properties

Physical properties such as thermal expansion, friction behaviour, electric characteristics, permeability to gases or fluids etc. may be important for special applications. These issues will not be covered in further detail here.



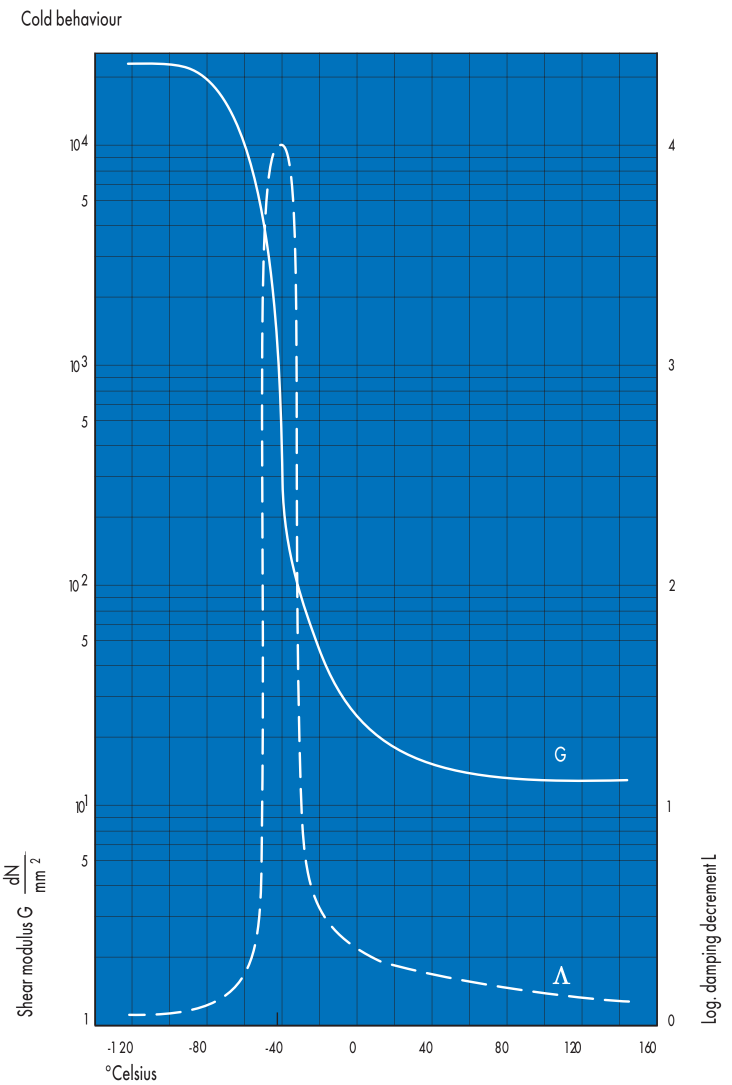
Graph 4 Relationship between hardness in Shore A and modulus of elasticity at approximately 10% compression set (form factor 0,2)

Temperature behaviour

As previously mentioned, the temperature has a significant influence on the physical properties of the highly elastic materials. → Graph 5 shows the dependence of the dynamic shear modulus G on the temperature (shear modulus measured in the torsion vibration test in accordance with DIN EN ISO 6721). The highly elastic region can be seen from right to left with an almost constant modulus, then with a steep rise the transition range and finally there is the glass state region, in which the rubber is hard and brittle, again with an almost constant modulus. When the temperature rises the cold brittleness disappears. The freezing process is therefore reversible. The transition from highly elastic to the glass state is particularly important, because in many cases it shows the low temperature limit. This transition, as shown in → Graph 4, is not sharp but extends over a specific range.

The range of the transition from the highly elastic range to the glass state is characterised by the glass transition temperature T_g (temperature of maximum of log. damping decrement Λ). However, this value can only be a general reference for the low temperature limit of the material, because in the practical application of an elastomer component it depends completely on the type of load involved. The same material will reach its load limit at a higher temperature when subjected to a sudden load at very high deformation speed than, for example, during a slow deformation. The torsion vibration test can be used to differentiate between different materials, but the temperature limit in practice must be tested when using the corresponding components.

Example:
With static contact seals heat is produced by the friction that occurs during motion. At temperatures where the risk of hardening due to freezing already exists, the frictional heat can suffice to keep the seal elastic, or quickly place the seal in a functional operating state after start of the motion. The testing of the low temperature behaviour is only worth while in the form of a material comparison in conjunction with experience on the engineering application.
The differences between various materials for low temperature use limits derived from the torsion vibration test and from use in practice are very close in many cases. If the cold limit for a material has been determined in practical trial (frequently very difficult to determine), the T_g values for the other materials can be used to make relatively reliable forecasts of their low temperature behaviour under practical use.



Graph 5 Torsion vibration test in accordance with DIN 53 445.
Dynamic shear modulus G and logarithmic decrement Λ of a material from Freudenberg based on CR

The situation is similar for the comparison of standard cold values that were measured under different laboratory test methods as for the comparison between the low-temperature limits determined in practical use and the glass transition state temperature measured in the torsion vibration test. Deviations of only a few degrees but also of 30 to 40 degrees can be found between different test methods.

The standard cold value must always include the measurement method used to determine it. The same methods as described above are applicable for transfer to the component behaviour in practical use. Various standard laboratory methods for characterising the low-temperature behaviour are described briefly below:

Differential Thermo-Analysis (DTA), Differential Scanning Calorimetry (DSC)

In this method (DIN 3761 Part 15) a small rubber specimen and an inert reference specimen are heated at a constant heating rate. The temperature difference between the sample and the reference sample is applied to the temperature. A constant of negative temperature difference is specified by change of the specific heat of the rubber material when the glass transition range is reached. The turning point of the glass stage of the DTA curve defines the standard cold value T_R.

Temperature retraction test

In this test (ASTM D 1329-79) a rod-shaped rubber specimen in elongated state is frozen in a temperature controlled bath and temperatures T_R 10, T_R30, ... are measured at which the elongation of the sample has been reduced by 10, 30, ... percent.

Cold brittleness temperature with impact load

The cold brittleness temperature T_s (DIN 53 546) is the temperature at which (after an increase in the temperature of surrounding coolant) all test specimens just do not break under a defined impact loading.
In addition information on the low-temperature behaviour can be derived from relatively simple tests. Examples are the cold bending test over a mandrel at a defined bending speed or the Shore hardness measurement at various temperatures.

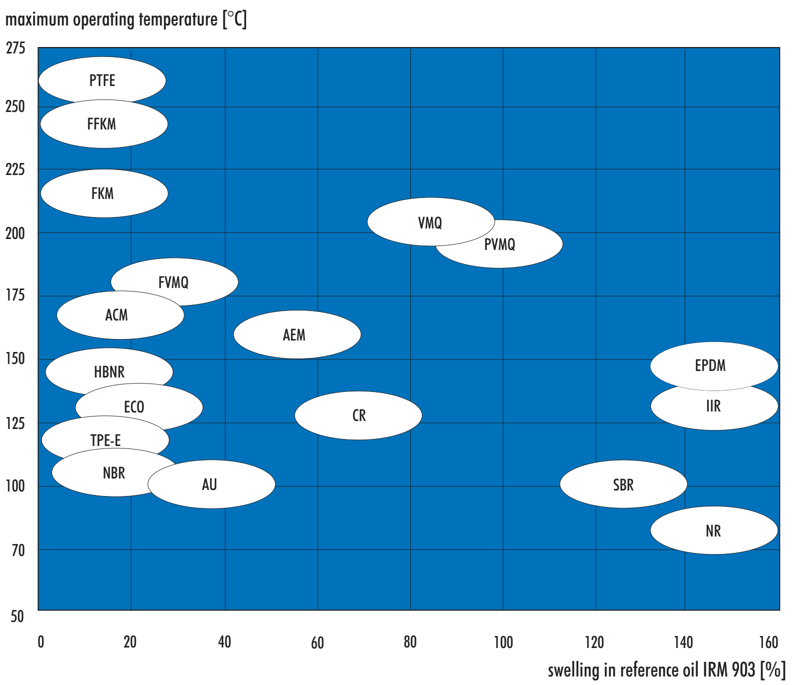
For example, the temperature at which the Shore A hardness is 90 points can be defined as the standard cold temperature. The sequence of the compression set at low temperatures also provides information on the temperature flexibility of the material. For example, the temperature at which the compression set is at 50% can be defined as the standard cold temperature.

Media resistance

The changes to the highly elastic materials caused by environmental and/or operating conditions are often much more significant than the initial values of the technological properties. The behaviour of the materials must be tested under practical conditions.

Swelling and chemical corrosion

The correct choice of a suitable material for seals frequently depends on the chemical resistance and the swelling behaviour of the material. The user should always be aware of which fluids or gaseous media come into contact with the material. The temperatures of the media also play an important role. The consequences of a chemical effect are similar to those of ageing in hot air, i.e. softening or hardening, reduction of strength, elongation at break and elasticity, loss of tension and creep. Another result is volumetric change by swelling or shrinkage depending on whether additional materials are absorbed or extractable substances are dissolved out. A minor increase in volume by swelling is not a danger to the function of the elastomer seal with suitable design. In contrast, volume shrinkage will adversely affect the sealing function in the form of leakage. There are no elastomers that meet all requirements for oil resistance, heat and cold resistance equally. Therefore, the ambient medium and the temperature conditions of the application must be considered when selecting a suitable sealing material. The basic chemical principle applies: "the same substance dissolves the same substance". This means that polar elastomers (e.g. NBR) in polar media (e.g. glycol) swell greatly while non-polar elastomers such as EPDM in non-polar media (e.g. mineral oil) are not resistant. For more information on the suitability of elastomer materials in selected sealing media see the appendix to this chapter.



Graph 6 Heat and oil resistance (in ASTM Oil No. 3) of elastomers (in accordance with ASTM D 2000)

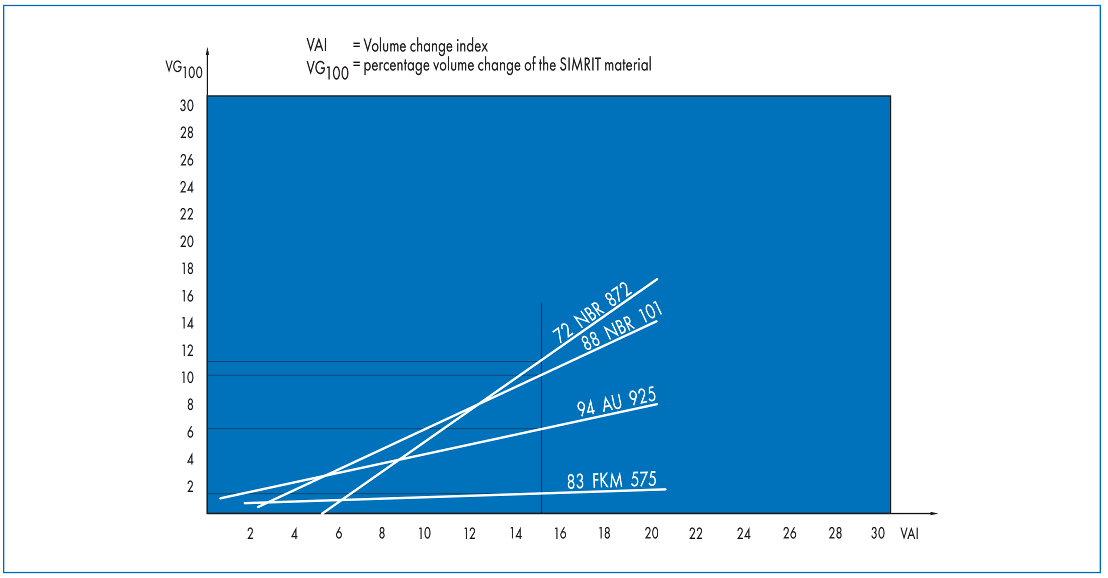
The testing behaviour against fluids, steams and gases is performed in accordance with DIN ISO 1817 in the medium used in the application, or in standardised testing fluids (e.g. ASTM Oil No. 1, IRM 902* and IRM 903**, ASTM Reference Fuel A, B and C, FAM test fuels).

* Replacement product for ASTM Oil No. 2
** Replacement product for ASTM Oil No. 3

Volumetric change index

The regularity of the swelling effect of mineral oils in contact with highly elastic materials can be tested on standard reference elastomers. Such a NBR standard reference elastomer (SRE) has already been proposed as test material NBR 1 and is also standardised under DIN 53538. The volumetric change determinated on this SRE under standardised conditions in a mineral oil is referred to as the volumetric change index (VA) of the tested oil in accordance with a VDMA proposal.

If an elastomer material is left to swell to its saturation state in any oils, there is a linear relationship between the observed volumetric change of the elastomer in the oils and the volumetric change determined on the standard reference elastomer (SRE) in the same oils, i.e. the VAI of the oils, observed under similar conditions. If the maximum volumetric change of an elastomer in various oils is plotted on a coordinate system over the VAI values of the same oils, a straight line is derived that characterises the swelling behaviour (QVH) of the elastomer. A straight QVH line can be plotted for every elastomeric material. The maximum volumetric changes of the associated elastomers can be forecast for all oils with known VAI. These QVH straight lines are available for all materials from Freudenberg. Using this diagram, materials being considered for the respective applications can be combined with the suitable oils. The volumetric change index (VAI) is not specified by the oil manufacturers.



Graph 7 Swelling behaviour of materials from Freudenberg

Example: the following volumetric change values occur in a mineral oil with VAI 15:

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

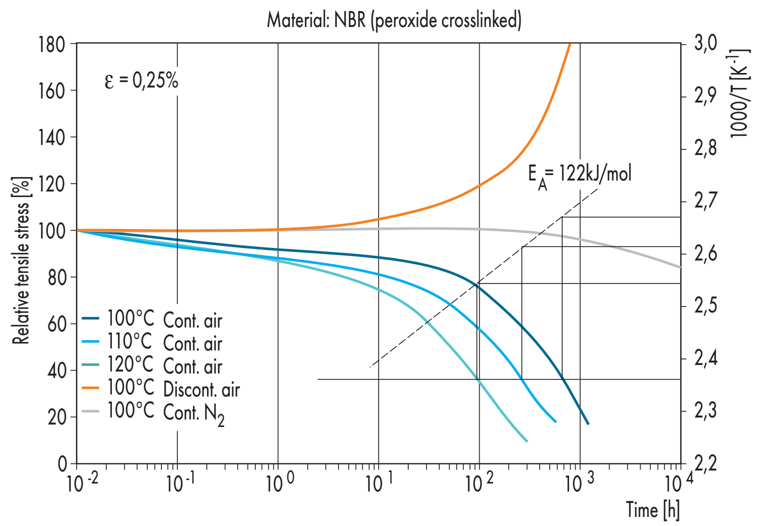
Heat resistance, ageing behaviour

Like all organic chemical products, the polymers on which highly elastic materials are based can be altered by the action of oxygen, wear and/or other media. As a result of these processes, referred to as ageing, important properties such as hardness, flexibility, elasticity can be adversely changed. The material can become susceptible to cracking and may break.
Heat accelerates the ageing processes. Exposure to light and radiation may also have destructive effects. The higher the temperature to which the material is subjected the lower the service life of a component. This means that there are different permissible maximum operating temperatures for short-term and continuous loading for the individual materials.

The respective limits depend primarily on the base polymer. Ageing can be tested over a reduced period by storage in a heating cabinet (DIN 53508). However, the test temperature and the actual operating temperature should be too different.
The changes in hardness, tensile strength and elongation at break as well as the compression set or the tensile relaxation are included in the assessment of the ageing behaviour.

Chemical tensile relaxation

An exact assessment of the ageing behaviour and an in-depth examination of the ageing mechanism enables measurement of the chemical tensile relaxation at various temperatures. Comparative measurements are also conducted in nitrogen or in fluid media to allow a better assessment of the various chemical ageing influences. An Arrhenius plot of the results enables extrapolation to long exposure periods at lower temperatures.



Graph 8 Predicted service life based on extrapolation of measured values of the tensile stress relation (material: NBR wetted with peroxide) measured in air and nitrogen at various temperatures. E = elongation, E_A = activation energy of the ageing process.

In thick test specimens the diffusion of the oxygen or ozone into the elastomer is the limiting factor for destruction of the elastomer matrix and the associated ageing processes. Therefore, thick elastomer components age more slowly than thin components in practice.
The known crack formation on stretched rubber parts exposed to weather is primarily caused by the ozone in the air. Procedures for testing ozone resistance are described in DIN 53509.

