SKF hydraulic seals – general technical information

Specifications for effective sealing systems

Designing hydraulic rod and piston sealing systems requires careful attention to the dynamic seal interaction and the principles of tribology to ensure long service life, proper seal function, minimal wear, low friction and smooth operation. Tribology is the study of the design, friction, wear and lubrication of interacting surfaces in relative motion. The most important considerations for tribological properties of a dynamic sealing system are:

- the seal material
- the seal profile design
- the counter-surface material and finish properties
- the hydraulic fluid, which is the lubrication for the dynamic sealing surfaces

For information about seal profile design, see the relevant product chapter.

Counter-surface finish properties

The surface properties of the cylinder bore and the piston rod have a great influence on the function and service life of the seal. Parameters for specifying a surface finish are defined by ISO 4287. The most common surface roughness parameter specified is R_a (in units µm or µin.), i.e. the arithmetic mean deviation of the surface profile. This value does not, however, completely describe how the surface can be expected to affect the seal. The reason for this is that two surfaces with the same values of R_a but with different surface profile characteristics can lead to different lubrication film thickness, resulting in varying seal performance and level of wear.

The material ratio curve (Abbott-Firestone curve) provides more information about the surface profile characteristics. It describes the ratio of the material-filled length to the evaluation length at a given cutting depth expressed in percent (→ **fig. 1**). The slope at the beginning of the curve represents the peaks in the profile, which are causing initial wear on the seal. The slope at the end of the curve represents the valleys in the profile, which serve as lubricant reservoirs.

Fig. 1

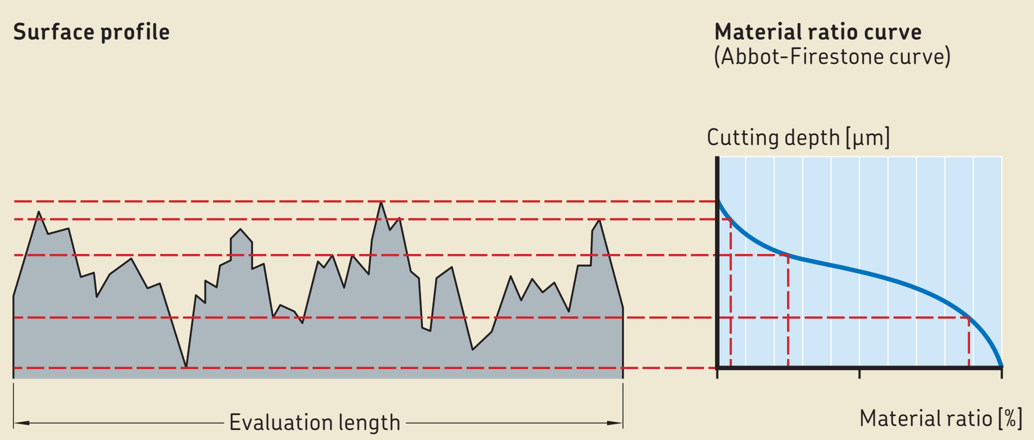


Table 1 shows some surface profiles. To ensure a surface finish with a suitable profile and characteristics for effective dynamic sealing, SKF recommends a defined combination of the following surface parameters:

- R_a – arithmetic mean roughness
- R_z – mean peak-to-valley height
- R_{max} – maximum peak-to-valley height
- R_{mr} – material ratio at a given depth

SKF recommends evaluating R_{mr} at a cutting depth of 0,5 R_z based on c_{ref} = 0% (→ **diagram 1**).

Diagram 1

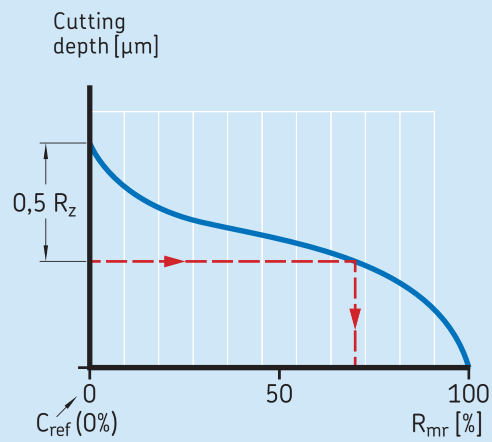
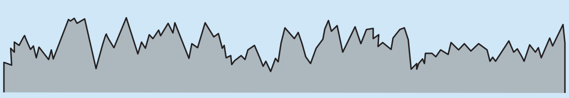
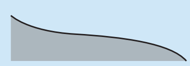
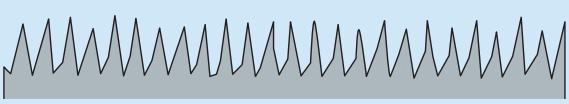
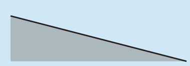
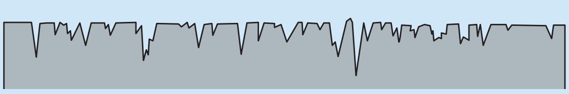
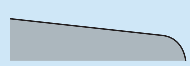


Table 1

Seal counter-surface examples

Surface profile	R_a	R_z	R_{max}	R_{mr}	Material ratio curve
–	µm	µm	µm	%	–
Eroded surface 	2,4	7,3	10,4	≈ 40	
Machined surface 	2,5	9,5	10,2	≈ 20 ... 25	
Ground and polished surface 	0,09	1,2	1,8	≈ 90	

Recommendations for dynamic sealing surfaces

The dynamic sealing surfaces on the piston rod and in the cylinder bore (→ **fig. 2**) require similar, but somewhat different surface finishing.

Piston rod

The recommendations for the piston rod sealing surface (→ **table 2**) assume that typical materials and processes are used to manufacture the piston rod by induction hardening a carbon steel rod, grinding, hard-chromium plating and then polishing it to achieve the specified diameter and finish.

For alternative rod materials and coatings, other surface specifications, finishing methods, seal materials and designs may be required. Examples of such alternative rod coatings include:

- various hard metals applied by high velocity oxygen fuel (HVOF)
- ceramic coatings of various compositions and finishes
- stainless steel
- iron nitride

For recommendations for sealing systems with alternative rod materials and coatings, contact SKF.