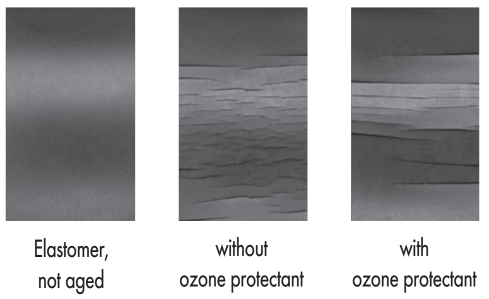


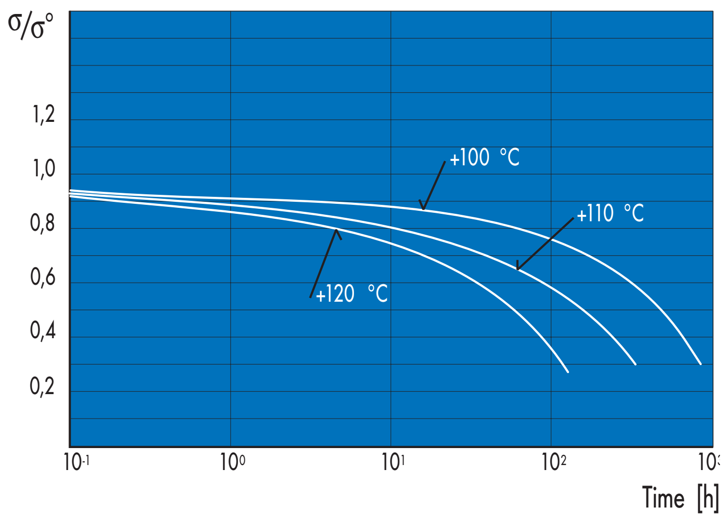
Fig. 61 Damage to elastomer by the effect of ozone

Service life

Static continuous load and continuous deformation

If an elastomer component is constantly deformed for a period, a certain degree of deformation remains after relaxation. The residual deformation, which is measured in a compression test in accordance with DIN ISO 815 and is given as a percentage of the original deformation, is referred to as compression set.

The compression set depends largely on the temperature and the duration of deformation. At lower temperatures the influence of the viscoelasticity is stronger and at higher temperatures the influence of ageing (for more information see → Explanation of DIN ISO 815).



Graph 9 Compressive stress relaxation of an elastomeric material at various temperatures

The compression set can be connected with the function of sealing components in same cases, e.g. for O-rings.
The flow behaviour, the vulcanisation status and the heat resistance influence the test value. This means that the measurement of the compressive stress relaxation is more suitable (DIN 53537), because it gives a direct scale for the reduction of the contact pressure over time of a constantly deformed seal.
If highly elastic components are under constant load instead of constant deformation, the deformation increases over time. This is referred to as creep.
Compression set, tensile relaxation and creep are related phenomena with the same causes. If the test temperatures for the base polymer are below the maximum permissible continuous operation temperature, compressive stress relaxation and creep follow an approximate logarithmic time law, i.e in practical terms they come to a stop after some time.

Dynamic loading, fatigue and service life

Destruction of rubber parts is the result of dynamic loading far more often than exceeding the strength or elongation limits once. Under continuously repeated deformation, the material is damaged as a result of internal friction, where initially small cracks can occur, which grow and ultimately lead to fracture.
Standardised methods for test conditions are specified in publications such as DIN 53522 and 53533.

Resistance to wear

This important property for friction loading is also strongly dependent on the operating conditions, such as the type of lubrication, material and roughness of the mating surface, sliding speed, slip, contact pressure, temperature.
Wear tests should therefore only be conducted with the finished product and under conditions as close as possible to the operating conditions.

Material models

The measured mechanical, thermal and dynamic values are the basis for the development of material models. Other than,for example, metal and ceramic materials, there is no linear connection between tension and elongation for elastomers. As a result it is not sufficient to use linear-elastic material models for simulations. Special models, referred to as hyperelastic material models, are used. They can be used to describe the behaviour of even very large elongations.

In addition to the static non-linear behaviour of elastomers the stiffness of the material depending on the speed of loading must be considered. Freudenberg has developed optimised material models for this purpose, which are still applicable for larger material deformations (>150%).

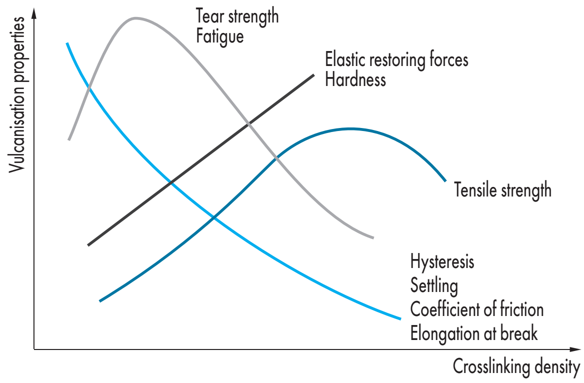
Additional information from component analyses and ageing tests lead to numerical analyses that give a comprehensive view of the service life of elastomer seals. Simulations with appropriate FEM models are used for optimising the topology and shapes of mechanically loaded components with consideration of moderate non-linearities and assurance of component function. For more information please contact your Freudenberg representative.

Properties of seal materials

The properties of a Freudenberg material are primarily determined by the base polymer. However, they can be varied in many ways depending in the mixing ration and can be adapted to the required application.

Cross-linking density

The cross-linking system determines the processing properties, the chemical structure of the polymer network and the physical properties of the elastomers. The two most common cross-linking types are sulphur cross-linking and peroxide cross-linking. Sulphur cross-linking is used primarily in cross-linking diene rubbers such as NR, SBR, BR, NBR or CR. Peroxide cross-linking can be used to cross-link rubbers without double links in the main chain. It also offers improved heat resistance, particularly with NBR. In addition to the rubber type, the degree of linked chemical inks between the polymer chains during vulcanisation depends primarily on the type and amount of the selected cross-linking system and is referred to as cross-linking degree or cross-linking density. The cross-linking density is very important for material properties such as hardness, tensile strength, elongation at break, friction, shrinkage behaviour and fatigue. With increasing cross-linking density modulus of elasticity, hardness and elasticity increase, while elongation at break, damping, lasting deformation decrease, and resistance to tear propagation and tensile strength reach and pass through a maximum.



Graph 10 Influence of cross-linking density on the elastomer properties

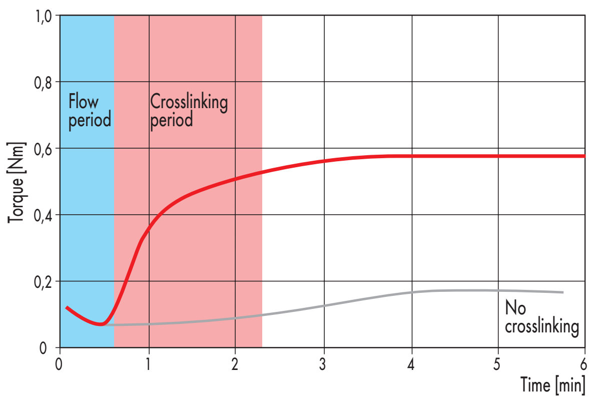
This means that at a specific cross-linking density an optimum for all material properties cannot be achieved. In general the cross-linking density is selected to achieve the appropriate physical properties for the application. The cross-linking reaction can be measured over time and used for assessment of the cross-linking degree by measurement of the torque, which is approximately proportional to the cross-linking degree. The vulcameter curve shows information on the mixture viscosity at the vulcanisation temperature. Three characteristic sections are distinguished: → Graph 10.

1) The flow period covers the time interval from the start of measurement to the start of cross-linking, i.e. to the increase of torque. It identifies the range of viscous flow, which is used to fill the mould. During this period the torque initially decreases.

2) The cross-linking period shows information on the required times for the material to transition to the stable shape status.

3) Complete cross-linking is achieved when all possible cross-linking points have formed.

The characteristic properties and the resulting main areas of application of materials from Freudenberg are described in general terms below. Refer to the material tables for more detailed differences between individual materials.



Graph 11 Cross-linking characteristics of elastomers by measurement of the torque

General Material Descriptions

Elastomeric materials

ACM (Acrylate rubber)

It is a polymer made of ethyl acrylate or butyl acrylate with a minor addition of the monomers required for cross-linking. Elastomers based on ACM are more heat resistant than those based on NBR or CR. Simmerrings, O-Rings and moulded components made of material based on ACM are primarily used at higher temperature ranges and in oils with additives for which materials from Freudenberg of NBR are no longer sufficient, however materials based on fluorine elastomer and silicone rubber are not yet necessary. Resistance to ageing and to ozone are very good.

- Good swelling resistance in: mineral oils (engine, gearbox, ATF oils), also with additives.
- Heavy swelling in: aromatic and chlorinated hydro-carbons, alcohols, brake fluids with a glycol ether base, flame retardant hydraulic fluids. Hot water, steam, acids, alkalis, and amines have a destructive effect on the material
- Thermal application range: approx. −25 °C to +150 °C.

AEM (Ethylene-acrylate rubber)

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 with additives and based on paraffin, water and coolants. Good resistance to weather and ozone
- Heavy swelling in: ATF and transmission oils, mineral oils rich in aromatics, brake fluid on a glycol ether base, concentrated acids and phallic acid esters
- Thermal application range: approx. −40 °C to +150 °C.

AU (Polyurethane)

Polyurethane is a highly molecular organic material, in which the chemical structure is characterised by a large number of urethane groups. within specific temperature limits polyurethane has the characteristic elastic properties of rubber. Three components characterise the structure of the material:

- polyol
- diisocyanate
- chain extender.

Depending on the type, amount and reaction condition they are the determining factors for the properties of the resulting polyurethane material.
Polyurethanes have the following properties:

- high mechanical strength
- good wear resistance
- modulus of elasticity variable over a wide range
- good flexibility
- wide hardness range with good elasticity, (polyurethane closes 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, aliphatic hydro-carbons
- application temperature range −30 °C to +80 °C, high-load resistant types up to above +100 °C in mineral oils.

Not resistant to polar solvents, chlorinated hydrocarbons, aromatics, brake fluids with glycol ether base, acids and alkalis.

BR (Polybutadiene rubber)

It is a polymer made of butadiene. It is characterised by high elasticity, abrasion resistance, very good heat and cold resistance properties and light elongation at break.
It is used as blending agent with NR and SBR for tyres, drive belts, conveyor belts etc.

- Good swelling resistance in: dilute acids and bases, in alcohols and water.
- Heavy swelling in: hydro-carbons
- Thermal application range: approx. −60 °C to +100 °C.

CSM (Chlorosulfonated polyethylene)

- Good swelling resistance in: hot water, steam, water lye, oxidising media, acids, bases, polar organic media, ketones, flame retardant hydraulic fluids of the Group HFC and some types of the Group HFD, brake fluids on a glycol ether base
- Average swelling resistance in: aliphatic hydro-carbons and greases. Resistant in oxidising media, inorganic and organic acids and bases
- Heavy swelling in: aromatic and chlorinated hydro-carbons and esters
- Thermal application range: approx. −20 °C to +120 °C.

CR (Chlorine butadiene rubber)

It is a polymer based on chlorine butadiene. Elastomers with corresponding composition of Compound are characterised by chemical resistance, good resistance to ageing, weathering, ozone and flame resistance.

- Good swelling resistance in: mineral oils with high aniline point, greases, many refrigerants and water (with special composition of Compound)
- Average 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, ketones
- Thermal application range: approx. −45 °C to +100 °C depending on composition (transient up to 130 °C).

ECO (Ethyleneoxide-epichlorhydrin rubber) CO (Polyepichlorhydrine)

It is a polymer made of epichlorhydrine and ethylene oxide. Materials based on this rubber are characterised by low gas permeability, good resistance to ozone and weathering.

- Good swelling resistance in: mineral oils and greases, plant and animal-based oils and greases as well as aliphatic hydro-carbons, such as propane, butane etc. and petrol as well as water
- Heavy swelling in: aromatic and chlorinated hydro-carbons, flame retardant hydraulic fluids of the Group HFD
- Thermal application range: approx. −40 °C to +140 °C.

EPDM (Ethylene propylene diene rubber)

It 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. Moulded parts and sealing components made of EPDM are preferred in washing machines, dishwashing machines and plumbing fittings. Seals made of this material are also used in hydraulic system with flame retardant hydraulic fluids of the Group HFC and Group HFD and in hydraulic brake systems. Elastomers made of EPDM have good resistance to ozone, ageing and weathering and are therefore ideal for manufacture of profile strips and sealing strips that are exposed to weathering.

- Good swelling resistance in: hot water, steam, water lye, oxidising media, acids, bases, polar organic media, ketones, flame retardant hydraulic fluids of the Group HFC and some types of the Group HFD, brake fluids on a glycol ether base
- Heavy swelling in: mineral oils and greases, petrol and aliphatic as well as aromatic and chlorinated hydro-carbons. Special lubricants are required for extra lubrication of the seals
- Thermal application range: approx. −50 °C to +150 °C.

FFKM (Perfluoro elastomer Simriz)

Special perfluorinated (i.e. completely free of hydrogen) monomers and corresponding compounding and process technologies can be used to manufacture materials with highly elastic properties that are very close to PTFE in media resistance and thermal resistance. Seals made of perfluororubber are used everywhere extreme safety standards are applicable and higher maintenance and repair costs exceed the price of the seals. Preferred areas are the chemical industry, oil-producing and processing industry, instrumentation and power station construction and aerospace industry.

- Thermal application range: −15 °C to +230 °C.

FKM (Fluoro elastomer)

Polymerisation of vinylidene fluoride (VF) and selective application of variable proportions of hexafluoropropylene (HFP), tetrafluoroethylene (TFE), 1-hydropentafluoropropylene (HFPE) and perfluor (methylvinylether) (FMVE) can be used to manufacture co, ter or tetrapolymers with various structures and fluoro content of 65–71% and as a result with different media resistance and cold flexibility. They are cross-linked by diamines, bisphenols or organic peroxides.

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

The gas permeability is low. In vacuum conditions elastomers made of FKM show minimum weight loss. The resistance to ozone, weathering and light tearing is very good, as is the flame resistance.

Amines may have a destructive effect on the material and require a selection of suitable types as well as special composition of compound. A special elastomer group is copolymers made of TFE and propene with a relatively low fluoro content (57%). Materials using these elastomers have outstanding resistance to hot water, steam as well as amines or media containing amines with low swelling resistance to mineral oils.

- Good swelling resistance in: mineral oils and greases (including with most additives), fuels as well as aliphatic and aromatic hydro-carbons, some flame retardant hydraulic fluids and synthetic aeroplane engine oils. Newly developed peroxide cross-linked materials also have good resistance to media that have little or no compatibility to conventional FKM. For example, they are: alcohols, hot water, steam and fuels containing alcohol.
- Heavy swelling in: polar solvents and ketones, flame retardant hydraulic fluids, type: Skydrol, brake fluid on a glycol ether base
- Thermal application range: approx. −20 °C to +200 °C (transient up to +230 °C).
  Special types: −35 °C to +200 °C.

With suitable shaping and material compositions specially developed for such applications seals and moulded components can also be used at lower temperatures.

FVMQ (fluorosilicone rubber fluoromethyl polysiloxane)

It is a methyl vinyl silicone rubber with fluorine-containing groups. 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 application range: approx. −80 °C to +175 °C (transient up to +200 °C).

HNBR (Hydrogenated acrylonitrile-butadiene rubber)

Made of normal NBR polymer by full or partial hydrogenation of butadiene components containing double bonds. With peroxide cross-linking this increases the heat and oxidation stability. High mechanical strength and improved abrasion resistance characterise the materials manufactured of it. Media resistance similar to NBR.

- Thermal application range: approx. −30 °C to +150 °C.

NBR (Acrylonitrile-butadiene rubber)

It is a polymer made of butadiene and acrylonitrile. The acrylonitrile content can be between 18 and 50% and it influences the following properties of the NBR sealing materials manufactured of it:

- swelling resistance in mineral oils, greases and fuels
- elasticity
- cold flexibility
- gas permeability
- compression set.

For example, an NBR material with 18% ACN content has a very good low-temperature flexibility up to approx. −38 °C with moderate oil and fuel resistance, while one with 50% ACN content and optimum oil and fuel resistance only has low-temperature flexibility up to only approx. −3 °C. With increasing ACN content the elasticity and gas permeability is reduced while the compression set is worse.
Materials from Freudenberg based on this synthetic rubber are suitable for a very large number of applications with their good technological properties. In particular, the proven Simmerrings, sealing components for hydraulics and pneumatics as well as O-Rings are manufactured in large numbers of materials based on NBR. Freudenberg has more experience than all other seal manufacturers with 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 mineral-oil-based grease, flame retardant hydraulic fluids of the HFA, HFB and Group HFCs, plant and animal-based oils and greases, light heating oil, diesel fuel. Some materials are particularly resistant to: hot water up to temperatures of +100 °C (sanitary valves), inorganic acids and bases at reasonable concentration and temperature.
- Average swelling resistance in: fuels with high aromatic content (super fuels).
- Heavy swelling in: aromatic hydro-carbons, e.g. benzene, chlorinated hydro-carbons, e.g. trichlorethylene, flame retardant hydraulic fluids of the Group HFD, esters, polar solvents as well as in brake fluids on a glycol ether base.
- Thermal application range: depending on the composition of compound between −30 °C and +100 °C, transient up to 130 °C; at higher temperatures the material hardens. With special mixtures the cold flexibility is up to −55 °C.