Table 2

Recommendations for the dynamic sealing surface on piston rods
(induction hardened and chrome plated rods)

	Thermoplastics and rubbers	PTFE materials
R_a	0,05 to 0,3 µm *(2 to 12 µin.)*	0,05 to 0,2 µm *(2 to 8 µin.)*
R_z	0,4 to 2,5 µm *(15 to 100 µin.)*	0,4 to 2 µm *(15 to 80 µin.)*
R_{max}	0,4 to 2,5 µm *(15 to 100 µin.)*	
R_{mr}	50 to 95% (cutting depth 0,5 R_z based on c_{ref} = 0%)	
Hardness	≥ 50 HRC	
Hardening depth	~1,2 to 2,5 mm *(~0.05 to 0.1 in.)*	
Chromium layer thickness	~20 to 30 µm *(~800 to 1 200 µin.)*	

Fig. 2

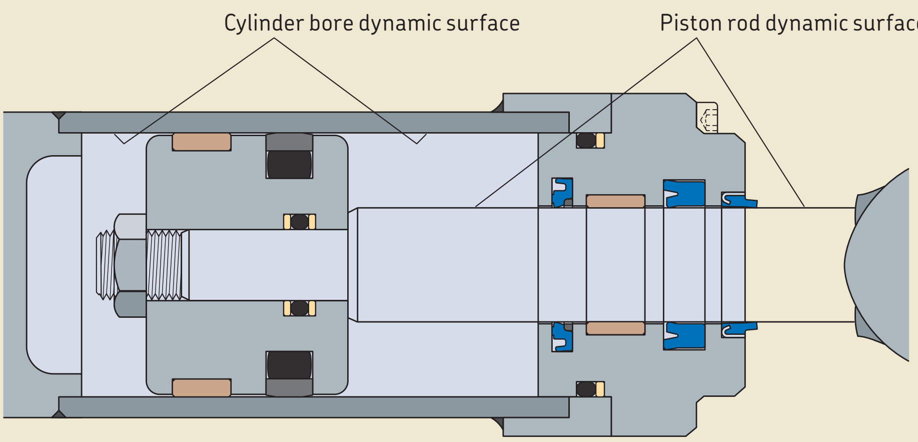


Table 3

Recommendations for the dynamic sealing surface on cylinder bores
(honed or roller burnished tubes)

	Thermoplastics, rubbers and PTFE materials
R_a	0,05 to 0,2 µm *(2 to 8 µin.)*
R_Z	0,4 to 2 µm *(15 to 80 µin.)*
R_{max}	0,4 to 2,5 µm *(15 to 100 µin.)*
R_{mr}	50 to 95% (cutting depth 0,5 R_z based on c_{ref} = 0%)

Cylinder bore

The recommendations for the cylinder bore surface (→ **table 3**) assume that typical materials and processes are used to machine the bore by either honing or roller burnishing to achieve the specified diameter and finish.

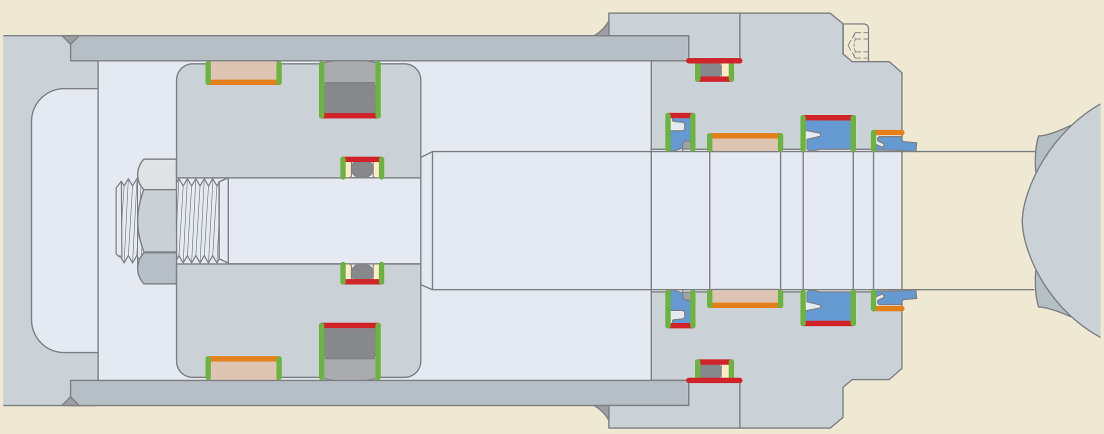
Recommendations for static sealing surfaces

Static sealing surfaces must also have a proper surface finish to enable the desired sealing performance (→ **fig. 3**).

The counter-surfaces of static seals exposed to pressure, including the static side of dynamic rod and piston seals, should have a roughness $R_a \leq 0,8$ µm *(30 µin.)*.

Seat diameters of guide rings and wiper seals should have a roughness of $R_a \leq 1,6$ µm *(63 µin.)*. Axial faces of all grooves should have a roughness of $R_a \leq 3,2$ µm *(125 µin.)*.

Fig. 3



Counter-surfaces of static seals exposed to pressure
$R_a \leq 0,8$ µm *(30 µin.)*

Seat diameters of guide rings and wiper seals
$R_a \leq 1,6$ µm *(63 µin.)*

Axial faces of all grooves
$R_a \leq 3,2$ µm *(125 µin.)*

Materials

Materials play a major role in the performance and lifetime of seals. Generally, hydraulic seals are exposed to a variety of application and working conditions, such as a wide temperature range, contact with various hydraulic fluids and the outside environment as well as high pressures and contact forces. The appropriate seal materials have to be selected to achieve a reasonable service life and service intervals. A wide variety of seal materials from four major polymeric material groups is available:

- thermoplastic elastomers, such as polyurethane (TPU) and thermoplastic polyester elastomers (TPC)
- rubbers, such as nitrile rubber (NBR) and hydrogenated nitrile rubber (HNBR), fluorocarbon rubbers (FKM, FPM)
- polytetrafluoroethylene (PTFE) and its compounds
- rigid thermoplastics and thermosets and their composites

Many different material properties should be considered to support and maintain the sealing function over the expected seal service life, for example:

- good elasticity over a wide temperature range, especially at low temperatures
- excellent compression set and stress relaxation behaviour to keep the sealing force for the requested operating period
- adequate hardness and flexibility to avoid leakage and allow easy installation
- superior gap extrusion resistance to cover the increased pressures of fluid power equipment
- adequate working temperature range
- good chemical compatibility to cover a wide assortment of hydraulic fluids such as mineral and synthetic oils, biodegradable and water-based fluids or fire-resistant fluids
- excellent tribological properties, i.e. low friction values and high wear resistance to achieve a high efficiency and avoid early failures especially when sealing against rough counter-surfaces

In addition to these considerations, the structure and morphology of polymeric materials make selection and specification of seal materials much more complicated than the standard materials used in mechanical engineering (e.g. aluminium or steel). Mechanical properties of polymeric materials are strongly influenced by time, temperature, load and rate of motion. Highly complex intermolecular processes affect the stress relaxation and retardation phenomena. Furthermore, the tribology conditions of the system (e.g. friction and wear) has a strong influence on the seal material behaviour and vice versa. Therefore, state-of-the-art sealing systems can only be developed by close cooperation between material experts and product designers, supported by advanced design tools like non-linear FEA and extensive seal testing capabilities.

SKF has a global material development organization that closely cooperates with the product development and testing functions. SKF is uniquely suited to develop, simulate, test and manufacture tailor-made materials for specific customer needs.

The following tables list the most common materials used by SKF for serial production of hydraulic seals. A wide variety of additional seal materials are available for special hydraulic seals or other seal applications.

Thermoplastic elastomers

SKF has a long history in developing and supplying special polyurethane grades for sealing purposes. SKF manufactures the well-known ECOPUR family of polyurethanes including H-ECOPUR for outstanding chemical and hydrolysis resistance, X-ECOPUR for extrusion resistance or S-ECOPUR for low friction and resistance to wear.

Polyurethanes combine the elastic properties of elastomers with the processability of thermoplastic materials. Seals made of polyurethanes provide excellent wear and pressure resistance and avoid leakage. Due to their elasticity and flexibility, they are easy to install. Special sealing polyurethane grades have a superior compression set and relaxation performance as well as temperature stability compared to commodity industrial grades.

Table 4 (→ **page 28**) lists common thermoplastic elastomers.

Rubbers

Rubbers are widely used in the seals industry for rotary shaft seals, static sealing elements such as O-rings and energizers, as well as dynamic seals in the fluid power industry. Depending on the chemical composition, rubbers can cover a wide temperature range up to 200 °C *(390 °F)* and more and withstand a wide variety of hydraulic fluids. NBR elastomers in a hardness range from 70 to 90 Shore A (shA) are the most commonly used rubbers in the fluid power industry. For higher temperatures and more aggressive hydraulic fluids, SKF recommends HNBR or FKM elastomers.

Table 5 (**→ page 29**) lists common rubbers.

PTFE

PTFE is a polymer with very unique properties. Due to its chemical composition, it is the plastic material with the highest chemical resistance and the lowest coefficient of friction, however, it has some restrictions in terms of mechanical properties and wear. Therefore, PTFE is very often modified by adding various organic and/or inorganic fillers to improve specific properties such as wear or extrusion resistance.

One of the most important characteristics of PTFE is the low coefficient of friction that provides outstanding start-up behaviour as well as minimized stick-slip phenomenon. Therefore, PTFE is the preferred material in applications that require accurate positioning of hydraulic cylinders. Due to the increased modulus of elasticity compared to rubbers and polyurethanes, PTFE seals can usually not be installed by simple snap-in procedures and require special tools and procedures for installation.

Table 6 (**→ page 29**) lists common PTFE materials.

Rigid thermoplastics and thermosets

Rigid thermoplastics and thermosets and their composites are characterized by much higher hardness and stiffness as well as reduced elasticity compared to polyurethanes, rubbers or PTFE. Therefore, they are used for components where mechanical strength is more important than flexibility, such as guide rings, anti-extrusion rings or special piston seal arrangements for heavy duty applications.

SKF offers rigid thermoplastics and composites in a wide variety of homogenous (unfilled or “virgin”) grades (e.g. polyacetal or polyamide), filled grades (e.g. glass fibre reinforced PA) and fabric-reinforced composites (e.g. phenolic resin with cotton fabric, PF). For extreme conditions, SKF can provide high performance materials such as PEEK (polyetheretherketone).

Table 7 (**→ page 30**) lists common rigid thermoplastic and thermosets.

WARNING

At temperatures above 300 °C *(570 °F)* all fluoro elastomers and PTFE compounds give off dangerous fumes. If there is contact with your skin or if the vapours are inhaled, seek medical advice immediately.

General technical information

Table 4

Thermoplastic elastomers (TPU and TPC)

Material code	Material description	Hardness Shore A (shA)	Hardness Shore D (shD)	Colour[1]	Example uses
LUBRITHANE U-1003	TPU	95		black	Rod seals, piston seals, wiper seals
LUBRITHANE U-1004	TPU		55	black	Wiper seals
LUBRITHANE U-1023	TPU	93		blue	Rod seals, buffer seals, piston seals, wiper seals
LUBRITHANE U-1029	TPU	94		light blue	Rod seals, buffer seals, piston seals, wiper seals
PU54/199	TPU	97	54	blue	Piston seal slide rings
W93	TPU	93		white	Press-in wiper seals
Y95A	TPU	95		yellow	Back-up rings for O-rings
395A	TPU	98		black	Back-up rings for O-rings
B93	TPU	93		dark blue	Rod seals
ECOPUR	TPU	95	48	green	Premium U-cup seals, wiper seals and chevron packings
X-ECOPUR	TPU with increased hardness and extrusion resistance	97	57	dark green	Rod and buffer seals
X-ECOPUR PS	TPU with increased hardness and extrusion resistance	98	60	green	Piston seals for heavy duty hydraulic applications
H-ECOPUR	TPU with increased chemical resistance against biodegradeable and water based fluids	95	48	red	Rod and piston seals for applications requiring hydrolysis resistance, increased chemical resistance or conformance with FDA regulations
XH-ECOPUR	TPU with increased chemical resistance and higher hardness	97	60	dark red	Rod and piston seals for applications requiring hydrolysis resistance, increased chemical resistance or conformance with FDA regulations
S-ECOPUR	TPU with improved tribological characteristics	95	48	dark grey	Rod and piston seals for water hydraulics, non-lubricated pneumatics or dry-running conditions
FLUOROTREL F-1504	TPC		55	turquoise	Energized rod seals, piston seals, anti-extrusion rings
TPC-ET72/075	TPC		72	black	Piston seal support rings

[1] The colour examples may deviate from the actual colour of the material.

Table 5

Rubbers

Material code	Material description	Hardness Shore A	Colour[1]	Example uses
A-8501	NBR	70	black	Rod seals, piston seals, energizers
A-8504	NBR-LT (low-temperature grade)	70	black	Rod seals, piston seals, energizers
A-8526	NBR	90	black	Piston seal energizers
C-7021	HNBR	70	black	Rod seals, piston seals, energizers
C-7022	HNBR	80	black	Rod seals, piston seals, energizers
V-7501	FKM	70	black	Piston seals
V-7503	FKM	90	black	Rod seals, piston seals, energizers
N70/015	NBR	70	black	Piston seal energizers
N70/6052	NBR	70	black	O-rings and energizers
N80/047	NBR	80	black	Piston seals
N80/198	NBR	80	black	Energizers for heavy duty applications
SKF Ecorubber-1	NBR	85	black	U-cup seals, chevron packings, machined seals
SKF Ecorubber-2	FKM	85	brown	U-cup seals, machined seals, chevron packings, wiper seals
SKF Ecorubber-H	HNBR	85	black	U-cup seals, chevron packings, machined seals

[1] The colour examples may deviate from the actual colour of the material.