NR (natural rubber)

It is a high polymer isoprene. The vulcanisates are characterised by high mechanical strength and elasticity as well as good low temperature behaviour. It is preferably used in manufacture of torsional oscillation dampers, engine mounts, machine bearings, rubber-metal suspension components, diaphragms, moulded parts etc.

- Good swelling resistance in: acids and bases at low concentration as well as in alcohols and water at not excessively high temperatures and concentration. Brake fluids on 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 hydrocarbons.
- Thermal application range: approx. −60 °C to +80 °C.Natural rubber may soften after initial hardening under extended effect of higher temperatures.

Silicone rubbers
VMQ (vinyl-methyl polysiloxane)
PVMQ (phenyl-vinyl-methyl polysiloxane)

They are high polymer organosiloxanes that are particularly noted for high thermal resistance, good cold flexibility, good dielectric properties, very good resistance to attack by oxygen and ozone, particularly low temperature dependency of technological properties. The gas permeability at room temperature is higher than for other elastomers. This is particularly important for thin-walled diaphragms. The material is decomposed by depolymerisation when exposed to oxygen at higher temperatures.

- Average swelling resistance in: mineral oils (comparative to materials based on CR) and brake fluids on a glycol ether base. It can be used in water up to about +100 °C. Sufficient resistance in aqueous salt solutions, single and multiple value alcohols.
- Heavy swelling in: low molecular esters and ethers, aliphatic as well as aromatic hydro-carbons. Concentrated acids and alkalis, water and steam temperatures above approx. 100 °C have a destructive effect on the material.
- Thermal application range: approx. −60 °C to +200 °C (transient up to +230 °C). Components that only become brittle below −100 °C can be manufactured from special mixtures.

SBR (Styrene-butadiene rubber)

It is a polymer made of butadiene and styrene. SBR materials are preferred for manufacturing sealing components for hydraulic brakes.

- Good swelling resistance in: inorganic and organic acids and bases as well as in alcohols and water, brake fluids on a glycol ether base.
- Heavy swelling in: mineral oils, lubricating greases, petrol and aliphatic, aromatic and chlorinated hydro-carbons.
- Thermal application range: approx. −50 °C to +100 °C.

IIR (Butyl rubber)
CIIR (Chlorine butyl rubber)
BIIR (Bromine butyl rubber)

They are polymers made of isobutylene and chlorinated or brominated isobutyls and a small proportion of isoprene. Elastomers of IIR have a very good resistance to weathering and ageing. The gas and vapour permeability of these materials is low. Some materials have a very good electrical insulating capacity.

- Good swelling resistance in: brake fluids on a glycol ether base, inorganic and organic acids and bases, hot water and steam up to 120 °C, hydraulic fluids of the Group HFC and some types in the Group HFD.
- Heavy swelling in: mineral oils and greases, petrol and aliphatic as well as aromatic and chlorinated hydro-carbons.
- Thermal application range: approx. −40 °C to +120 °C.

XNBR (Carboxylated nitrile rubber)

They are terpolymers or blends made of butadiene, acrylonitrile and (meth)acrylic acid. The main properties correspond to those of the NBR polymer, but they are characterised by improved wear behaviour in dynamic sealing applications. The cold flexibility is restricted compared to the comparable NBR types.

- Thermal application range: approx. −25 °C to +100 °C (transient up to +130 °C).

TPE (Thermoplastic rubbers)

TPEs have properties between those of elastomers and thermoplastics. TPEs are multi-phase systems with a hard and a soft phase. The hard segments are layered together to form a crystalline structure that is laminated with soft segments. A pseudo-crosslinked structure is formed.

Categorisation of TPEs
TPE-O Thermoplastic rubber based on olefins e.g. (YEPDM)
TPE-S Thermoplastic rubber based on styrene (YSBR)
TPE-E Thermoplastic rubber based on esters (YBBO).

YEPDM (Olefin thermoplastic rubber)

Properties are comparable to EPDM, i.e. very good chemical resistance, but not resistant to oil.
The products cannot be used above a temperature limit of 120 °C.

YBBO (Copolyester TPE)

YBBOs are characterised by:

- high tensile strength
- high tensile modulus
- good stretchability
- excellent resistance to solvents
- resistance to oxidising acids
- aliphatic hydro-carbons
- alkaline solutions, various greases and oils.

Strongly oxidising acids and chlorinated solvents cause strong swelling.

YSBR (Thermoplastic rubber containing styrene)

The hard phase is styrene, the soft butadiene.
Properties:the mechanical properties are comparable to SBR. Hard or softer products are obtained depending on the ratio of styrene/butadiene. Above 60 °C creep and loss of tensile strength are encountered. The cold resistance extends up to −40 °C.
Good chemical resistance to water, dilute acids and alkalis, alcohols and ketones. YSBR is not resistant to non-polar solvents, fuels and oils.

Thermoplastic materials

Products made of thermoplastic material are used in large quantities today in all areas of engineering, including for seals and moulded components.

The softer types (polyethylene, soft PVC, thermoplastic elastomers) compete with highly elastic materials in many applications, while the mechanically strong plastics (polyamides, acetal resins) are being used in applications that were formerly reserved exclusively for metals.

Sealing components and construction parts made of thermoplastic materials are different depending on the base materials. In many cases they can be varied by including specific additives and can be designed specifically for the purpose of the manufactured component.

Some characteristic properties and the resulting major areas of application are described below.
For more information see the material tables.

ETFE (ethylene tetrafluoroethylene copolymer)

It is an injection-mouldable fluoroplastic with very good chemical and thermal properties, which however to do quite reach the values of PTFE.
Upper application temperature approx. +180 °C.

PA (Polyamide)

Is characterised by very high strength values. The high wear resistance, the tough material structure, the damping capacity and the good dry-running characteristics make this material particularly suitable for machine elements of various types (gearwheels, plain bearings, guide strips, cams etc.).
Upper application temperature +120 °C to +140 °C.

PBTP (Polybutylenterephtalate)

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

PBTP has the following properties:

- high stiffness and hardness
- good sliding properties
- low wear
- very low water absorption (= high dimensional stability)
- temperature application range −30 °C to +120 °C (shape resistance)

Resistant to all lubricants and all hydraulic fluids used in hydraulics, dilute alkalis, acids and alcohols. Not resistant to strong alkalis and acids.

PFA (Perfluoroalkoxy copolymer)

It is an injection-mouldable fluoroplastic with similar chemical and physical properties to those of PTFE. Both materials are particularly suitable for manufacturing high-quality moulded and injection-moulded parts.
Upper application temperature approx. +260 °C.

POM (Polyoxymethylene), (Polyacetal)

Is one of the mechanically highly loadable thermoplastics. Its stiffness, hardness and strength combined with outstanding form stability even at higher temperatures (up to approx. +80 °C) make it suitable for replacement of die-cast, brass or aluminium parts. The low water absorption is particularly worth noting. It retains its form better than moulded polyamide parts even when exposed to moisture. Acetal resins are attacked by acids.
Temperature application range −40 °C to +140 °C.

PP (Polypropylene)

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

PPO (Polyphenylene oxide)

It is a tough, rigid material that is primarily characterised by good dimensional stability, low tendency to creep and low water absorption. It has high puncture resistance and a virtually constant low loss factor. PPO is hydrolysis-resistant but not oil-resistant. Various properties of polyamides, acetal resins and PPO can be substantially improved with glass fibres. For example, the tensile strength in general can be more than twice as high as that of unreinforced material. The heat resistance is significantly improved and notched impact strength, which without glass fibre reinforcement falls quickly as the temperature falls, remains virtually unchanged. The compression strength is also increased and the tendency to cold flow is reduced. The linear thermal expansion is significantly reduced. It is in the general range of die-cast metal.
Upper application temperature short term approx. +130 °C, extended period approx. +90 °C.

PTFE (Polytetrafluoroethylene)

PTFE is a thermoplastic polymer made of tetrafluoroethylene. This non-elastic material is characterised by a series of outstanding properties:
The surface is smooth and repellent. This makes it suitable for use in all applications in which adhesion of residues is to be avoided.

PTFE is physiologically safe at operating temperatures up to +200 °C. The coefficient of friction is very low with most mating materials. Static and dynamic friction are virtually identical.
The electrical insulation properties are extraordinarily good. They are virtually independent of the frequency as well as temperature and weathering effects. The chemical resistance is superior to all other elastomers and other thermoplastics. The swelling resistance is good in almost all media.
Liquid alkali metals as well as some fluorine compounds attack PTFE at higher pressures and temperatures.

The thermal application range is between approx. – 200 °C to +260 °C. At −200 °C PTFE still has some elasticity; the material can therefore be used for seals and design components, e.g. for liquid gases.

Note the following when using parts of pure PTFE:

- that the material is permanently deformed from a specific load by creep or cold flow,
- that the abrasion resistance is low,
- that the thermal expansion, as with most plastics, is about 10 times higher compared to metals,
- that the thermal conductivity is low, so the heat dissipation in bearings and moving seals may become a problem,
- that the material is not elastic rubber but horn-like similar to polyethylene.

For the above reasons designs with elastomeric seals cannot be converted to PTFE without other modifications. For lip seals an additional contact pressure by springs or other means is required.
PTFE is filled with graphite, glass fibres, bronze and carbon to give it special properties.

PVC (Polyvinyl chloride)

is currently frequently used instead of the formerly used elastomer materials because of its good technological and chemical properties.
The materials based on PVC have rubber-like properties in contract to the other thermoplastics described in this section. PVC is used for: bellows, faceplates, seals, covers, sleeves, caps, bushes and moulded air-duct components.

Thermal application range: −35 °C to +70 °C.

High-load resistant thermoplastic polycondensates "high-tech, engineering plastics"

These products are generally very expensive because of the very complex manufacturing techniques required in many cases. They are always used for moulded components where other plastics would certainly fail but metallic properties would cause problems, particularly in the electrical industry.

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

Special features of the individual materials:

polyethersulfane (PESU)

- resistant to water
- not resistant to brake fluids.

polysulfane (PPSO)

- not usable in boiling water
- specific solvents, esters, ketones, aromatics, chlorinated hydro-carbons destroy the material by formation of tension cracks.

polyphenylene sulphide (PPS)

- greater chemical resistance than the other products
- not tough and sensitive to notching because of crystalline structure.

polyether ketone (PEEK)

- very good chemical resistance
- universally usable
- reinforced types can be used up to +180 °C.

polyetherimide (PEI)

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

Duroplastics

Materials that do not soften or melt in heat. They retain their shape better when hardened than uncrosslinked plastics.

The most important product groups are:
- Phenol formaldehyde masses (PF)
- Unsaturated polyester resins (UP)
- Polyimides (PI).

PF (Phenol formaldehyde)

The reaction of phenol with formaldehyde results in resin-like condensation products – novolak or resol resins.
DIN-classified masses have different filler and reinforcement materials. The mechanical and technical properties are extremely useful. Tempered components can be subjected to temperatures up to +300 °C for short periods.
Other general properties:
- temperature range −30 °C to +120 °C
- hard and very strong
- low tendency to creep
- low flammability
- sensitive to notching
- not for use with food
- resistant to organic solvents, weak acids and alkalis, salt solutions.

PI (polyimides)

They are derived from bis-maleinimide. Under polymerisation duroplastic polyimides with different molecular structures are formed. The general characteristic of these heterocyclic polymers is the imidering within the main chain. Polyimide components are characterised by high temperature resistance up to more than +260 °C, and even above +300 °C for short periods, while retained most of their mechanical properties. The materials are also characterised by good sliding and wear properties, which can be improved even more with suitable additives. The electrical properties and radiation resistance of polyimide are outstanding.
The materials are generally resistant to solvents, greases, fuels, oils and dilute acids. Strong acids, alkalis and hot water attack polyimides.

UP (Unsaturated polyester resins)

Reaction products of
- unsaturated dicarboxylic acid ester
- diol
- dicarboxylic acid and styrene.

They are used as injection-moulding materials, bulk-moulding compounds (BMC) or track material, sheet-moulding compounds (SMC).
Processing by presses and injection moulding.

Properties: unlike phenol resins
- lower shrinkage
- lower water absorption
- easier to colour
- better price
- suitable for contact with food
- good notch and impact sensitivity.

Seals and moulded components of Simriz

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

These sealing materials

- have almost the same resistance as pure PTFEs
- also have the great advantage of high elasticity
- they are also characterised compared to conventional elastomers by a much longer service life.

The universal usability

of these perfluoro elastomers is based on their resistance to aggressive media and their usability in unusually wide temperature ranges. Simriz offers reliable sealing of:

- chlorinated and high-polar organic solvents, such as chloroform, dichloromethane, alcohols, lower aldehydes, ketones, esters and ether, N-methyl pyrrolidone, cellosolve, nitrated hydro-carbons, amines, amides
- aromatics such as benzene, toluene or xylene.

Simriz is also particularly suitable for sealing:

- strong inorganic acids and alkalis such as sulphuric acid, hydrochloric acid, nitric acid and their mixtures as well as sodium and potassium hydroxide or ammonia,
- strong organic acids and bases, e.g. formic acid or ethylene diamine.

Simriz seals are also top in their temperature limits. They remain

- cold flexible down to −12 °C and
- can be used up to +300 °C without problems.

Safe solutions for many applications

Simriz seals are excellently suited for all sealing applications under high chemical and/or thermal loads. Simriz is the ideal seal for:

- analysis technology
- systems and mechanical engineering
- aerospace industry
- machines and units
- mineral oil processing
- medical technology
- pharmaceutical industry
- pumps
- processing technology
- packaging machines.

Tell what form your seal should be. We will supply it.

Seals and moulded components of Simriz are manufactured in standard sizes of the ISC O-Ring range by Simrit or customised to your requirements.
ISC O-Rings, ISC O-Ring special shapes or moulded components of Simriz can be designed precisely for your application or requirements.

Solutions for complex requirements

High pressure, cyclic temperatures, static or dynamic loading, chemical and abrasive attack by the sealing fluid form a matrix of requirements for a seal which can become extremely complex.
We will be pleased to work with you to develop customised solutions for safe and reliable sealing in such difficult cases. High temperature and FDA materials on enquiry. Our technicians will be pleased to assist you with your requirements.