Table 6

PTFE materials

Material code	Material description	Hardness Shore D	Colour[1]	Example uses
292	PTFE + 40 % bronze + MoS_2	62	brown-grey	Piston seal slide rings, guide strips
SKF Ecoflon 1, 100	PTFE unfilled	57	white	Anti-extrusion rings, chevron sets, O-rings, food-compatible products (FDA certificate)
SKF Ecoflon 2, 702	PTFE + 15% glass fibres + 5% MoS_2	60	grey	Anti-extrusion rings, chevron sets, O-rings
SKF Ecoflon 3, 741	PTFE + 40% bronze	65	brown	Anti-extrusion rings, chevron sets, O-rings
SKF Ecoflon 4	PTFE + 23% hard carbon + 2% graphite	65	black	Anti-extrusion rings, chevron sets, O-rings

[1] The colour examples may deviate from the actual colour of the material.

General technical information

Table 7

Rigid thermoplastics and thermosets

Material code	Material description	Colour [1]	Example uses
707	PA 6	black	Anti-extrusion rings
P-2501	PA 6.6 + 30% glass fibres	black	Split piston seal slide rings
P-2506	PA 6.12	black	Anti-extrusion rings
P-2518	POM	black	Anti-extrusion rings
P-2551	PA 6 + 40% glass fibres	dark grey	Guide rings and split piston seal slide rings
P-2552	PA 6 + 40% glass fibres + PTFE	black	Guide rings
PA66/011	PA 6.6 + 20% glass fibres	black	Split piston seal slide rings
POM/076	POM	red	Guide rings in compact sets (light and medium duty cylinders)
PF	Phenolic resin with cotton fabric	brown	Guide rings
SKF Ecomid	PA 6	black	Anti-extrusion rings, guide rings
SKF Ecotal, 728	POM	black	Anti-extrusion rings, guide rings and scraping wiper seals
SKF Ecopaek	PEEK	beige	Anti-extrusion rings, guide rings
SKF Ecowear 1000	UHMWPE (ultra-high-molecular-weight polyethylene)	white	Anti-extrusion rings, guide rings
SKF Ecotex	Polyester resin with polyester fabric and graphite filler	light orange	Guide rings

[1] The colour examples may deviate from the actual colour of the material.

Hydraulic fluids

Fluids used in hydraulic systems serve multiple functions for the system performance:

- transfer power by flow under pressure acting on moveable parts
- lubricate surfaces in contact and relative motion – hydraulic cylinder components and seals, as well as other system components such as pumps and valves
- prevent corrosion of components
- cool the system, by carrying heat from areas of high load, motion or turbulence and spread it to the entire volume of the system including reservoir tanks and cooling equipment
- clean the system by carrying contaminants and wear particles to filter bodies or settling areas

The fluids used in hydraulic systems come in various chemical compositions and viscosity grades as suited to specific applications.

Viscosity is a measurement of the thickness of a fluid or the resistance to flow. Seal performance is affected by the viscosity of the fluid and changes to the viscosity during use. Most typical hydraulic fluids exhibit decreased viscosity with increasing temperature and increased viscosity with increasing pressure.

The most commonly used media in hydraulic systems are mineral oil based fluids with various additives. However, a variety of alternative fluids may be encountered in special applications. For example, biodegradable fluids such as synthetic (HEES) or natural esters (HETG) and polyalphaolefines (PAO) may be used to reduce environmental impact in the event of accidental spills. Flame retardant fluids based on water or synthetic esters may be safely used in confined spaces or where the hydraulic system is used in close proximity to ignition sources. The data, specifications and recommendations in this catalogue are for common mineral oil fluids. For guidance on specifications of sealing systems for alternative fluids, contact SKF.

The chemical composition of hydraulic fluids can impact the seal life and performance depending on compatibility with the seal material(s). Absorption and reaction of the seal material(s) with non-compatible fluids can cause, for example:

- changes in seal material volume – increased “swelling” or decreased “shrinking” and their respective impacts on seal contact force and friction
- hardening and embrittlement of the seal material
- softening, loss of strength or dissolving of the seal material
- degradation of the polymer chains or cross-linking, causing the material to fatigue or lose resilience
- discoloration of the seal material

Generally, these changes are accelerated by higher temperature. To avoid these changes and the resulting damage to seal function and life, careful consideration should be taken to ensure compatibility between the fluid and all seal materials, as well as the temperature and mechanical loads on the seal material. SKF has a long history and extensive database of test results concerning compatibility of various seal materials and fluids, as well as unparalleled expertise in developing materials to meet customers’ needs for chemical resistance of seal materials.

Table 8 (**→ page 32**) summarizes the compatibility rating for the most important fluids and materials used in the fluid power industry. For materials not listed, contact SKF. **Table 8** provides general guidelines for new, clean fluids. Fluids vary by manufacturer, additives and contaminant levels. Materials vary by specific compound. The guidelines cannot substitute for testing the compatibility of a seal in the actual fluid and under actual operating conditions. Temperatures higher than specified in **table 8** can lead to degradation of the basic fluid or its additives. This can cause deterioration of the seal material. For applications where higher temperatures are required, contact SKF.

In addition to the specified hydraulic fluid, seal materials can be attacked by exposure to other fluids from other parts of the machinery (e.g. greases, fuels, coatings), environmental factors (e.g. humidity or radiation) and degradation and reaction with the fluids, additives and contaminants in the system producing additional chemicals.

General technical information

Hydraulic fluids and seal material compatibility

Fluids	Thermoplastic elastomers: ECOPUR, LUBRITHANE — Temperature Normal	High	H-ECOPUR, XH-ECOPUR — Normal	High	Ether-based TPU — Normal	High	TPC (≥ 95 shA) — Normal	High
Hydraulic fluids	≤ 60 °C (≤ 140 °F)	≤ 100 °C (≤ 210 °F)	≤ 60 °C (≤ 140 °F)	≤ 100 °C (≤ 210 °F)	≤ 60 °C (≤ 140 °F)	≤ 100 °C (≤ 210 °F)	≤ 60 °C (≤ 140 °F)	≤ 100 °C (≤ 210 °F)
Mineral oils HL, HLP, HVLP	A	B	A	A	A	B/C	A	A/B
ATF (automatic transmission fluids)	A	B	A	A	A	B/C	A	B
HETG (triglycerides, rape seed oil)	A	B/C	A	A	A	C	A	B/C
HEES (synthetic esters)	A	B/C	A	A	A	C	A	B/C
HEPG (polyalcylene glycols)	B	D	A	C	B/C	D	C	D
HEPR (polyalphaolefines)	A	B	A	A	A	B/C	A	B
Fire resistant fluids, water-based	≤ 40 °C (≤ 105 °F)	≤ 60 °C (≤ 140 °F)	≤ 40 °C (≤ 105 °F)	≤ 60 °C (≤ 140 °F)	≤ 40 °C (≤ 105 °F)	≤ 60 °C (≤ 140 °F)	≤ 40 °C (≤ 105 °F)	≤ 60 °C (≤ 140 °F)
Water	B	D	A	A	A	B	A	B
HFA-fluids (oil in water)	B	D	A	A	B	B/C	A	B
HFB-fluids (water in oil)	B	D	A	A	B	D	A	B
HFC-fluids (water-glycol)	C	D	A	B/C	B	B/C	C	D
Fire resistant fluids, water-free	≤ 60 °C (≤ 140 °F)	≤ 100 °C (≤ 210 °F)	≤ 60 °C (≤ 140 °F)	≤ 100 °C (≤ 210 °F)	≤ 60 °C (≤ 140 °F)	≤ 100 °C (≤ 210 °F)	≤ 60 °C (≤ 140 °F)	≤ 100 °C (≤ 210 °F)
HFD-R fluids	D	D	D	D	D	D	D	D
HFD-U fluids (polyol and carboxylic esters)	B	D	A	A	B	D	A	B/C
Mineral greases	A	B	A	A	A	B	A	A