Standard materials for hydraulic components

			Media to be sealed with information on continuous temperature (in °C)																					
			Mineral lubricants					Synthet. lubricants		Mineral. hydr. fluids		Biodegradable hydraulic fluids as per VDMA 24568 & DIN 24569			Flame retardant hydraulic fluids as per VDMA 24317 & DIN 24320 *				Other media					
Material	ASTM D 2000	Permissible low temperature °C	Engine oils	Transmission oils	Hypoid transmission oils	ATF oils	Greases	Polyalkyleneglycols (PAG)	Polyalphaolefins (PAO)	HLP as per DIN 51524 Part 2	HLVP as per DIN 51524 Part 3	HETG rapeseed oil *	HEES – synthetic ester	HEPG polyglycols**	Group HFA	Group HFB	Group HFC	Group HFD ***	Heating oil EL and L	Brake fluid DOT 3/DOT 4	Water	Water lye	air	Comment
94 AU 925	M 7 BG 910	–30	+	+	⊗	+	110	⊗	+	110	110	50	80	40	50	50	40	⊗	–	–	40	–	100	
98 AU 928	M 7 BG 910	–25	+	+	⊗	+	110	⊗	+	110	110	50	80	40	50	50	40	⊗	–	–	40	–	100	
95 AU V142	–	–30	+	+	⊗	+	110	⊗	⊗	110	110	50	80	40	50	50	40	–	–	–	40	–	100	
95 AU V149	–	–30	+	+	⊗	+	110	⊗	⊗	110	110	50	80	40	50	50	40	–	–	–	40	–	100	
94 AU 985	M 7 BG 910	–30	+	+	⊗	+	100	⊗	+	100	100	60	80	50	60	60	50	⊗	–	–	80	–	100	
93 AU V167	–	–30	+	+	⊗	+	100	⊗	⊗	100	100	60	80	50	60	60	40	–	–	–	60	–	80	
93 AU V168	–	–30	+	+	⊗	+	100	⊗	⊗	100	100	60	80	50	60	60	40	–	–	–	60	–	80	
70 FKM K655	–	–10	150	150	140	150	150	150	150	150	150	80	100	80	55	60	60	150	150	–	⊗	⊗	200	
HGWH G517	–	–50	+	+	+	+	+	+	+	120	120	+	+	+	60	60	60	80	–	–	90	–	120	
HGWH G600	–	–40	+	+	+	+	+	+	+	120	120	+	+	+	60	60	60	80	–	–	90	–	120	
88 NBR 101	M 7 BG 910	–30	100	100	80	100	100	80	80	100	100	80	80	80	55	60	60	–	80	–	90	+	100	
90 NBR 109	M 7 BG 910	–30	100	100	80	100	100	80	80	100	100	80	80	80	55	60	60	–	80	–	90	+	100	
80 NBR 709	M 6 BG 814	–30	100	100	80	100	100	80	80	100	100	80	80	80	55	60	60	–	80	–	90	90	100	
72 NBR 872	M 2 BG 714	–35	100	100	80	100	100	80	80	100	100	80	80	80	55	60	60	–	80	–	90	90	100	
80 NBR 878	M 7 BG 814	–30	100	100	80	100	100	80	80	100	100	80	80	80	55	60	60	–	80	–	90	+	100	
80 NBR 99033	M 7 BG 814	–30	100	100	80	100	100	80	80	100	100	80	80	80	55	60	60	–	80	–	90	+	90	
80 NBR 99035	M 7 BG 814	–30	100	100	80	100	100	80	80	100	100	80	80	80	55	60	60	–	80	–	90	+	90	
85 NBR B203	–	–30	100	100	80	100	100	80	80	100	100	80	80	60	55	60	60	–	80	–	100	90	100	
70 NBR B209	M 2 BG 710	–30	100	100	80	100	100	80	80	100	100	80	80	60	55	60	60	–	80	–	100	90	100	
89 NBR B217	M 2 BG 910	–30	100	100	80	100	100	80	80	100	100	80	80	60	55	60	60	–	80	–	100	90	100	
81 NBR B219	M 2 BG 810	–30	100	100	80	100	100	80	80	100	100	80	80	60	55	60	60	–	80	–	100	90	100	
79 NBR B246	M 2 BG 810	–30	100	100	80	100	100	80	80	100	100	80	80	60	55	60	60	–	80	–	100	90	100	
87 NBR B247	M 2 BG 910	–30	100	100	80	100	100	80	80	100	100	80	80	60	55	60	60	–	80	–	100	90	100	
70 NBR B276	M 2 BG 710	–30	100	100	80	100	100	80	80	100	100	80	80	60	55	60	60	–	80	–	100	90	100	
75 NBR B281	M 2 BG 821	–30	100	100	80	100	100	80	80	100	100	80	80	60	55	60	60	–	80	–	100	90	100	
90 NBR B283	M 2 BG 910	–30	100	100	80	100	100	80	80	100	100	80	80	60	55	60	60	–	80	–	100	90	100	
PA 4112	–	–30	+	+	+	+	+	+	+	130	130	+	+	+	55	60	60	90	–	–	90	–	100	
PA 4201	–	–30	+	+	+	+	+	+	+	120	120	+	+	+	55	60	60	80	–	–	90	–	100	
PA 6501	–	–30	+	+	+	+	+	+	+	120	120	80	80	50	60	60	60	80	–	–	60	–	+	

			Media to be sealed with information on continuous temperature (in °C)																					
			Mineral lubricants					Synthet. lubri-cants		Mineral. hydr. fluids		Biodegrad-able hydraulic fluids as per VDMA 24568 & DIN 24569			Flame retardant hydraulic fluids as per VDMA 24317 & DIN 24320 *				Other media					
Material	ASTM D 2000	Permissible low temperature °C	Engine oils	Transmission oils	Hypoid transmission oils	ATF oils	Greases	Polyalkyleneglycols (PAG)	Polyalphaolefins (PAO)	HLP as per DIN 51524 Part 2	HLVP as per DIN 51524 Part 3	HETG rapeseed oil *	HEES – synthetic ester	HEPG polyglycols**	Group HFA	Group HFB	Group HFC	Group HFD ***	Heating oil EL and L	Brake fluid DOT 3/DOT 4	Water	Water lye	air	Comment
PF 48	–	–50	+	+	+	+	+	+	+	120	120	+	+	+	55	60	60	80	–	–	90	–	120	
POM 20	–	–40	+	+	+	+	+	+	+	100	100	+	+	+	55	60	60	80	–	–	80	–	100	
POM PO202	–	–40	+	+	+	+	+	+	+	110	110	+	+	+	60	60	60	80	–	–	80	–	+	
POM PO530	–	–40	+	+	+	+	+	+	+	110	110	+	+	+	60	60	60	80	–	–	80	–	+	
PTFE B502	–	–40	+	+	+	+	+	+	+	200	200	80	100	80	–	–	–	200	+	+	–	+	200	
PTFE B504	–	–40	+	+	+	+	+	+	+	200	200	80	100	80	–	–	–	200	+	+	–	+	200	
PTFE B602	–	–30	+	+	+	+	+	+	+	200	200	80	100	80	–	–	–	200	+	+	–	+	200	
PTFE GM201	–	–30	+	+	+	+	+	+	+	100	100	80	100	60	60	60	60	150	+	+	100	+	200	
PTFE/15 177026	–	–80	+	+	+	+	+	+	+	200	200	80	100	100	+	+	+	150	+	+	150	+	200	
PTFE/25 177027	–	–80	+	+	+	+	+	+	+	200	200	80	100	100	+	+	+	150	+	+	150	+	200	
PTFE/25 177030	–	–80	+	+	+	+	+	+	+	200	200	80	100	100	+	+	+	150	+	+	150	+	200	
PTFE/40 177024	–	–80	+	+	+	+	+	+	+	200	200	80	100	100	+	+	+	150	+	+	150	+	200	
PTFE/60 177023	–	–80	+	+	+	+	+	+	+	200	200	80	100	100	+	+	+	150	+	+	150	+	200	
97 TPE 113TP	–	–30	+	+	⊗	+	100	⊗	⊗	110	110	60	80	50	60	60	40	–	–	–	60	–	+	

* operating limits defined by the medium

** for static use only; dynamic use requires an additional test

*** resistance depends on the HFD type

+ resistant, in general not used for these media

⊗ of limited resistance

– not resistant

Special materials for hydraulic components

Material	ASTM D 2000	Permissible low temperature °C	Media to be sealed with information on continuous temperature (in °C)																				
			Mineral lubricants					Synthet. lubri-cants		Mineral. hydr. fluids		Biodegrad-able hydraulic fluids as per VDMA 24568 & DIN 24569			Flame retardant hydraulic fluids as per VDMA 24317 & DIN 24320 *				Other media				
			Engine oils	Transmission oils	Hypoid transmission oils	ATF oils	Greases	Polyalkyleneglycols (PAG)	Polyalphaolefins (PAO)	HLP as per DIN 51524 Part 2	HLVP as per DIN 51524 Part 3	HETG rapeseed oil *	HEES – synthetic ester	HEPG polyglycols**	Group HFA	Group HFB	Group HFC	Group HFD ***	Heating oil EL and L	Brake fluid DOT 3/DOT 4	Water	Water lye	air
94 AU 20889	M 7 BG 910	–25	+	+	⊗	+	110	⊗	+	110	110	60	80	50	60	60	50	⊗	–	–	80	–	110
92 AU 21100	-	–50	+	+	⊗	+	80	⊗	+	100	100	50	70	40	50	50	40	–	⊗	–	50	–	80
80 EPDM L700	M 2 CA 810	–40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	60	100	–	+	150	130	150
85 FKM 580	M 3 HK 910	–5	150	150	140	150	150	150	150	150	150	80	100	100	55	60	60	150	150	–	80	⊗	200
75 FKM 595	M 2 HK 710	–5	150	150	140	150	150	150	150	150	150	80	100	100	55	60	60	150	150	–	80	⊗	200
86 FKM K664	M 2 HK 910	–10	150	150	140	150	150	150	150	150	150	80	100	80	55	60	60	150	150	–	–	–	200
90 HNBR 136428	M 4 DH 910	–25	120	120	100	120	120	100	120	120	120	80	⊗	100	55	60	60	–	80	–	120	120	130
85 HNBR 137891	M 4 CH 910	–25	120	100	100	100	120	100	120	120	120	80	⊗	100	55	60	60	–	80	–	120	120	120
80 HNBR 150351		–25	120	120	100	120	140	100	120	140	140	80	80	100	55	60	60	–	80	–	120	120	140
70 HNBR U463	-	–25	120	120	100	120	120	120	120	120	120	80	⊗	100	55	60	60	–	80	–	120	120	130
80 HNBR U464	-	–25	120	120	100	120	120	120	120	120	120	80	⊗	100	55	60	60	–	80	–	120	120	130
70 NBR B262	M 2 BG 710	–35	100	100	80	100	100	80	80	100	100	80	⊗	60	55	60	60	–	80	–	80	90	100
75 NBR B280	M 2 BG 810	–45	80	80	60	80	80	60	60	80	80	60	⊗	60	55	60	60	–	80	–	80	80	80
PTFE B604	-	–30	+	+	+	+	+	+	+	200	200	80	100	80	–	–	–	200	+	+	–	+	200
PTFE M202	-	–30	+	+	+	+	+	+	+	100	100	80	100	60	60	60	60	150	+	+	100	+	200
97 TPE 106 TP	-	–30	+	+	⊗	+	100	⊗	⊗	110	110	60	80	50	60	60	40	–	–	–	60	–	140

* operating limits defined by the medium
** for static use only; dynamic use requires an additional test
*** resistance depends on the HFD type

\+ resistant, in general not used for these media
⊗ of limited resistance
– not resistant

Chemical resistance

The information in the following table has been processed and compiled from our own testing, recommendations or our suppliers of base materials and experience reports from our customers.
However, this information can only be used as a general guide. It cannot be transferred to all operating conditions without additional testing.
With the variety of factors affecting seals and moulded components the chemical resistance is a very important factor but still only part of the overall operating conditions. Other factors that must be considered include the selection of material by Freudenberg and the shape of the sealing component:

- rotational speed and stroke length
- stroke speed for parts with axial movement
- static or dynamic loading
- surface characteristics of metal components
- type of material of machine components to be sealed.

If there are no special instructions given in the table, standard purity, concentration and room temperature are specified with the media. In case of doubt, particularly with untested or new applications, we recommend consulting us to allow us to conduct special testing if necessary.
The elastomers listed in the table are referred to with their chemical names as well as the codes specified in ASTM D 1418.

The chemical names, generally used names or trade names have been used for the media.

Explanation of material codes	
ACM	Acrylate rubber
AU	Polyurethane
CR	Chlorine butadiene rubber
CSM	Chlorosulfonated polyethylene
EPDM	Ethylene propylene diene rubber
FFKM	Perfluoro elastomer
FKM	Fluoro elastomer
FVMQ	Fluorosilicone rubber
HNBR	hydrogenated acrylonitrile-butadiene rubber
IIR	butyl rubber
NBR	Acrylonitrile butadiene rubber
NR	Natural rubber
PTFE	polytetrafluoroethylene
SBR	Styrene-butadiene rubber
VMQ	silicone rubber

Medium	°C[1]	ACM	AU	CR	CSM	EPDM	FFKM	FKM	FVMQ	HNBR	IIR	NBR	NR	PTFE	SBR	VMQ
acetaldehyde with acetic acid, 90/10%	20	○	⊙	○	◑	◑	●	○	○	○	◑	○	◑	●	◑	○
acetamide	20	⊙	⊙	⊙	⊕	⊕	●	⊙	⊕	⊕	⊕	⊕	⊙	●	⊙	⊙
acetic acid, aqueous, 25 to 60%	60	⊙	⊙	⊙	●	●	●	⊙	⊙	○	●	○	○	●	○	⊙
acetic acid, aqueous, 85%	100	⊙	⊙	⊙	⊕	⊕	●	⊙	⊙	○	⊕	○	○	●	○	⊙
acetic anhydride	20	⊙	⊙	●	●	●	●	○	⊙	○	●	○	◑	●	●	⊙
acetic anhydride	80	⊙	⊙	◑	⊕	⊕	◑	○	⊙	○	⊕	○	○	●	◑	⊙
acetone	20	○	○	○	⊕	●	●	○	○	○	●	○	●	●	●	○
acetophenone	20	⊙	⊙	⊙	⊕	⊕	●	⊙	⊙	⊙	⊕	⊙	⊙	●	⊙	⊙
acetylene	60	●	⊕	●	●	●	●	●	●	●	●	●	●	●	●	●
acrylic acid ethyl ester	20	○	○	⊙	⊙	⊕	●	○	○	○	◑	○	⊙	●	⊙	○
acrylonitrile	60	⊙	⊙	○	⊙	⊕	●	○	○	○	○	○	○	●	○	○

● = little or no corrosion

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[1] test temperature in °C

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Medium	°C 1)	ACM	AU	CR	CSM	EPDM	FFKM	FKM	FVMQ	HNBR	IIR	NBR	NR	PTFE	SBR	VMQ
adipic acid, aqueous	20	⊕	⊕	●	●	●	●	●	⊕	●	●	●	●	●	●	⊕
air, clean	80	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
air, oily	80	●	●	●	●	○	●	●	●	●	○	●	○	●	◑	●
alaum, aqueous	60	⊙	○	○	●	●	●	●	⊙	○	●	○	◑	●	◑	⊙
alaum, aqueous	100	⊙	⊙	●	●	●	●	●	⊕	●	●	●	○	●	●	⊕
allyl alcohol	80	⊙	○	◑	◑	●	●	○	⊙	◑	●	◑	●	●	●	⊙
aluminium sulphate, aqueous	60	⊙	○	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
aluminium sulphate, aqueous	100	⊙	○	◑	●	●	●	○	⊕	●	●	●	◑	●	●	⊕
ammonia liquor	40	○	○	◑	●	●	●	○	◑	●	●	●	●	●	●	◑
ammonia, 100%	20	⊙	○	◑	●	●	◑	○	⊙	◑	●	◑	●	●	●	⊙
ammonium acetate, aqueous	60	⊙	○	◑	●	●	●	○	⊕	●	●	●	●	●	●	⊕
ammonium carbonate	60	⊙	○	◑	●	●	●	○	⊕	●	●	●	●	●	●	⊕
ammonium chloride, aqueous	60	⊙	○	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
ammonium fluoride, aqueous	20	⊙	⊙	◑	●	●	●	●	●	●	●	●	●	●	●	●
ammonium fluoride, aqueous	100	⊙	⊙	◑	●	●	●	○	⊕	●	●	●	○	●	●	⊕
ammonium fluoride, aqueous	20	⊙	⊙	◑	●	●	●	●	●	●	●	●	●	●	●	●
ammonium fluoride, aqueous	100	⊙	⊙	◑	●	●	◑	○	⊕	●	◑	●	○	●	●	⊕
ammonium nitrate, aqueous	60	⊙	○	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
ammonium nitrate, aqueous	100	⊙	⊙	◑	●	●	●	○	⊕	●	●	●	○	●	●	⊕
ammonium phosphate, aqueous	60	⊙	○	◑	●	●	●	○	⊕	●	●	●	●	●	●	⊕
ammonium sulphate	60	⊙	○	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
ammonium sulphate	100	⊙	○	◑	●	●	●	○	⊕	●	●	●	○	●	●	⊕
ammonium sulphide, aqueous	60	⊙	○	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
ammonium sulphide, aqueous	100	⊙	○	◑	●	●	●	○	⊕	◑	●	◑	○	●	◑	⊕
amyl acetate	20	⊙	⊙	⊙	⊕	●	●	○	⊙	○	●	○	●	●	○	⊙
amyl alcohol	60	⊙	○	◑	●	●	●	○	⊕	◑	●	◑	●	●	●	⊕
aniline	60	⊙	○	○	⊙	⊙	●	○	○	○	⊙	○	○	●	○	○
aniline chlorohydrate	20	⊙	○	◑	◑	◑	●	●	⊕	◑	◑	◑	○	●	○	◑
aniline chlorohydrate	100	⊙	○	⊕	⊙	⊙	●	⊙	⊙	○	⊙	○	○	●	○	⊙
anisole	20	⊙	⊙	○	⊙	⊙	●	⊙	⊙	○	⊙	○	○	●	○	⊙
anthraquinone sulphonic acid, aqueous	30	⊙	○	⊙	●	●	●	⊙	⊙	◑	●	◑	●	●	●	⊙
anti-freeze (automotive)	60	⊙	○	●	●	●	●	●	●	●	●	●	●	●	●	●
antimony chloride, aqueous	20	●	⊙	●	●	●	●	●	●	●	●	●	●	●	●	●
antimony trichloride, dehydrated	60	⊙	⊙	◑	●	●	●	⊙	⊙	●	●	●	●	●	●	⊙
aqua regia	20	○	○	○	○	○	●	○	○	○	○	○	○	●	○	○