A	Excellent
B	Good
C	Limited
D	Not recommended

1) Ethylene-propylene rubber for reference only – not common for hydraulic cylinders
2) For filled PTFE, compatibility of filler must be considered separately (e.g. bronze not recommended for water-based fluids).
3) Exposure to water-based fluids or moisture causes swelling.
4) Contact SKF

Table 8

Rubbers NBR, HNBR		FKM		EPDM[1]	Thermoplastics and thermosets PA, PF	POM	PEEK	PTFE[2]
Temperature Normal	High	Normal	High	All	Temperature All	All	All	All
≤ 60 °C (≤ 140 °F)	≤ 100 °C (≤ 210 °F)	≤ 60 °C (≤ 140 °F)	≤ 100 °C (≤ 210 °F)					
A	A	A	A	D	A	A	A	A
A	A	A	A	D	A	A	A	A
A/B	A/B	A	A	D	A	A	A	A
A/B	A/B	A	A	D	A	A	A	A
A	A/B	A/B	C/D	A	A	A	A	A
A/B	A/B	A	A	D	A	A	A	A
≤ 40 °C (≤ 105 °F)	≤ 60 °C (≤ 140 °F)	≤ 40 °C (≤ 105 °F)	≤ 60 °C (≤ 140 °F)					
A	A	A	A	A	C[3]	A	A	A
A	A	A	B	D	C[3]	A	A	A
A	A	A	A	D	C[3]	A	A	A
A	A	A/B	B/C	A	C[3]	A	A	A
≤ 60 °C (≤ 140 °F)	≤ 100 °C (≤ 210 °F)	≤ 60 °C (≤ 140 °F)	≤ 100 °C (≤ 210 °F)					
D	D	A/C[4]	A/C[4]	A	A	A	A	A
A/B	C	A	A	D	A	A	A	A
A	A	A	A	D	A	A	A	A

Gap extrusion

The process by which seal material is forced into the clearances between components is called gap extrusion. The dimension of this clearance gap is referred to as the extrusion gap, or “e-gap” (→ **fig. 4**).

The resistance of a given seal component to gap extrusion is mainly determined by the material composition and quality. Materials of greater hardness and stiffness typically also have improved resistance to extrusion. Therefore, full-face anti-extrusion or back-up rings of materials harder than the seal material may be used to prevent seal extrusion into the e-gap (→ **fig. 5**).

Pressure is the main driver of extrusion, but the e-gap size and application temperature are also major factors. **Diagram 2** shows the pressure resistance of different materials as a function of temperature. The values were measured on an SKF test rig. The tests were carried out with a rectangular sample, dimensions 38,7 x 49 x 5 mm under static pressure and an extrusion gap of 0,3 mm. The pressure values were taken at an extrusion length of 0,5 mm (→ **fig. 4**). While these sample values illustrate the differences in extrusion resistance for standard grades of typical seal materials, there are many variations of each basic composition that impact the extrusion resistance of seals. In addition, the profile design and the seal friction affect extrusion. For maximum allowable pressure, temperature and e-gap of each seal profile, refer to the profile data for each profile in the relevant chapters.

The maximum e-gap in a hydraulic cylinder occurs when the cylinder components are at the maximum radial misalignment of components. This misalignment is affected by:

- external forces acting upon the cylinder assembly (e.g. acceleration forces, frictional moments from rotation of cylinder end connections)
- the weight of the cylinder components (especially when used horizontally)
- deformation of cylinder components (rod flexing, guide ring radial deformation under force)
- the tolerance stack up of multiple cylinder components

Fig. 4

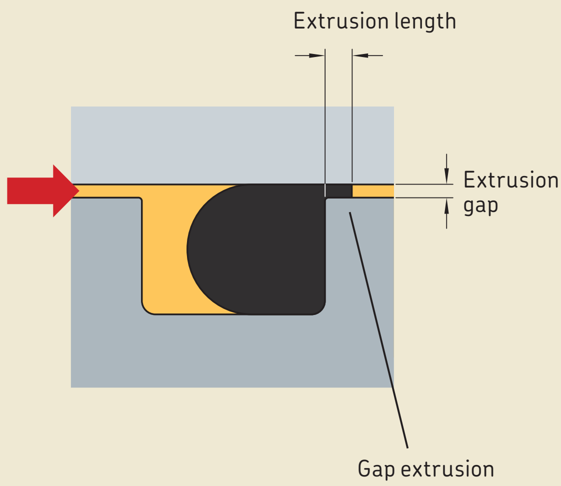


Fig. 5

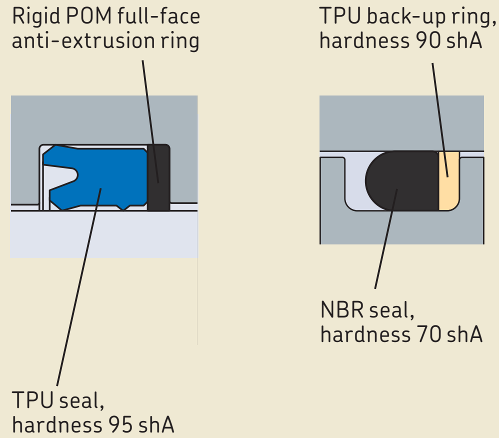
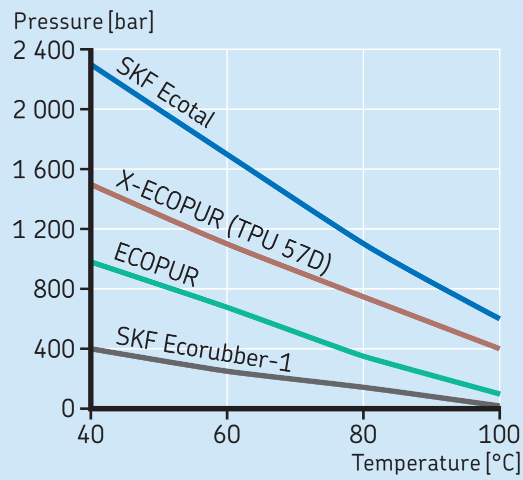


Diagram 2



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Therefore, it is necessary to calculate the e-gap at the maximum misalignment at minimum material conditions of the cylinder and guide components.