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1) test temperature in °C

Medium	°C[1]	ACM	AU	CR	CSM	EPDM	FFKM	FKM	FVMQ	HNBR	IIR	NBR	NR	PTFE	SBR	VMQ
arsenic acid, aqueous	100	⊙	⊙	◑	●	●	●	○	⊕	●	●	●	○	●	●	⊕
arsenic acid, aqueous	60	⊕	○	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
asphalt	100	⊕	⊙	⊙	⊙	⊙	●	⊕	⊙	⊙	⊙	⊙	⊙	●	⊙	⊙
ASTM fuel A	60	◑	●	◑	◑	○	●	●	●	●	○	●	○	●	○	○
ASTM fuel B	60	○	○	○	○	○	●	●	●	◑	○	◑	○	●	○	○
ASTM fuel C	60	○	○	○	○	○	●	●	◑	○	○	○	○	●	○	○
ASTM Oil No. 1	100	●	◑	●	○	○	●	●	●	●	○	●	○	●	○	●
ASTM Oil No. 2	100	●	◑	◑	○	○	●	●	●	●	○	●	○	●	○	●
ASTM Oil No. 3	100	●	◑	◑	○	○	●	●	●	◑	○	●	○	●	○	◑
ATE brake fluid	100	○	⊙	◑	⊙	●	⊕	○	●	○	●	○	●	●	●	●
ATF oil	100	○	◑	◑	○	○	●	●	●	●	○	●	○	●	○	◑
aviation fuels JP3 (MIL-J-5624)	20	◑	◑	○	○	○	●	●	●	◑	○	●	○	●	○	○
aviation fuels JP4 (MIL-J-5624)	20	◑	◑	○	○	○	●	●	◑	◑	○	●	○	●	○	○
aviation fuels JP5 (MIL-J-5624)	20	◑	◑	○	○	○	●	●	◑	◑	○	●	○	●	○	○
aviation fuels JP6 (MIL-J-25656)	20	◑	◑	○	○	○	●	●	◑	◑	○	●	○	●	○	○
barium hydroxide, aqueous	60	⊙	○	●	●	●	●	●	⊕	●	●	●	●	●	●	⊕
barium salts, aqueous	60	⊙	○	◑	●	●	●	●	●	●	●	●	●	●	●	●
battery acid (sulphuric acid)	60	⊙	○	○	●	●	●	●	⊙	○	●	○	◑	●	◑	⊙
beef tallow emulsion, sulphurated	20	⊙	⊙	◑	●	○	●	●	◑	●	○	●	○	●	○	◑
beer	20	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
benzaldehyde, aqueous	60	⊙	○	○	⊙	◑	●	●	⊙	○	◑	○	◑	●	◑	⊙
benzene	20	○	○	○	○	○	●	◑	◑	○	○	○	○	●	○	○
benzoic acid, aqueous	60	⊙	○	◑	●	●	●	●	●	●	●	●	●	●	●	●
benzyl alcohol	60	⊙	○	⊙	⊕	⊕	●	⊙	◑	⊙	⊕	⊙	⊕	●	⊕	◑
biogas	20	⊕	◑	●	●	⊙	●	●	○	●	⊙	●	○	●	○	●
bisulphite alkali	50	⊙	○	◑	●	●	◑	⊙	⊕	◑	●	◑	●	●	●	⊕
bitumen	60	⊙	⊙	○	⊙	⊙	●	●	⊙	○	⊙	○	⊙	●	⊙	⊙
black liquor	100	⊙	⊙	◑	●	●	●	●	⊙	◑	●	◑	◑	●	◑	⊙
blast-furnace gas	100	●	⊕	◑	◑	◑	●	●	●	◑	◑	◑	○	●	◑	●
bleach	60	⊙	○	◑	●	●	●	◑	⊙	○	◑	○	○	●	◑	⊙
bone oil	60	●	●	○	○	○	●	●	●	●	○	●	○	●	○	◑
borax, aqueous	60	⊙	○	◑	●	●	●	●	●	●	●	●	●	●	●	●
boric acid, aqueous	60	⊙	○	◑	●	●	●	●	●	●	●	●	●	●	●	●
brake fluids (glycol ether)	80	○	⊙	◑	⊕	●	⊕	⊙	●	○	●	○	●	●	●	●
bromine vapours	20	⊙	⊙	○	◑	⊕	⊕	⊙	⊙	○	⊕	○	○	●	○	⊙

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Medium	°C[1]	ACM	AU	CR	CSM	EPDM	FFKM	FKM	FVMQ	HNBR	IIR	NBR	NR	PTFE	SBR	VMQ
bromine water, cold saturated	20	⊙	⊙	○	◑	⊕	⊕	⊙	⊙	○	⊕	○	○	●	○	⊙
bromine, liquid	20	⊙	⊙	○	◑	⊕	⊕	⊙	⊙	○	⊕	○	○	●	○	⊙
bromobenzene	20	⊙	⊙	⊙	⊙	⊙	⊕	⊕	⊕	⊙	⊙	⊙	⊙	●	⊙	⊙
bromochloromethane	20	⊙	⊙	⊙	◑	◑	◑	◑	◑	⊙	◑	⊙	⊙	●	⊙	⊙
bunker oil	60	⊕	⊙	⊙	⊙	⊙	⊕	⊕	⊕	◑	⊙	◑	⊙	●	⊙	⊙
butadiene	60	⊙	⊕	◑	○	○	●	●	●	⊕	○	⊕	○	●	○	◑
butane, gaseous	20	●	●	◑	○	○	●	●	●	●	○	●	○	●	○	⊕
butanediol, aqueous	20	⊙	⊕	◑	●	●	●	◑	⊕	●	●	●	●	●	●	⊕
butanediol, aqueous	60	⊙	○	●	●	●	⊕	⊕	⊕	●	●	●	◑	●	●	⊕
butanol, aqueous	20	◑	●	○	●	●	●	◑	●	◑	●	●	●	●	●	●
butanol, aqueous	60	⊙	○	◑	●	●	●	⊙	⊕	○	●	○	●	●	●	⊕
butter	20	⊕	●	●	⊙	⊙	●	●	●	●	⊙	●	⊙	●	⊙	●
butter	80	⊕	⊕	◑	⊙	⊙	●	●	⊕	●	⊙	●	○	●	○	⊕
butyl acetate	20	⊙	⊙	○	○	◑	●	○	⊙	○	◑	○	◑	●	○	⊙
butyl alcohol	60	⊙	○	◑	●	●	●	⊙	⊕	○	●	○	●	●	●	⊕
butyl phenol	20	○	○	○	○	○	●	◑	⊙	○	○	○	○	●	○	○
butylene glycol	60	⊙	●	●	●	●	●	◑	●	●	●	●	●	●	●	●
butylene, liquid	20	⊕	●	◑	⊙	⊙	●	●	●	●	⊙	●	○	●	○	⊕
butynediol	20	⊙	●	◑	●	●	◑	◑	⊕	●	●	●	●	●	●	⊕
butyraldehyde	20	⊙	⊙	⊙	◑	◑	◑	⊙	⊙	⊙	◑	⊙	◑	●	◑	⊙
butyric acid, aqueous	20	⊙	⊕	◑	⊕	⊕	●	●	⊕	●	⊕	●	○	●	⊕	⊕
calcium bisulphite, aqueous	20	⊙	●	●	●	●	●	●	⊕	●	●	●	●	●	●	⊕
calcium chloride, aqueous	100	⊙	○	●	●	●	●	●	●	●	●	●	○	●	●	●
calcium hydroxide, aqueous	20	⊙	○	●	●	●	●	●	●	●	●	●	●	●	●	●
calcium hypochloride, aqueous	60	○	○	◑	●	●	●	◑	⊙	○	●	○	○	●	○	⊙
calcium nitrate, aqueous	40	⊙	⊙	●	●	●	●	●	●	●	●	●	●	●	●	●
calcium phosphate, aqueous	20	⊙	⊕	●	●	●	●	●	●	●	●	●	●	●	●	●
camphor	20	⊙	⊙	◑	○	○	●	◑	⊙	●	○	●	○	●	○	⊙
camphor oil	20	⊙	⊙	○	◑	○	●	◑	⊙	◑	○	●	○	●	○	⊙
carbolineum	60	⊙	⊙	⊙	◑	◑	●	⊕	⊕	⊙	◑	⊙	⊙	●	⊙	⊙
carbolineum	80	○	●	○	○	○	●	●	●	○	○	○	○	●	○	○
carbon dioxide, dry	60	●	⊕	●	●	●	●	●	●	●	●	●	●	●	●	●
carbon disulphide	20	⊙	○	○	◑	○	●	●	⊙	○	○	○	○	●	○	○
carbon monoxide, dry	60	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
carbon monoxide, wet	20	●	⊙	●	●	●	●	●	●	●	●	●	●	●	●	●

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carbon tetrachloride	60	⊙	⊙	○	○	○	●	●	⊙	○	○	○	○	●	○	⊙
cellosolve	20	⊙	⊙	⊙	◑	◑	⊕	⊙	⊙	⊙	◑	⊙	⊙	●	⊙	⊙
chloral hydrate, aqueous	60	⊙	⊙	○	◑	◑	●	◑	⊙	○	◑	○	○	●	○	⊙
chloramine, aqueous	20	⊕	⊕	●	●	●	◑	⊙	⊕	●	●	●	●	●	●	⊕
chloric acid, aqueous	80	⊙	⊙	○	◑	◑	●	◑	⊙	○	◑	○	○	●	○	⊙
chlorinated lime, aqueous	60	⊙	○	○	●	●	●	●	⊙	○	●	○	○	●	○	⊙
chlorine water, saturated	20	⊙	⊙	○	●	●	●	●	⊙	○	◑	○	○	●	○	⊙
chlorine, dry gaseous	20	⊙	◑	○	◑	◑	◑	◑	⊙	○	◑	○	○	●	○	⊙
chlorine, liquid	20	⊙	⊙	○	◑	◑	◑	◑	⊙	○	◑	○	○	●	○	⊙
chlorine, wet gaseous	20	⊙	⊙	○	◑	◑	◑	◑	⊙	○	◑	○	○	●	○	⊙
chloroacetic acid	60	⊙	○	◑	●	●	◑	⊙	⊙	◑	●	◑	○	●	○	⊙
chlorobenzene	20	○	⊕	○	○	○	◑	◑	○	○	○	○	○	●	○	○
chloroform	20	⊙	○	○	○	○	●	◑	⊙	○	○	○	○	●	○	⊙
chlorsulphonic acid	20	○	⊙	○	○	○	⊕	⊙	○	○	○	○	○	●	○	○
chromic acid, aqueous	60	⊙	⊙	○	●	⊕	●	●	⊙	○	⊕	○	○	●	○	⊙
chromic acid/sulphuric acid/water, 50/15/35%	40	⊙	⊙	○	●	⊕	●	●	⊙	○	⊕	○	○	●	○	⊙
citric acid, aqueous	60	⊙	⊙	◑	●	●	●	☆	⊕	●	●	●	●	●	●	⊕
clophen A types	100	⊕	○	○	⊙	⊙	●	●	●	○	⊙	○	○	●	○	●
clophen T 64	100	⊕	○	○	⊙	⊙	●	●	⊕	○	⊙	○	○	●	○	◑
coconut oil	80	●	●	◑	○	○	●	●	●	●	○	●	○	●	○	●
coconut oil	80	⊕	⊕	◑	⊙	⊙	●	●	⊕	●	⊙	●	○	●	○	⊕
coconut oil	60	●	●	◑	○	○	●	●	●	●	○	●	○	●	○	●
coconut oil alcohol	20	⊕	⊙	●	◑	◑	●	●	⊕	●	◑	●	◑	●	◑	⊕
cod liver oil	20	●	●	●	◑	◑	●	●	●	●	◑	●	◑	●	◑	●
coking-oven gas	80	⊙	⊙	○	○	○	●	●	⊕	○	○	○	○	●	○	⊕
copper chloride, aqueous	20	●	●	◑	●	●	●	●	●	●	●	●	●	●	●	●
copper fluoride, aqueous	50	⊙	⊙	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
copper nitrate, aqueous	60	⊙	⊙	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
copper sulphate, aqueous	60	⊙	⊙	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
corn oil	60	⊕	⊕	◑	⊙	○	●	●	⊕	●	○	●	○	●	○	⊕
cotton-seed oil	20	⊕	●	◑	◑	◑	●	●	⊕	●	◑	●	◑	●	◑	⊕
cresol, aqueous	45	⊙	●	○	○	○	●	●	⊙	○	○	○	○	●	○	⊙
crotonaldehyde	20	⊙	⊕	⊙	●	●	◑	○	⊙	⊙	●	⊙	◑	●	◑	⊙
crude oil	20	●	●	◑	◑	○	●	●	●	◑	○	●	○	●	○	◑

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cyclohexane	20	◑	●	○	⊙	○	●	●	◑	●	○	●	○	●	○	◑
cyclohexanol	20	⊙	●	○	○	○	●	⊙	◑	●	○	●	○	●	○	⊙
cyclohexanone	20	⊙	⊙	○	⊙	○	●	⊙	⊙	○	○	○	○	●	○	⊙
cyclohexanone	20	⊙	⊙	○	○	○	●	⊙	⊙	○	○	○	○	●	○	⊙
cyclohexylamine	20	⊙	⊙	○	○	○	◑	○	⊙	○	○	○	○	●	○	⊙
decahydronaphtaline (decalin)	20	◑	⊙	○	○	○	◑	◑	⊙	○	○	○	○	●	○	⊙
decahydronaphtaline (decalin)	60	◑	⊙	○	○	○	◑	◑	⊙	○	○	○	○	●	○	⊙
Desmodur T	20	○	◑	○	○	○	◑	⊙	⊙	○	○	○	○	●	○	⊙
Desmophen 2000	80	⊕	⊙	⊕	⊕	⊕	⊕	⊕	⊕	●	⊕	●	⊕	●	●	⊕
detergent, synthetic	60	○	⊕	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
detergents	100	⊙	⊙	◑	●	●	◑	◑	⊙	●	●	●	○	●	◑	⊙
dextrine, aqueous	60	⊙	○	●	●	●	●	●	●	●	●	●	●	●	●	●
dextrose, aqueous	80	⊙	⊙	●	●	●	●	●	●	●	●	●	○	●	●	●
diacetone alcohol	20	⊙	⊕	◑	●	●	●	⊙	⊕	◑	●	◑	●	●	●	⊕
dibenzyl ether	20	⊙	⊙	○	◑	◑	●	○	⊙	○	◑	○	○	●	○	⊙
dibuthylether	20	⊙	⊙	○	◑	◑	●	○	⊙	○	◑	○	○	●	○	⊙
dibuthylphtalate	20	⊙	●	○	⊕	⊕	●	●	●	○	⊕	○	○	●	○	●
dibuthylphtalate	60	⊙	⊕	○	⊕	⊕	●	◑	●	○	⊕	○	○	●	○	●
dibuthylsebacate	60	⊙	⊕	○	○	○	◑	⊙	◑	○	○	○	○	●	○	◑
dichloracetic acid	60	⊙	○	○	●	●	◑	○	⊙	○	●	○	○	●	○	⊙
dichlorbenzene	20	⊙	⊙	○	○	○	●	●	◑	○	○	○	○	●	○	⊙
dichlorbutylene	20	⊙	⊙	○	○	○	●	◑	⊙	○	○	○	○	●	○	⊙
dichlorethane	20	○	○	○	⊙	○	◑	◑	⊕	○	○	○	○	●	○	○
dichlorethylene	20	⊙	⊙	○	⊙	⊙	◑	◑	⊙	○	⊙	○	○	●	○	⊙
dichlormethane	20	○	○	○	○	○	●	●	⊙	○	○	○	○	●	○	○
diesel fuel	60	◑	◑	◑	○	○	●	●	●	●	○	●	○	●	○	◑
diethyl ether	20	⊙	⊙	○	○	○	●	○	⊙	○	○	○	○	●	○	⊙
diethyl sebacate	20	⊙	⊙	○	◑	◑	◑	◑	⊙	○	◑	○	○	●	○	⊙
diethylamine	20	⊙	⊙	○	●	●	◑	○	⊙	◑	●	◑	○	●	○	⊙
diethylene glycol	20	⊙	⊙	●	●	●	●	●	●	●	●	●	●	●	●	●
diglycolic acid, aqueous	60	⊙	⊙	◑	●	●	●	●	⊕	◑	●	◑	●	●	●	⊕
dihexylphtalate	60	⊙	⊙	○	○	⊙	◑	○	⊙	○	⊙	○	○	●	○	⊙
diisobutylketone	60	⊙	⊙	○	⊕	●	◑	○	⊙	○	●	○	◑	●	○	⊙
dimethylamine	20	⊙	⊙	○	●	●	◑	○	⊙	○	●	○	○	●	○	⊙
dimethylether	20	⊙	⊙	○	●	●	◑	○	⊙	○	●	○	◑	●	○	⊙