For rod seals, the maximum e-gap should be calculated with the following conditions (→ **fig. 6**):

- guide ring groove at maximum diameter D
- rod at minimum diameter d
- guide ring cross section at minimum thickness t (considering tolerances and any radial deformation of the guide ring under load)
- rod seal housing throat at maximum diameter h

For piston seals, the maximum e-gap should be calculated with the following conditions (→ **fig. 7**):

- bore at maximum diameter D
- guide ring groove at minimum diameter d
- guide ring cross section at minimum thickness t (considering tolerances and any radial deformation of the guide ring under load)
- piston seal housing at minimum outside diameter OD

The maximum allowable e-gap is provided in the profile data for each rod seal and piston seal profile in the relevant chapter. The e-gap can be kept within these limits by specifying and controlling the tolerances of dimensions described above and shown in **figs. 6** and **7**.

Fig. 6

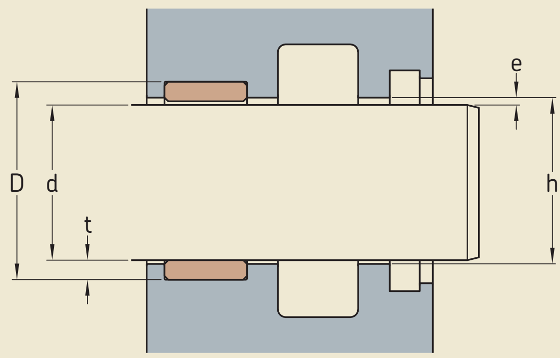
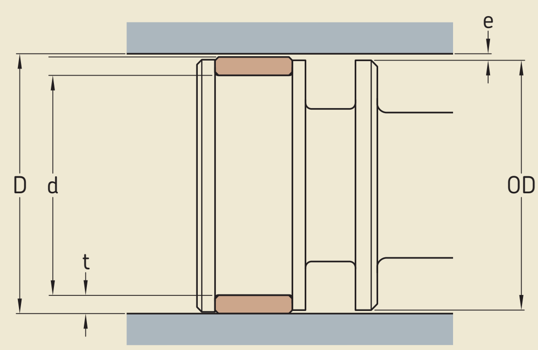


Fig. 7



Storage

During storage, the properties of elastomer products can be damaged either by chemical reactions or by physical processes. Chemical reactions are basically caused by the influence of heat, light, oxygen, ozone or contamination by chemicals. The physical processes, which are called physical ageing, are either due to the influence of external stresses leading to cracks and permanent deformation, or due to the migration of plasticizers, which makes the material more brittle and can lead to deformation of the parts.

Therefore, elastomer products only maintain their characteristics for several years without major changes, if they are properly stored. The ageing behaviour of elastomer products and their reaction on storage conditions depend considerably on their chemical structure. Unsaturated elastomers (e.g. nitrile rubber) age more quickly under improper storage conditions than saturated elastomers (e.g. fluorocarbon rubber).

Storage conditions

Elastomer products should be stored in accordance with the following recommendations, which are in line with the recommendations provided in ISO 2230 or DIN 7716.

- Rubber and plastic products should be stored in a cool and dry room. The relative humidity should be < 65%. Storage temperature should be around 15 °C *(60 °F)* and not exceed 25 °C *(75 °F)*. If the storage temperature is below 15 °C *(60 °F)*, care should be taken during handling of stored products because they may have stiffened. They should be warmed up slowly at ambient temperature.
- The storage room must not contain any ozone-producing devices, such as electric motors or high-voltage devices.
- Rubber and plastic products should not be exposed to direct sunlight or artificial light with a high UV content (bulbs are preferred to neon lamps).
- Rubber products should not be exposed to drafts. They should be stored in airtight packaging. The package material must not contain plasticizers. Polyethylene is the most suitable package material.
- Contact between rubber products of different compositions should be avoided.
- Contact between rubber and plastic products and chemicals or dangerous metals (e.g. copper, manganese) should be avoided.
- Rubber and plastic products should be stored as tension-free as possible, i.e. the parts should not be subject to tension, pressure or bending. Rubber products, especially seals, must not be hung on nails or tightly folded or rolled for reasons of space.

Shelf life

When stored under the conditions mentioned above, elastomer products retain their typical properties for several years (→ **table 9**).

The typical shelf life may be prolonged based on the actual product conditions at the end of the typical shelf life. Trained and experienced experts can approve a prolonged storage period based on a visual inspection of representative samples. The samples should not reveal any permanent distortion, mechanical damage or surface cracking. The material should not show any signs of hardening or softening nor any kind of tackiness.

Table 9

Shelf life recommendations in years

Material	Typical shelf life	Possible prolongation
TPU (standard)	5	2
ECOPUR, LUBRITHANE	5	2
H-ECOPUR, XH-ECOPUR	10	2
TPC	5	2
NBR	6	3
HNBR	8	4
FKM, FPM	10	4
EPDM	8	4
MVQ (silicone)	10	5
PTFE	15	5
PA, POM, PF	8	4
PEEK	15	5
UHMWPE	10	5

Installation and assembly

Seal housing grooves

The type of seal housing determines the method of installation, required equipment and the degree of difficulty. There are four main types of seal housings.

Closed housing grooves

Closed housing grooves are the most common seal housings (→ **fig. 8**). They require the most planning and effort to ensure that the seal is installed properly without damage. Not all seal cross section sizes and material combinations can be installed into this type of seal housing.

Open housing grooves

Open housing grooves allow the seal to be pressed in with minimal deformation and are therefore a good choice when the seal design, material or size prevent installation into a closed or stepped housing. Some seals, such as press-in wiper seals, have a metal sleeve that retains the seal in an open groove by press forces (→ **fig. 9**), whereas other seals may require a snap ring (→ **fig. 10**). Plastic snap rings, such as RI for rods or RR for piston, are available from SKF on request. Open housing grooves require specified edge radii or chamfers to prevent seal damage when the seal enters the housing groove or passes the snap ring groove.

Fig. 8

Closed housing groove

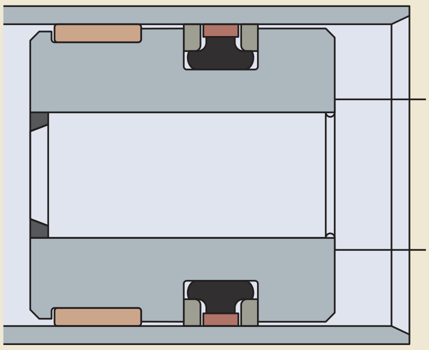


Fig. 9

Open housing groove

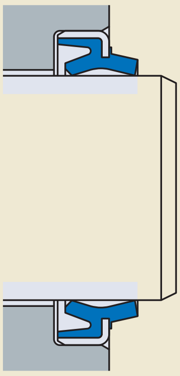
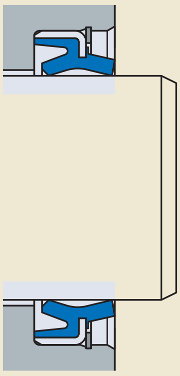


Fig. 10

Open housing groove with snap ring



Split two-piece closed grooves

These grooves incorporate two separable machine components to provide an open groove when the seal is installed and a closed groove when the machine is fully assembled (→ **fig. 11**).

Stepped grooves

Stepped grooves allow seals to be installed with less deformation (→ **fig. 12**). Snap-in wiper seals are a common example in hydraulic cylinder applications.

Corner radii

The corner radii inside the groove should be sized to avoid inadvertent contact with with the adjacent portion of the seal. Static side corner radius recommendations are provided in the product tables of the relevant chapter.

Groove edge radii

All outside groove edges and any other edges that may come into contact with the seal during installation or use should be broken with a small radius. Otherwise, the sharp edge may damage the seal. Unless otherwise specified, all outside groove edges should have a radius of approximately 0,2 mm (*0.008 in.*).

Fig. 11

Split two-piece closed housing groove

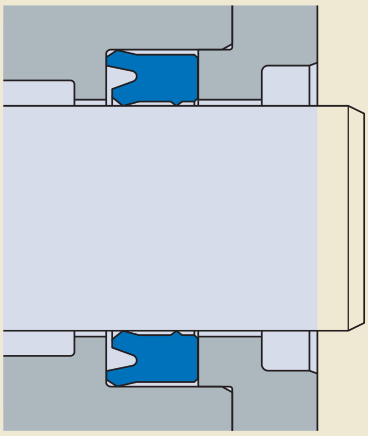
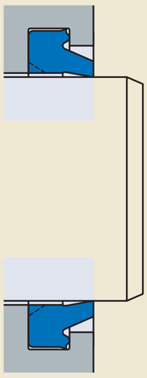


Fig. 12

Stepped housing groove

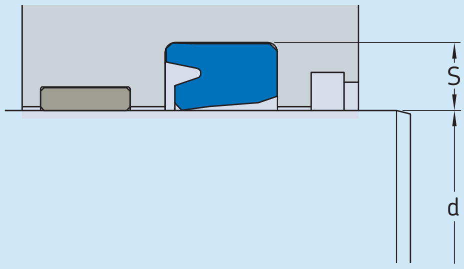


Installation chamfers

Installation chamfers should be designed into the cylinder bore and onto the assembly end of the piston rod to ensure that the seal can easily transition from its free state diameter into its installed diameter. The installation chamfer should also be blended into the cylinder bore or piston rod diameter with a generous radius. The chamfer angle and minimum length recommendations are provided in the product tables of the relevant chapter.

Table 10

General recommendations for selecting the type of installation for rubber and TPU materials
(hardness ≤ 95 shA)



Diameter/radial depth ratio	Type of installation
d/S ≤ 6	Open groove
6 < d/S ≤ 10	Closed groove, installation with tool
d/S > 10	Closed groove, installation by hand

Installing rod seals

The method of installation and the possible groove types for rod seals depend on the materials, seal design and ratio between the diameter and cross-sectional height. **Table 10** provides general recommendations for profiles made of rubber or TPU with a hardness ≤ 95 shA. PTFE or other harder materials may require a smaller radial depth S or even open grooves. The recommendations in **table 10** are not a substitute for careful installation tests in the particular application.

Installing rod seals in closed grooves

Rod seals can often be installed into closed grooves through carefully bending the profile similar to a kidney shape and then inserting it into the groove. It is very important to avoid sharp bending.

Thin and flexible profiles can be installed by hand (→ **figs. 13 a** and **b**). Installation tools for TPU rod seals help to install profiles of greater section thickness (→ **figs. 14 a** to **f**). After installation, the seal may need to be reshaped to a round form using a cone-shaped tool.

For PTFE seals, small diameter seals or for serial assembly, special assembly tools (→ **fig. 15**, **page 42**) may be required to save time or avoid seal damage. For additional information about such special installation tools, contact SKF.