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dimethylformamide	60	⊕	○	○	◑	◑	◑	○	⊕	○	◑	○	◑	●	○	○
dinonylphtalate	30	⊙	⊙	○	○	⊙	◑	○	⊙	○	⊙	○	○	●	○	⊙
dioctylphtalate	60	○	⊙	○	○	⊙	●	◑	⊙	○	⊙	○	○	●	○	⊙
dioctylsebacate	60	⊙	⊙	○	⊙	⊙	◑	○	⊙	○	⊙	○	○	●	○	⊙
dioxane	60	⊙	⊙	○	◑	◑	⊕	○	⊙	○	◑	○	◑	●	◑	⊙
dipentene	20	⊕	⊕	○	○	○	●	●	⊕	◑	○	◑	○	●	○	⊕
diphenyl	20	⊙	⊕	○	○	○	●	●	⊙	○	○	○	○	●	○	⊙
diphenyl oxide	100	⊙	⊙	⊙	⊙	⊙	⊕	⊙	⊙	⊙	⊙	⊙	⊙	●	⊙	⊙
engine oils	100	●	◑	◑	○	○	●	●	●	●	○	●	○	●	○	◑
epichlorhydrine	20	⊙	⊙	⊙	⊙	◑	⊕	○	⊙	⊙	⊙	⊙	⊙	●	⊙	⊙
essential oils	20	⊙	⊙	○	○	○	●	◑	⊙	○	○	○	○	●	○	⊙
ethane	20	●	●	◑	○	○	●	●	●	●	○	●	○	●	○	◑
ethanol (spirits)	20	⊙	◑	◑	●	●	●	☆	●	◑	●	◑	●	●	●	◑
ethanol (spirits)	80	⊙	○	○	●	●	●	☆	⊕	○	●	○	●	●	●	⊕
ethanol (spirits) with acetic acid (fermentation mixture)	60	⊙	⊙	○	●	●	●	☆	⊙	○	●	○	●	●	●	⊙
ethanol (spirits) with acetic acid (fermentation mixture)	20	⊙	⊙	◑	●	●	●	☆	⊙	○	●	○	●	●	●	⊙
ethyl acetate	20	⊙	⊙	⊙	◑	◑	◑	○	⊙	○	⊕	○	○	●	○	⊙
ethyl acetate	60	⊙	○	○	○	○	◑	○	⊙	○	○	○	○	●	○	⊙
ethyl acrylate	20	○	⊙	⊙	⊙	⊕	◑	○	○	○	◑	○	⊙	●	⊙	○
ethyl benzene	20	○	⊕	○	○	○	●	◑	◑	○	○	○	○	●	○	○
ethyl chloride	20	○	◑	◑	⊕	◑	●	◑	⊙	◑	◑	◑	◑	●	◑	○
ethylene chloride	20	○	◑	◑	⊕	◑	●	◑	⊙	◑	◑	◑	◑	●	◑	○
ethylene chlorohydrin	60	⊙	⊙	○	◑	◑	◑	○	⊙	○	◑	○	○	●	○	⊙
ethylene diamine	60	○	○	○	⊕	●	◑	○	⊙	○	●	○	◑	●	◑	○
ethylene glycol	100	⊙	○	◑	⊕	●	●	●	⊕	●	●	●	○	●	●	◑
ethylene trichloride	20	⊙	⊙	⊙	⊙	⊙	◑	⊕	⊙	⊙	⊙	⊙	⊙	●	⊙	⊙
ethylether	20	○	○	○	○	◑	●	○	○	○	◑	○	◑	●	○	○
exhaust gases, contained hydrogen fluoride, traces	60	⊕	⊙	●	●	●	●	●	⊕	●	●	●	●	●	●	⊕
exhaust gases, contained nitrous gases, traces	60	○	⊙	●	●	●	●	●	◑	⊕	◑	⊕	○	●	⊕	○
exhaust gases, contained nitrous gases, traces	80	○	⊙	●	●	●	●	●	◑	⊕	◑	⊕	○	●	⊕	○
exhaust gases, containing carbon dioxide	60	●	⊕	●	●	●	●	●	●	●	●	●	●	●	●	●

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exhaust gases, containing carbon monoxide	60	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
exhaust gases, containing hydrochloric acid	60	⊙	⊙	●	●	●	●	●	⊕	◑	●	◑	●	●	●	⊕
exhaust gases, containing sulphur dioxide	60	⊙	⊙	●	●	●	●	●	⊕	◑	●	◑	◑	●	◑	⊕
exhaust gases, containing sulphuric acid	60	⊙	⊙	◑	●	●	●	●	⊕	◑	●	◑	◑	●	◑	⊕
exhaust gases, containing sulphuric acid	80	⊙	⊙	◑	●	●	●	●	⊕	○	●	○	◑	●	◑	⊕
FAM test fuels DIN 51604-A	20	⊙	●	○	○	○	●	●	●	◑	○	◑	○	●	○	○
FAM test fuels DIN 51604-C	20	○	○	○	○	○	●	☆	◑	○	○	○	○	●	○	○
fatty acids	100	⊙	⊙	◑	◑	⊙	●	●	⊙	◑	⊙	◑	⊙	●	⊙	⊙
fatty alcohol	20	●	⊙	●	◑	◑	●	●	⊕	●	◑	●	◑	●	◑	●
ferric chloride, aqueous	40	⊙	⊕	●	●	●	●	●	⊕	●	●	●	●	●	●	⊕
fertiliser salt, aqueous	60	⊙	⊙	◑	●	●	●	●	●	●	●	●	●	●	●	●
firedamp	20	●	⊕	●	◑	◑	●	●	●	●	◑	●	◑	●	◑	●
fish oil	20	●	⊕	●	◑	◑	●	●	●	●	◑	●	◑	●	◑	●
fluorine, dry	60	⊙	⊙	⊙	⊙	⊙	⊕	⊙	⊙	○	⊙	○	○	●	⊙	⊙
fluorobenzene	20	○	⊙	○	○	○	●	◑	○	○	○	○	○	●	○	○
fluorocarbon oils	100	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	●	⊕	●
fluorosilicic acid	100	⊙	⊙	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	○	●	⊕	⊕
fluorosilicic acid, aqueous	60	⊙	⊙	◑	●	●	●	●	⊙	●	●	●	●	●	●	⊙
formaldehyde, aqueous	60	○	⊙	◑	●	●	◑	⊙	⊕	◑	●	◑	●	●	●	⊕
formamide	60	⊙	⊙	○	●	●	●	◑	⊙	○	●	○	●	●	⊕	⊙
formic acid, aqueous	60	⊙	○	○	◑	◑	●	⊙	⊙	○	◑	○	◑	●	◑	⊙
freon as per DIN 8962 R 11	20	⊙	⊙	◑	⊙	⊙	⊙	◑	⊕	◑	⊙	●	⊙	●	⊙	⊙
freon as per DIN 8962 R 113	20	⊙	◑	●	⊙	⊙	⊙	◑	⊕	◑	⊙	●	⊙	●	⊙	⊙
freon as per DIN 8962 R 114	20	⊙	●	●	●	●	⊙	⊕	⊕	◑	●	●	●	●	●	⊙
freon as per DIN 8962 R 12	20	⊙	●	●	◑	◑	⊙	◑	⊙	◑	◑	●	◑	●	◑	⊙
freon as per DIN 8962 R 13	20	⊙	◑	●	●	●	⊙	◑	⊙	◑	●	●	⊙	●	●	⊙
freon as per DIN 8962 R 134a	20	⊙	⊙	●	⊙	●	○	○	⊕	◑	⊙	◑	⊙	●	⊙	⊙
freon as per DIN 8962 R 22	20	⊙	◑	●	●	●	⊙	○	⊕	○	●	○	●	●	●	⊙
fruit juices	100	⊙	○	◑	●	●	●	●	⊕	◑	●	◑	○	●	●	●
furan	20	⊙	○	⊙	⊙	⊙	◑	○	⊙	⊙	⊙	⊙	⊙	●	⊙	⊙
furfural	20	⊙	○	⊙	⊙	⊙	◑	⊙	⊙	○	⊙	○	⊙	●	⊙	⊙
furfuryl alcohol	20	⊙	○	⊙	⊙	⊙	◑	⊙	⊙	⊙	⊙	⊙	⊙	●	⊙	⊙
furnace gases, dry	60	⊙	⊙	◑	●	●	●	●	●	○	●	○	●	●	●	●

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gas oil	80	●	●	◑	○	○	●	●	●	●	○	●	○	●	○	◑
gas water	40	○	⊙	○	○	○	●	●	○	●	○	●	○	●	○	○
gasohol	20	○	○	○	○	○	●	☆	◑	○	○	○	○	●	○	○
gelatine, aqueous	40	◑	⊙	◑	●	●	●	●	●	●	●	●	●	●	●	●
glacial acetic acid	60	⊙	○	○	◑	◑	◑	○	⊙	○	◑	○	○	●	○	⊙
glucose, aqueous	80	⊙	⊙	◑	●	●	●	●	●	●	●	●	◑	●	●	●
glue	20	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
glycerine, aqueous	100	⊙	⊙	◑	●	●	●	●	●	●	●	●	◑	●	●	●
glycerol chlorohydrine	60	⊙	⊙	○	◑	◑	◑	⊙	⊙	○	◑	○	◑	●	◑	⊙
glycine, aqueous, 10%	40	⊕	⊙	●	◑	●	●	●	⊕	◑	●	◑	◑	●	◑	⊕
glycol, aqueous	100	⊙	○	◑	●	●	●	◑	⊕	●	●	●	◑	●	●	◑
glycolic acid, aqueous, 37%	20	⊙	⊙	◑	●	●	●	●	●	●	●	●	●	●	●	●
greases, mineral, animal or vegetable	80	●	●	◑	◑	○	●	●	●	●	○	●	○	●	○	●
heating oil, mineral	60	●	●	◑	○	○	●	●	●	●	○	●	○	●	○	◑
Henkel P 3 solution	100	⊙	⊙	◑	●	●	●	⊙	⊕	●	●	●	◑	●	●	⊕
heptane	60	●	●	◑	○	○	●	●	●	●	○	●	○	●	○	○
hexachlorobutadiene	20	⊙	⊙	⊙	⊙	⊙	●	●	⊙	○	⊙	○	○	●	○	⊙
hexachlorocyclohexane	20	⊙	◑	⊙	⊙	⊙	●	●	⊕	⊙	⊙	⊙	○	●	○	⊙
hexaldehyde	20	⊙	⊙	○	⊙	⊙	◑	⊙	⊙	○	⊙	○	○	●	○	⊙
hexane	60	●	●	◑	○	○	●	●	●	●	○	●	○	●	○	○
hexanetriol	20	⊙	⊙	◑	●	●	●	●	●	●	●	●	⊕	●	⊕	●
hexene	20	●	●	◑	◑	○	●	●	●	◑	○	◑	○	●	○	⊕
hydraulic fluids, oil-in-water emulsions HFA	55	⊙	⊙	◑	○	○	●	☆	⊕	●	○	●	○	●	○	⊕
hydraulic fluids, polyglycol water HFC	60	⊙	⊙	◑	●	●	●	●	●	●	●	●	●	●	●	●
hydraulic fluids, water-oil emulsions HFB	60	⊙	⊙	◑	○	○	●	☆	⊕	☆	○	☆	○	●	○	⊕
hydraulic fluids, hydraulic oils DIN 51524	80	●	●	◑	○	○	●	●	●	●	○	●	○	●	○	◑
hydraulic fluids, phosphoric acid ester HFD	80	○	○	○	○	☆	●	☆	○	○	☆	○	○	●	○	○
hydrazine hydrate	20	⊙	◑	◑	●	●	◑	⊙	◑	◑	●	◑	○	●	◑	⊙
hydrobromic acid, aqueous	60	⊙	○	◑	●	●	⊕	⊙	⊙	◑	●	◑	⊕	●	⊕	⊙
hydrochloric acid, conc.	20	⊙	⊙	○	●	●	●	●	⊙	○	●	○	◑	●	◑	⊙
hydrochloric acid, conc.	80	⊙	⊙	○	●	●	●	◑	⊙	○	●	○	○	●	○	⊙
hydrochloric acid, dilute	20	⊙	○	◑	●	●	●	●	⊙	◑	●	●	●	●	●	⊙
hydrocyanic acid	20	⊙	⊙	◑	●	⊕	●	⊕	⊕	⊕	●	⊕	⊕	●	⊕	●

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hydrofluoric acid, conc.	20	⊙	⊙	⊙	◑	◑	◑	⊙	⊙	⊙	◑	⊙	⊙	●	◑	⊙
hydrogen	20	●	⊙	●	●	●	●	●	●	●	●	●	●	●	●	●
hydrogen chloride gas	60	⊙	⊙	○	●	●	●	●	⊙	○	●	○	◑	●	◑	⊙
hydrogen peroxide, aqueous	20	⊙	⊙	○	●	●	●	●	◑	○	●	○	○	●	○	◑
hydrogen phosphide	20	⊙	⊙	◑	●	●	◑	◑	⊕	○	●	○	●	●	⊕	⊕
hydrogen sulphide, aqueous	60	⊙	⊙	◑	●	●	●	●	⊙	◑	●	◑	◑	●	●	⊙
hydrogen sulphide, dry	60	⊙	⊕	◑	●	●	●	●	⊕	◑	●	◑	◑	●	◑	⊕
hydroquinone, aqueous	20	◑	⊙	◑	●	●	●	●	⊕	●	●	●	◑	●	◑	⊕
hydrosulphite, aqueous	40	⊙	⊙	◑	●	●	◑	⊙	⊕	◑	●	◑	●	●	●	⊕
hydroxyl amine sulphate, aqueous	35	⊙	⊙	◑	●	●	◑	⊙	●	●	●	●	●	●	●	●
ink	20	●	●	●	●	●	●	◑	●	◑	●	●	●	●	●	●
iodine tincture	20	⊙	○	◑	●	●	●	●	◑	●	●	●	●	●	●	◑
iodoform	20	⊙	⊙	⊙	⊙	●	●	●	⊙	⊙	●	⊙	⊙	●	⊙	⊙
isobutyl alcohol	20	○	○	●	●	●	●	●	◑	◑	●	◑	●	●	●	●
isooctane	20	●	◑	◑	○	○	●	●	●	●	○	●	○	●	○	◑
isophorone	20	⊕	◑	⊕	⊕	●	◑	⊕	⊕	⊕	●	⊕	⊕	●	⊕	⊕
isopropanol	60	○	⊙	◑	●	●	●	☆	●	◑	●	◑	●	●	●	●
isopropyl acetate	80	○	⊙	○	◑	◑	◑	○	○	○	◑	○	○	●	○	○
isopropyl chloride	20	○	○	○	○	○	●	●	◑	○	○	○	○	●	○	○
isopropyl ether	60	○	○	○	⊙	⊙	●	○	○	○	⊙	○	⊙	●	○	○
kerosine	20	●	●	○	○	○	●	●	●	◑	○	●	○	●	○	◑
lactam	80	⊙	⊙	○	○	○	◑	○	⊙	○	○	○	○	●	○	⊙
lactic acid, aqueous 10%	40	⊙	●	●	●	●	●	●	⊕	●	●	●	●	●	●	⊕
lanolin	50	●	●	●	●	●	●	●	●	●	●	●	◑	●	●	●
lanolin (wool grease)	60	●	●	◑	◑	○	●	●	●	●	○	●	◑	●	◑	●
lauryl alcohol	20	⊕	⊕	●	◑	◑	●	●	⊕	●	◑	●	◑	●	◑	⊕
lavender oil	20	◑	⊕	○	⊙	⊙	●	●	◑	◑	⊙	◑	⊙	●	⊙	⊙
lead acetate, aqueous	60	⊙	○	◑	●	●	●	●	⊕	◑	●	●	●	●	●	⊕
lead acetate, aqueous	100	⊙	○	◑	●	●	●	○	⊕	◑	●	●	○	●	●	⊕
lead nitrate, aqueous	20	⊕	○	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
lemon juice, undiluted	20	⊙	⊕	◑	⊕	⊕	●	☆	⊕	●	⊕	●	●	●	●	●
linoleic acid	20	⊙	⊕	⊙	⊙	⊙	●	◑	⊕	◑	⊙	◑	⊙	●	⊙	◑
linseed oil	60	⊕	◑	●	◑	◑	●	●	⊕	●	◑	●	◑	●	◑	●
liqueurs	20	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
lithium chloride, aqueous	20	⊙	●	◑	●	●	●	●	●	●	●	●	●	●	●	●

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lithiumbromide, aqueous	20	⊙	●	◑	●	●	●	●	●	●	●	●	●	●	●	●
machine oils, mineral	80	●	●	◑	○	○	●	●	●	●	○	●	○	●	○	◑
magnesium chloride, aqueous	100	○	⊙	◑	●	●	●	●	⊕	●	●	●	⊙	●	●	⊕
magnesium sulphate, aqueous	100	○	⊙	◑	●	●	●	●	⊕	●	●	●	⊙	●	●	⊕
maleic acid anhydride	60	⊙	⊙	⊙	⊙	⊙	●	●	⊕	⊙	⊙	⊙	⊙	●	⊙	⊙
maleic acid, aqueous	100	⊙	⊙	◑	●	●	●	●	⊕	●	●	●	○	●	○	⊕
margarine	80	●	●	◑	○	○	●	●	●	●	○	●	○	●	○	●
menthol	60	⊙	⊙	○	○	○	●	◑	⊙	○	○	○	○	●	○	⊙
mercury	60	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
mercury salts, aqueous	60	⊙	⊙	◑	●	●	●	●	●	●	●	●	●	●	●	●
mesityl oxide	20	⊙	⊕	⊙	⊙	◑	⊕	⊕	⊕	⊕	◑	⊕	⊙	●	⊙	⊙
methane	20	●	⊕	●	◑	◑	●	●	●	●	◑	●	◑	●	◑	●
methanol	60	⊙	⊙	◑	●	●	●	☆	●	◑	●	◑	●	●	●	◑
methoxy butanol	60	⊙	⊕	◑	◑	◑	●	●	⊕	●	◑	●	○	●	○	⊕
methyl acrylate	20	○	○	○	○	○	◑	○	○	○	○	○	○	●	○	○
methyl amine, aqueous	20	⊙	⊙	⊙	●	●	◑	○	⊙	○	●	○	◑	●	◑	⊙
methyl bromide	20	○	○	○	○	○	●	●	⊕	○	○	○	○	●	○	○
methyl chloride	20	○	○	○	○	○	●	●	⊙	○	○	○	○	●	○	○
methyl chlorine	20	⊙	◑	○	○	○	●	◑	⊙	○	○	○	○	●	○	⊙
methyl ethyl ketone	20	○	○	○	◑	◑	●	○	○	○	◑	○	○	●	○	○
methyl isobuthyl ketone	20	○	○	○	○	◑	◑	○	○	○	◑	○	○	●	○	○
methyl methacrylate	20	○	○	○	○	○	◑	○	○	○	○	○	○	●	○	○
milk	20	⊙	●	●	◑	◑	●	●	●	●	◑	●	◑	●	◑	●
milk of lime	80	⊙	⊙	◑	⊕	⊕	●	●	⊙	○	⊕	○	○	●	◑	⊙
mineral oil	100	●	◑	○	○	○	●	●	●	●	○	●	○	●	○	◑
mineral water	60	⊙	⊕	◑	●	●	●	●	●	●	●	●	●	●	●	●
mixed acid I (sulphuric acid/ nitric acid < D % 0 >/water)	20	○	○	◑	●	●	●	●	○	○	●	○	○	●	○	○
mixed acid II (sulphuric acid/ phosphoric acid/water)	40	⊙	⊙	○	●	●	●	●	⊙	○	●	○	◑	●	◑	⊙
molasses	100	⊙	⊙	◑	◑	◑	●	●	⊕	●	◑	●	○	●	○	⊕
monobromobenzene	20	○	○	○	○	○	●	◑	○	○	○	○	○	●	○	○
monochloracetic acid ethyl ester	60	○	○	○	◑	◑	●	◑	○	○	◑	○	○	●	○	○
monochloracetic acid methyl ester	60	○	○	○	○	●	●	◑	○	○	●	○	○	●	○	○
morpholine	60	⊙	⊙	○	◑	◑	⊕	⊙	⊕	○	◑	○	○	●	○	⊕
myricyl alcohol	20	●	⊕	●	●	●	●	●	⊕	●	●	●	●	●	●	⊕

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naftolen ZD	20	⊕	⊙	○	○	○	●	●	⊕	◑	○	◑	○	●	○	⊙
naphta	20	◑	○	○	⊙	⊙	●	●	◑	○	⊙	○	⊙	●	⊙	⊙
naphthalene	60	⊙	⊙	○	○	○	●	●	⊙	○	○	○	○	●	○	⊙
naphtoic acid	20	⊙	⊙	⊕	⊙	⊙	●	●	●	◑	⊙	◑	⊙	●	⊙	⊙
natural gas	20	●	●	●	◑	◑	●	●	●	●	◑	●	◑	●	◑	●
natural gas	20	⊕	◑	●	●	⊙	●	●	○	●	⊙	●	○	●	○	●
nickel acetate, aqueous	20	⊙	○	◑	●	●	◑	⊕	⊕	●	●	●	●	●	●	⊕
nickel chloride, aqueous	20	⊙	⊙	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
nickel sulphate, aqueous	60	⊙	⊙	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
nitric acid, conc.	80	⊙	○	○	●	○	⊕	○	⊙	○	○	○	○	●	○	⊙
nitric acid, dilute	80	⊙	⊙	◑	●	◑	●	◑	⊙	◑	◑	◑	○	●	◑	◑
nitric acid, fuming	60	⊙	○	○	○	○	⊕	○	⊙	○	○	○	○	●	○	⊙
nitrobenzene	60	○	○	○	○	○	◑	○	○	○	○	○	○	●	○	○
nitrogen	20	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
nitrogen tetraoxide	20	⊙	⊙	⊙	⊙	○	⊕	⊙	⊙	⊙	○	⊙	⊙	●	⊙	○
nitroglycerine	20	⊙	⊙	⊙	●	●	●	●	⊙	○	●	○	◑	●	◑	⊙
nitroglycol, aqueous	20	⊙	⊕	◑	●	●	●	●	⊕	○	●	○	⊕	●	⊕	⊕
nitromethane	20	○	○	⊙	◑	◑	◑	○	○	○	◑	○	◑	●	◑	○
nitropropane	20	○	○	○	◑	◑	⊕	○	○	○	◑	○	◑	●	◑	○
nitrous gases	20	○	○	○	●	●	●	●	○	○	●	○	○	●	○	○
nitrous oxide	20	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
n-Propanol	60	⊙	○	◑	●	●	●	◑	●	◑	●	◑	●	●	●	●
octane	20	⊙	⊕	⊙	⊙	⊙	●	●	◑	⊕	⊙	⊕	⊙	●	⊙	⊙
octyl alcohol	20	⊙	⊙	●	●	●	●	●	◑	◑	●	◑	◑	●	◑	◑
octyl cresol	20	○	⊙	○	○	○	◑	◑	○	⊙	○	⊙	○	●	○	○
oleic acid	60	●	⊙	◑	○	○	●	●	◑	●	○	●	○	●	○	◑
oleum, 10%	20	○	○	○	◑	◑	●	●	○	○	◑	○	○	●	○	○
oleyl alcohol	20	●	○	●	●	●	●	●	●	●	●	●	●	●	●	●
olive oil	60	●	⊕	●	◑	◑	●	●	●	●	◑	●	◑	●	◑	●
o-nitrotoluene	60	○	⊙	○	○	○	⊕	○	○	○	○	○	○	●	○	○
oxalic acid, aqueous	100	⊙	⊙	○	●	●	●	●	⊙	○	●	○	○	●	◑	⊙
ozone	20	◑	⊕	◑	●	●	●	●	●	◑	◑	○	○	●	○	●
palm kernel fatty acid	60	⊕	⊕	●	○	○	●	●	⊕	●	○	●	○	●	○	⊕
palmitic acid	60	⊕	⊕	◑	○	○	●	●	⊕	◑	○	◑	○	●	○	⊕
paraffin	60	⊕	⊕	●	○	○	●	●	⊕	●	○	●	○	●	○	⊕

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paraffin emulsions	40	●	●	●	○	○	●	●	●	●	○	●	○	●	○	●
paraffin oil	60	●	●	●	○	○	●	●	●	●	○	●	○	●	○	●
pectin	20	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
pentachlorodiphenyl	60	⊙	⊙	○	○	○	⊕	⊙	⊙	○	○	○	○	●	○	⊙
pentane	20	⊕	⊕	◑	○	○	●	●	⊕	●	○	●	○	●	○	⊕
peracetic acid, < 1%	40	○	○	○	○	●	●	●	○	○	○	○	○	●	○	○
peracetic acid, < 10%	40	○	○	○	○	◑	●	☆	○	○	○	○	○	●	○	○
perchloric acid	100	⊙	⊙	○	●	●	●	●	⊙	○	●	○	○	●	○	⊙
perchloroethylene	60	⊙	⊙	○	○	○	●	●	⊙	○	○	○	○	●	○	○
petrol	60	○	○	◑	○	○	●	●	●	◑	○	◑	○	●	○	○
petrol-benzene mixture, 50/50%	20	○	◑	○	○	○	●	●	◑	○	○	○	○	●	○	○
petrol-benzene mixture, 60/40%	20	○	◑	○	○	○	●	●	◑	○	○	○	○	●	○	○
petrol-benzene mixture, 70/30%	20	○	●	○	○	○	●	●	●	○	○	○	○	●	○	○
petrol-benzene mixture, 80/20%	20	○	●	○	○	○	●	●	●	○	○	○	○	●	○	○
petrol-benzene-ethanol, 50/30/20%	20	○	○	○	○	○	●	☆	◑	○	○	○	○	●	○	○
petroleum	60	●	●	◑	○	○	●	●	●	●	○	●	○	●	○	◑
petroleum ether	60	●	●	◑	○	○	●	●	●	◑	○	●	○	●	○	◑
phenol, aqueous, up to 90%	80	⊙	⊙	○	○	○	●	◑	⊙	○	○	○	○	●	○	⊙
phenyl benzene	20	⊙	⊙	○	○	○	●	◑	⊙	○	○	○	○	●	○	⊙
phenyl ethyl ether	20	○	○	○	○	○	◑	○	○	○	○	○	○	●	○	○
phenyl hydrazine	60	⊙	⊙	○	○	○	●	◑	⊙	◑	○	◑	○	●	○	⊙
phenyl hydrazine chlorohydrate, aqueous	80	⊙	⊙	○	◑	●	◑	◑	⊙	◑	●	◑	○	●	○	⊙
phosgene	20	⊙	⊙	⊙	⊕	⊕	⊕	⊕	⊙	⊙	⊙	⊙	⊙	●	⊙	⊙
phosphoric acid, aqueous	60	⊙	⊙	◑	●	●	●	●	⊙	○	●	○	◑	●	●	⊙
phosphorus oxychloride	20	⊙	⊙	⊙	⊕	⊕	⊕	⊕	⊙	○	⊙	○	⊙	●	⊕	⊙
phosphorus trichloride	20	⊙	⊙	○	●	●	◑	◑	⊙	○	●	○	●	●	⊕	⊙
photo developer	40	⊙	⊙	◑	●	●	●	●	⊕	◑	●	◑	●	●	●	⊕
photo emulsions	20	⊙	⊙	●	●	●	●	●	⊕	●	●	●	●	●	●	⊕
photo fixing baths	40	⊙	⊙	◑	●	●	●	●	⊕	◑	●	◑	●	●	●	⊕
phthalic acid, aqueous	60	⊙	⊙	◑	●	●	●	●	⊕	●	●	●	○	●	⊕	⊕
pickling solution (leather pickling)	20	⊙	⊙	⊕	◑	◑	◑	◑	⊙	⊕	◑	⊕	⊙	●	⊙	⊙
picric acid	20	⊙	◑	●	◑	◑	●	●	◑	◑	◑	◑	◑	●	◑	⊙
picric acid, aqueous	20	⊙	⊙	◑	●	●	●	●	●	●	●	●	●	●	●	●
Pine needle oil	20	⊙	⊕	○	⊙	⊙	●	●	⊕	◑	○	◑	○	●	○	⊙
pinene	20	⊙	◑	◑	◑	⊙	●	●	◑	◑	⊙	◑	⊙	●	⊙	⊙

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pine-needle oil	60	●	●	○	○	○	●	●	●	◑	○	◑	○	●	○	◑
piperidine	20	⊙	⊙	⊙	⊙	⊙	⊕	⊙	⊙	⊙	⊙	⊙	⊙	●	⊙	⊙
potash, aqueous	40	⊙	⊙	◑	●	●	●	●	●	●	●	●	●	●	●	●
potassium acetate, aqueous	20	⊙	◑	◑	●	●	●	●	⊕	◑	●	●	●	●	●	⊕
potassium bisulphate, aqueous	40	⊙	○	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
potassium borate, aqueous	60	⊙	○	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
potassium bromate, 10%	60	⊙	○	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
potassium bromide, aqueous	60	⊙	○	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
potassium carbonate, aqueous	40	⊙	⊙	◑	●	●	●	●	●	●	●	●	●	●	●	●
potassium chlorate, aqueous	60	⊙	○	◑	●	●	●	●	⊕	○	●	○	◑	●	◑	⊕
potassium chloride, aqueous	60	⊙	○	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
potassium chromate, aqueous	20	⊙	○	◑	●	●	●	●	⊕	◑	●	◑	●	●	●	⊕
potassium cyanide, aqueous	40	⊙	⊕	◑	●	●	●	●	●	●	●	●	●	●	●	●
potassium cyanide, aqueous	80	⊙	○	◑	●	●	●	●	●	◑	●	◑	○	●	○	●
potassium dichromate, aqueous 40%	20	⊙	⊙	◑	●	●	●	●	⊕	◑	●	◑	○	●	◑	⊕
potassium hydroxide, 50%	60	○	○	◑	●	●	◑	○	○	◑	●	◑	◑	●	◑	○
potassium iodide, aqueous	60	⊙	○	◑	●	●	●	●	⊕	●	●	●	◑	●	●	⊕
potassium nitrate, aqueous	60	⊙	○	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
potassium perchlorate, aqueous	80	⊙	⊙	◑	●	●	●	●	⊕	○	●	○	○	●	○	⊕
potassium permanganate, aqueous	40	⊙	⊙	◑	●	●	●	●	⊙	○	●	○	○	●	◑	⊙
potassium persulphate, aqueous	60	⊙	⊙	○	●	●	●	●	⊙	○	●	○	○	●	◑	⊙
potassium sulphate, aqueous	60	⊙	⊙	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
propane, liquid/gaseous	20	●	●	●	⊙	⊙	●	●	●	●	⊙	●	○	●	○	●
propargyl alcohol, aqueous	60	⊕	⊙	●	●	●	●	●	⊕	●	●	●	◑	●	⊕	⊕
propionic acid, aqueous	60	⊙	⊙	◑	⊕	⊕	●	●	⊙	●	⊕	●	⊙	●	⊕	⊙
propylene glycol	60	⊙	⊙	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
propylene oxide	20	⊙	⊙	⊙	⊙	⊙	◑	⊙	⊙	○	⊙	○	⊙	●	⊙	⊙
pyridine	20	○	○	○	⊙	⊙	⊕	○	○	○	⊙	○	○	●	○	○
pyrrole	20	⊙	⊙	⊙	⊙	○	⊕	⊕	◑	⊙	○	⊙	○	●	○	◑
rapeseed oil	20	◑	◑	◑	◑	◑	●	●	●	◑	◑	◑	⊙	●	⊙	⊙
refrigerant as per DIN 8962 R 11	20	⊙	⊙	◑	⊙	⊙	⊙	◑	⊕	◑	⊙	●	⊙	●	⊙	⊙
refrigerant as per DIN 8962 R 113	20	⊙	◑	●	⊙	⊙	⊙	◑	⊕	◑	⊙	●	⊙	●	⊙	⊙
refrigerant as per DIN 8962 R 114	20	⊙	●	●	●	●	⊙	⊕	⊕	◑	●	●	●	●	●	⊙
refrigerant as per DIN 8962 R 12	20	⊙	●	●	◑	◑	⊙	◑	⊙	◑	◑	●	◑	●	◑	⊙
refrigerant as per DIN 8962 R 13	20	⊙	◑	●	●	●	⊙	◑	⊙	◑	●	●	⊙	●	●	⊙