Fig. 13 a

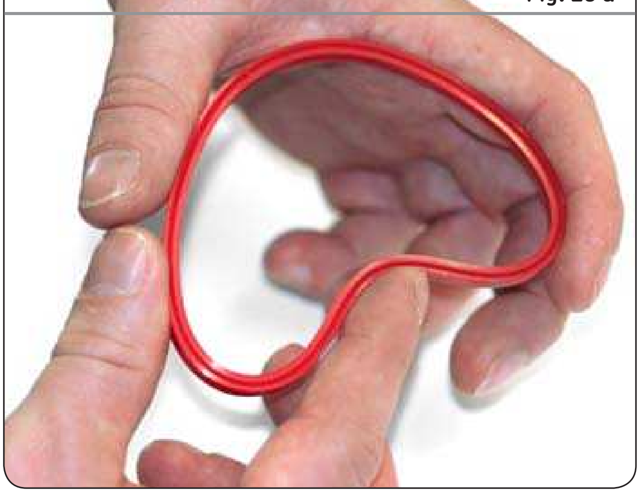


Fig. 13 b

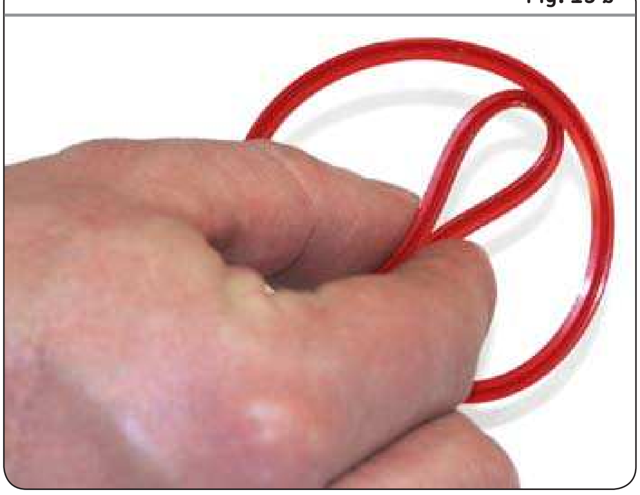


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Fig. 14a

Tool, rod seal and housing

Fig. 14b

Tool positioned for grasping the seal

Fig. 14c

Seal properly folded

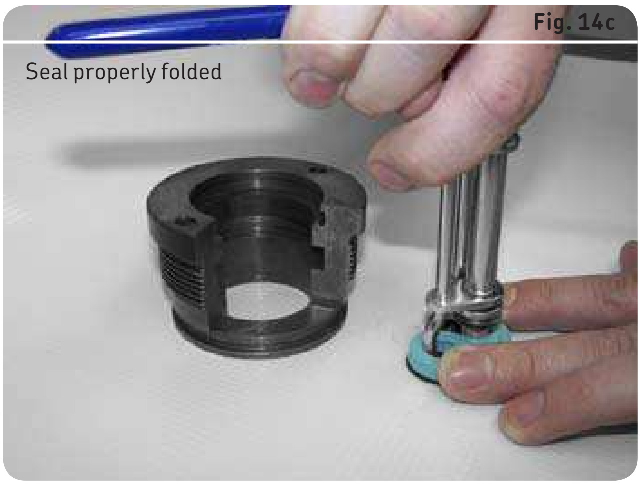


Fig. 14d

Inserting the seal into the housing

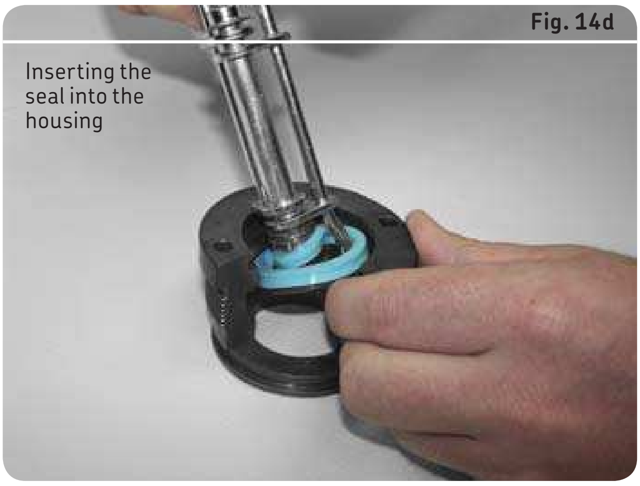


Fig. 14e

Seal positioned for installation

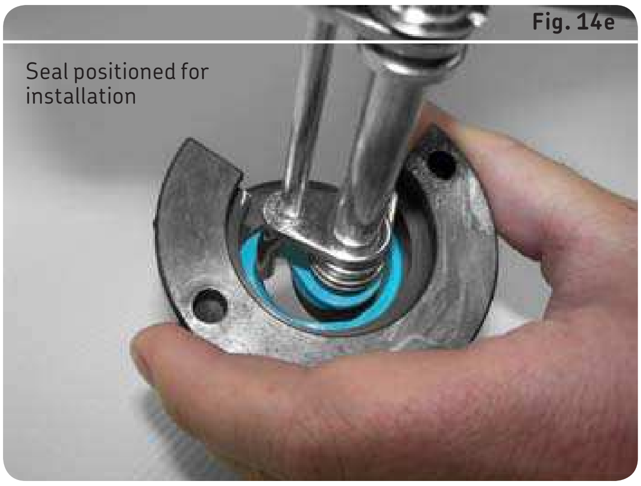
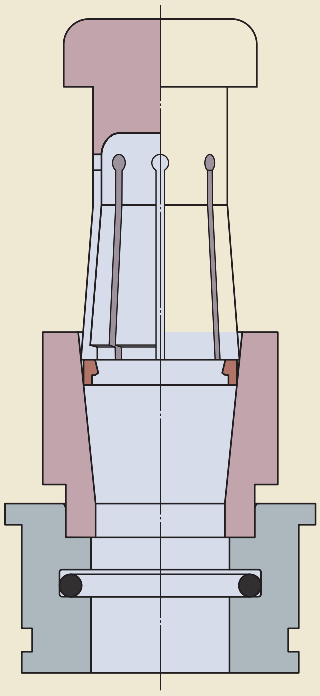


Fig. 14f

Seal properly installed

Fig. 15



Installing piston seals

Piston seals installed in closed grooves must be expanded or stretched into position. Seals with step cut slide rings such as CUT or SCP (→ *Piston seals with rigid split slide rings*, **page 54**) are relatively easy to expand into position. Non-split profiles should not be expanded to a material deformation of more than 20% for TPU or 30% for rubbers. Otherwise, the permanent deformation would be too large. Heating the seal, e.g. in an oil bath, decreases the required expansion force, but cannot increase the maximum material deformation.

Piston seals with a TPU slide ring can usually be installed by hand or with simple tools (→ **fig. 16**). PTFE seals or those with thicker radial sections may require special assembly tools to save time or avoid seal damage (→ **fig. 17**). For additional information about such special installation tools, contact SKF.

The recommendations cannot substitute for careful installation tests in the particular application.

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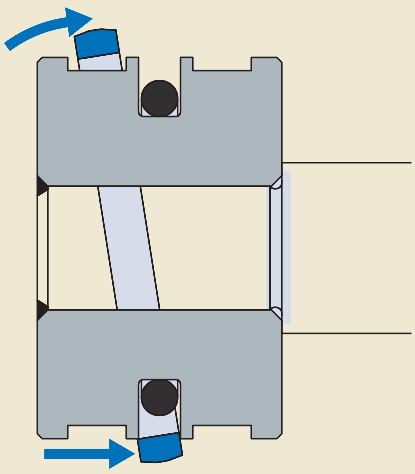
Fig. 16



Installing wiper seals

Snap-in wiper seals, which are installed in stepped grooves (→ **fig. 12**, **page 39**), are typically of a small radial section per diameter and close to the end of the cylinder head component. Therefore, installation by hand is usually possible.

Press-in wiper seals require special equipment and careful planning for ease of installation without damaging the wiper seal or housing. Assembly tools adapted for each press-in wiper seal size should be used in conjunction with appropriate steady force in a hand operated press. Installation by impact (e.g. striking the assembly tool with a hammer) is not advised. The press assembly tool should be configured to stop when the wiper seal has been pressed flush with the groove edge (→ **fig. 18**). Pressing beyond flush can damage the wiper seal.

Fig. 17

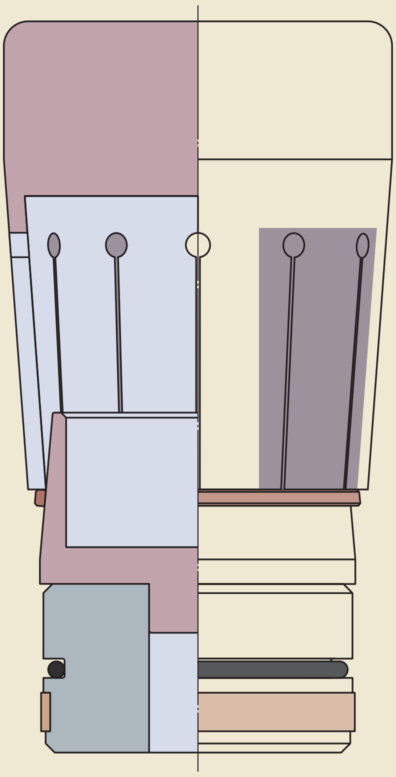


Fig. 18