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refrigerant as per DIN 8962 R 134a	20	⊙	⊙	●	⊙	●	○	○	⊕	◑	⊙	◑	⊙	●	⊙	⊙
refrigerant as per DIN 8962 R 22	20	⊙	◑	●	●	●	⊙	○	⊕	○	●	○	●	●	●	⊙
sagrotan	20	⊙	○	◑	●	●	●	●	●	◑	●	◑	●	●	●	●
salicylic acid	20	⊙	●	●	●	●	●	●	⊙	●	●	●	●	●	●	⊙
salt water	20	⊙	⊙	●	●	●	●	●	●	●	●	●	●	●	●	⊙
sea water	20	⊙	◑	◑	●	●	●	●	●	●	●	●	●	●	●	●
silicic acid, aqueous	60	⊙	⊙	◑	●	●	●	●	⊙	●	●	●	●	●	●	⊙
silicone grease	20	●	●	●	●	●	●	●	●	●	●	●	◑	●	●	○
silicone oil	20	●	●	●	●	●	●	●	●	●	●	●	◑	●	●	○
silver nitrate, aqueous	100	⊙	⊙	◑	●	●	●	●	⊕	◑	●	◑	⊙	●	◑	⊕
silver salts, aqueous	60	⊙	⊙	◑	●	●	●	●	●	◑	●	◑	◑	●	◑	●
skydrol	20	○	○	○	⊙	◑	◑	○	○	○	⊕	○	○	●	○	○
soap solution, aqueous	20	⊙	●	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
soda, aqueous	60	⊙	⊙	◑	●	●	●	●	●	●	●	●	●	●	●	●
sodium benzoate, aqueous	40	⊙	⊕	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
sodium bicarbonate	60	⊙	⊙	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
sodium bicarbonate, aqueous	60	⊙	⊙	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
sodium bisulphite, aqueous	100	⊙	⊙	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
sodium chlorate	20	⊙	⊙	○	●	●	●	●	⊕	○	●	○	○	●	○	⊕
sodium chloride	100	⊙	⊙	◑	●	●	●	●	⊕	●	●	●	⊙	●	●	⊕
sodium hydroxide	20	○	⊙	◑	●	●	●	○	○	◑	●	◑	◑	●	◑	○
sodium hypochlorite, aqueous	20	⊙	⊙	◑	●	●	●	●	⊕	◑	●	◑	○	●	○	⊕
sodium nitrate, aqueous	60	⊙	⊙	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
sodium nitrite	60	⊙	⊙	◑	●	●	●	●	⊕	◑	●	◑	●	●	●	⊕
sodium phosphate, aqueous	60	⊙	⊙	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
sodium silicate, aqueous	60	⊙	⊙	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
sodium sulphate, aqueous	20	◑	⊙	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
sodium sulphate, aqueous	60	⊙	⊙	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
sodium sulphide	40	⊙	⊙	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
sodium sulphide	100	⊙	⊙	◑	●	●	●	●	⊕	◑	◑	◑	○	●	◑	⊕
sodium thiosulphate	60	⊕	⊙	●	●	●	●	●	⊕	○	●	○	●	●	●	⊕
spermaceti	20	⊕	⊕	◑	○	○	●	●	⊕	●	○	●	○	●	⊙	⊕
spindle oil	60	●	●	◑	○	○	●	●	●	●	○	●	○	●	○	●
starch syrup	60	⊙	⊙	●	●	●	●	●	⊕	●	●	●	●	●	●	⊕
starch, aqueous	60	⊙	⊙	●	●	●	●	●	●	●	●	●	●	●	●	●

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[1] test temperature in °C

Medium	°C[1]	ACM	AU	CR	CSM	EPDM	FFKM	FKM	FVMQ	HNBR	IIR	NBR	NR	PTFE	SBR	VMQ
steam	130	⊙	○	○	◑	●	○	☆	○	○	●	○	○	●	○	○
steam	130	⊙	○	○	◑	●	○	☆	○	○	●	○	○	●	○	○
stearic acid	60	●	●	◑	●	●	●	●	●	●	●	●	○	●	●	●
stoddard solvent	20	●	●	○	○	⊙	●	●	●	●	⊙	●	⊙	●	⊙	⊙
styrene	20	⊙	⊙	○	○	○	⊕	◑	⊙	○	○	○	○	●	○	○
succinic acid, aqueous	60	⊙	○	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
sugar syrup	60	⊙	⊙	⊙	●	●	●	●	⊕	●	●	●	●	●	⊕	⊕
sulphur	60	⊙	⊕	⊙	●	●	●	●	⊕	⊙	●	⊙	⊙	●	⊙	⊕
sulphur chloride	20	⊙	⊙	○	◑	⊙	●	●	●	○	⊙	○	⊙	●	⊙	⊙
sulphur dioxide, aqueous	60	⊙	⊙	○	●	●	●	●	⊙	○	●	○	○	●	◑	⊙
sulphur dioxide, dry	80	⊙	⊙	○	●	●	●	●	⊕	○	●	○	○	●	◑	⊕
sulphur dioxide, liquid	60	⊙	⊙	○	●	●	●	●	⊙	○	●	○	○	●	⊙	⊙
sulphur hexafluoride	20	⊕	⊕	●	●	●	●	●	●	●	●	●	⊕	●	●	●
sulphuric acid, conc.	50	⊙	○	○	●	●	●	◑	⊙	○	●	○	○	●	◑	○
sulphuric acid, dilute	20	⊙	⊙	○	●	●	●	●	⊙	◑	●	◑	◑	●	◑	⊙
sulphuryl chloride	20	⊙	⊙	○	●	◑	●	●	⊙	○	◑	○	◑	●	◑	⊙
tallow	60	⊕	⊙	◑	○	○	●	●	⊕	●	○	●	○	●	○	⊕
tannic acid	60	◑	⊙	◑	●	●	●	●	●	●	●	●	●	●	●	●
tannin	40	⊙	●	●	●	●	●	●	⊕	◑	●	◑	●	●	●	⊕
tanning extract	20	◑	⊙	◑	●	●	●	●	●	●	●	●	●	●	●	●
tar	20	⊙	⊙	○	○	○	●	⊕	⊙	○	○	○	○	●	○	⊙
tar oil	20	⊙	⊙	○	○	○	●	⊕	⊙	○	○	○	○	●	○	⊙
tartaric acid, aqueous	60	⊙	⊙	◑	●	●	●	●	●	●	●	●	●	●	●	●
tetrachlorethane	60	⊙	⊙	○	○	○	●	◑	⊙	○	○	○	○	●	○	⊙
tetrachloroethylene	60	⊙	⊙	○	○	○	●	◑	⊙	○	○	○	○	●	○	⊙
tetraethyl lead	20	⊙	⊙	○	○	⊙	●	●	◑	◑	⊙	◑	⊙	●	⊙	⊙
tetrahydrofuran	20	⊙	⊙	○	○	○	◑	○	⊙	○	○	○	○	●	○	⊙
tetrahydronaphthalene (tetralin)	20	⊙	⊙	○	○	○	●	●	⊕	○	○	○	○	●	○	⊙
thionyl chloride	20	⊙	⊙	○	●	●	●	●	⊙	○	●	○	◑	●	◑	⊙
thiophen	60	⊙	⊙	○	○	○	⊕	○	⊙	○	○	○	○	●	○	⊙
tin(II) chloride, aqueous	80	⊙	⊙	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
titanium tetrachloride	20	◑	●	◑	●	●	●	◑	◑	●	●	●	●	●	●	◑
toluene	20	○	○	○	○	○	●	◑	○	○	○	○	○	●	○	○
town gas, benzene-free	20	●	●	◑	○	○	●	●	●	●	○	●	○	●	○	●
transformer oil	60	●	●	○	○	○	●	●	●	◑	○	●	○	●	○	◑

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transmission Fluid type A	20	●	●	◑	◑	⊙	●	●	●	●	⊙	●	⊙	●	⊙	◑
triacetin	20	⊙	⊙	◑	◑	●	⊕	⊙	⊙	◑	●	◑	◑	●	○	⊙
tributoxyethyl phosphate	20	⊙	⊙	○	○	○	●	◑	⊙	○	○	○	○	●	○	⊙
tributyl phosphate	60	⊙	○	○	○	○	●	◑	⊙	○	○	○	○	●	○	⊙
trichloroacetic acid, aqueous	60	⊙	⊙	○	◑	◑	●	○	⊙	◑	◑	◑	◑	●	◑	⊙
trichloroethyl phosphate	20	⊙	⊙	○	⊙	⊙	◑	○	⊙	○	⊙	○	⊙	●	⊙	⊙
trichloroethylene	20	⊙	○	○	○	○	●	◑	⊙	○	○	○	○	●	○	○
tricresyl phosphate	60	⊙	◑	○	○	◑	⊕	◑	⊕	○	◑	○	○	●	○	⊙
triethanolamine	20	⊙	⊙	◑	◑	◑	◑	⊙	⊙	○	◑	○	○	●	⊕	⊙
triethylaluminium	20	⊙	⊙	⊙	⊙	⊙	◑	◑	⊙	⊙	⊙	⊙	⊙	●	⊙	⊙
triethylborane	20	⊙	⊙	⊙	⊙	⊙	●	●	⊙	⊙	⊙	⊙	⊙	●	⊙	⊙
triglycol	20	⊙	⊕	●	●	●	●	●	⊕	●	●	●	●	●	●	⊕
trimethylol propane, aqueous	100	⊙	⊙	◑	◑	◑	●	●	⊕	○	◑	○	◑	●	⊕	⊕
trinitrotoluene	20	⊙	⊙	◑	◑	⊙	●	◑	◑	⊙	⊙	⊙	⊙	●	⊙	⊙
trioctyl phosphate	60	⊙	⊙	○	◑	◑	●	◑	⊕	○	◑	○	○	●	⊙	⊙
trisodium phosphate	20	⊙	⊕	◑	●	●	●	●	●	●	●	●	●	●	●	●
turpentine	60	⊕	○	○	○	○	●	●	⊙	◑	○	◑	○	●	○	⊙
turpentine oil	20	⊕	⊙	○	○	○	●	●	⊙	◑	○	◑	○	●	○	⊙
urea, aqueous	60	⊙	⊙	◑	●	●	●	●	⊕	●	●	●	●	●	●	⊕
vaseline	60	●	⊕	●	◑	○	●	●	●	●	○	●	○	●	○	◑
vaseline oil	60	●	⊕	●	◑	○	●	●	●	●	○	●	○	●	○	◑
vinyl acetate	20	⊙	⊙	⊙	⊙	⊙	◑	⊙	⊙	⊙	⊙	⊙	⊙	●	⊙	⊙
vinyl chloride, liquid	20	⊙	⊙	⊙	⊙	⊙	◑	⊙	⊙	⊙	⊙	⊙	⊙	●	⊙	⊙
water	100	○	○	◑	●	●	◑	◑	⊕	●	●	●	◑	●	●	◑
wax alcohol	60	⊕	⊕	◑	○	○	●	●	⊕	◑	○	●	○	●	⊙	⊕
whisky	20	⊙	●	●	●	●	●	●	●	●	●	●	●	●	●	●
white lye	100	⊙	⊙	◑	●	●	◑	○	⊙	◑	●	◑	○	●	●	⊙
white oil	20	●	⊕	◑	◑	⊙	●	●	●	●	⊙	●	⊙	●	⊙	●
white spirit	60	●	⊕	◑	○	○	●	●	⊕	◑	○	●	○	●	○	⊕
wine	20	⊕	●	●	●	●	●	●	●	●	●	●	●	●	●	●
xylamon	20	○	◑	○	○	○	●	◑	⊙	○	○	○	○	●	○	⊙
xylene	20	○	○	○	○	○	●	◑	○	○	○	○	○	●	○	○
yeast, aqueous	20	⊙	⊕	●	●	●	●	●	●	●	●	●	●	●	●	●
zeolite	20	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
zinc acetate	20	●	●	◑	◑	●	●	●	●	◑	●	◑	●	●	○	●

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Suggestion for Storage

(in conformity with the revision of ISO 2230 dated 16.09.1992)

Storage conditions

The storage temperature must be below 25 °C; the items must be stored away from sources of direct heat and must not be exposed to direct sunlight. The relative air humidity must be such that no condensation occurs when the temperature in the storage room changes. The effect of ozone and ionising radiation must always be excluded.

Packaging

All materials for bins, for covering and wrapping must be free of substances that have a decomposing effect on elastomers.
Suitable packaging materials include soda paper, aluminium foil or opaque PE foil (min. 0,075 mm thick).

The packaged items must be labelled as follows:

a) part/article number of manufacturer	ISC O-Ring 20-2/335674
b) description of polymer	72 NBR 872
c) quarter and year of manufacture of the elastomer part	1/99
d) the classification of the elastomer (group)	group 2
e) number of packages	10 pieces
f) name or trademark of manufacturer Simrit.	

The elastomer products are divided into three groups:

		1st storage time in years	1st extension in years
Group 1	NR, AU, EU, SBR	5	2
Group 2	NBR, HNBR, ACM, AEM, XNBR, ECO, CIIR, CR, IIR	7	3
Group 3	FKM, VMQ, EPDM, FVMQ, PVMQ, FFKM, CSM	10	5

Additional extensions are possible under certain circumstances, but only after consultation with the relevant technical department. The technical department will conduct appropriate tests and will decide whether the products can continue to be used or must be discarded.

Suggestions for the assessment of elastomer parts after the first storage time:

1) Test in accordance with the respective product specifications. If such action is not included in the product specifications:

2) Visual inspection
Every part or every component in the representative sample must be checked as follows:
- lasting deformation such as folds or flats
- mechanical damage such as cuts, cracks, abrasions or detached layers
- crack formation on the surface, observed under a 10x magnifying glass
- changes of status of the surface such as hardening, softening, tackiness, discoloration and dirt.

The inspected features of the stored parts or components must be recorded. If the tests yield recordable results, the records must include the acceptable confidence interval of the average values of every test parameter.

A record must also contain the following:

a) the stored quantity of every item or every component, the date of first packaging, the date of storage

b) the date of each subsequent re-packaging

c) the manufacturer's batch number

d) the number of parts or components that form a representative sample of these parts or components.

Summary of the Mentioned Standards

DIN 3760	Rotary shaft lip type seals
DIN 3761	Rotary shaft lip type seals for automobiles
DIN 3771	Fluid systems – O-rings
DIN 7168	General tolerances for linear and angular dimensions and geometrical tolerances
DIN 7715	Permissible deviations for soft rubber parts (extract from DIN 7715 part 2)
DIN 7716	Rubber products Requirements for storage, cleaning and maintenance
DIN 7724	Polymeric materials; grouping of polymeric materials based on their mechanical behaviour
DIN 9088	Aerospace series - Storage life of rubber products
DIN 16901	Plastic mouldings; tolerances and acceptance conditions for linear dimensions
DIN 24320	Fire-resistant fluids - Hydraulic fluids of categories HFAE and HFAS - Characteristics and requirements
DIN 51524	Hydraulic fluids – Hydraulic oils – HL, HLP, HVLP
DIN 51604	FAM testing fluid for polymer materials, Composition and requirements
DIN 52612	Testing of thermal insulating materials Determination of the thermal conductivity with the guarded hot plate apparatus, Procedure and evaluation
DIN EN ISO 6721	Testing of polymer materials Torsion vibration test
DIN EN ISO 1183	Testing of plastics and rubber Determination of the density
DIN 53504	Testing of rubber Tensile trials
DIN 53505	Testing of rubber Shore A and D hardness test
DIN ISO 34-1	Testing of rubber Determination of the tear strength of elastomers; Trouser test piece
DIN 53508	Testing of soft rubber Accelerated ageing
DIN 53509	Testing of rubber Resistance of rubber to ozone cracking
DIN 53512	Testing of rubber Determination the rebound resilience of rubber
DIN 53513	Testing of rubber and elastomers Determination of the viscoelastic properties of elastomers on exposure to forced vibration atnon-resonant frequencies
DIN 53516	Testing of rubber and elastomers Determination of abrasion resistance
DIN ISO 815	Testing of rubber Determination of the compression set. Thermal Testing Procedures.
DIN 53533	Testing of elastomers; Testing of heat generation and service life during the fatigue test (flexometer test)
DIN 53538	Testing of elastomers; Standard reference elastomers For characterising service fluids with respect to their action on vulcanised nitrile rubbers
DIN 53545	Testing of elastomers; Determination of low-temperature behaviour of elastomers; principles and test methods
DIN 53546	Testing of elastomers; Impact test for the determination of the low-temperature brittleness point

DIN ISO 1817	Testing of rubber and elastomers Determination of the behaviour of rubber and elastomers when exposed to fluids and vapours
DIN ISO 48	Elastomers and thermoplastic elastomers Tensile strength.
DIN ISO 1629	Rubber and latex Difference and abbreviations
VDMA 24317	Hydraulic fluids Flame retardant hydraulic fluids Minimum technical requirements
ASTM D 395	Test Methods for Rubber Property-Compression Set
ASTM D 471	Standard test method for rubber property-effect of Liquids
ASTM D 746	Test method for brittleness temperature of plastics and elastomers by impact
ASTM D 945	Test methods for rubber properties in compression or shear (Mechanical-Oscillograph)
ASTM D 1418	Practice for rubber and rubber latices - Nomenclature
ASTM D 1600	Abbreviations of terms relating to plastics
ASTM D 2000	Classification system for rubber products in automotive applications

DIN Standard Leaflets can be obtained from:
Beuth-Vertrieb GmbH,
D-10719 Berlin, Uhlandstraße 175,
as well as
D-50672 Cologne, Friesenplatz 16
ASTM standards can also be obtained from
Beuth-Vertrieb. Summary of applicable standards.

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