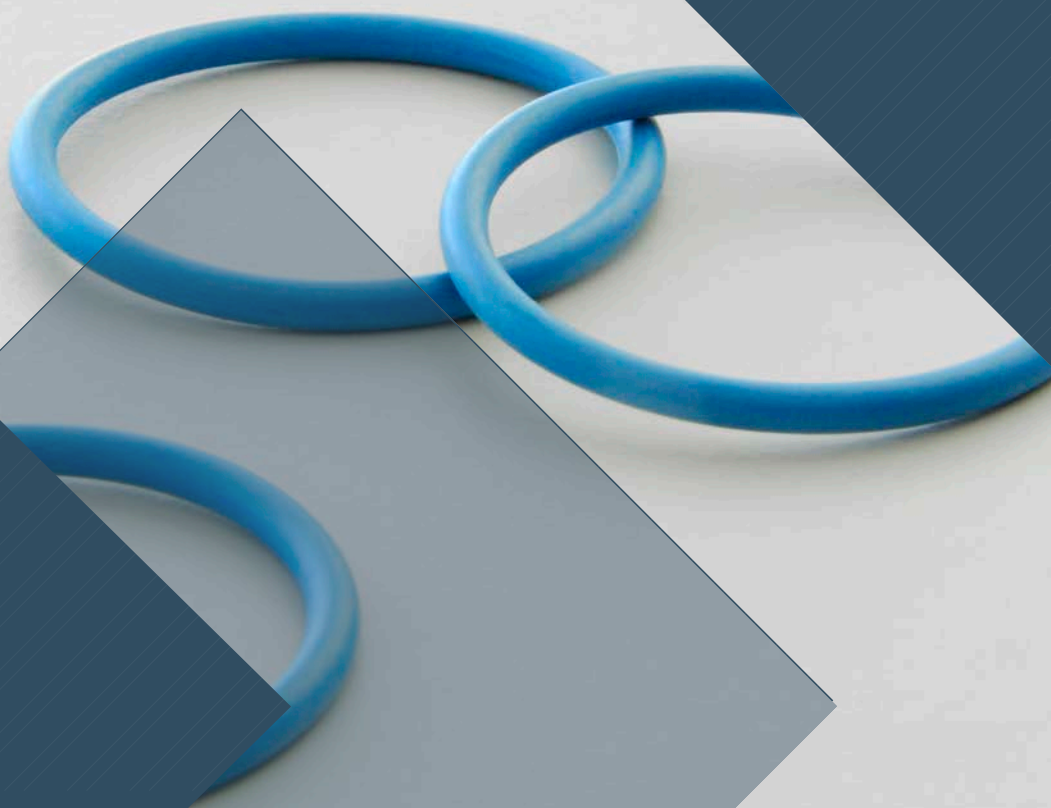**Angst+Pfister**

O-Rings

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- **Identification of elastomer O-Rings**
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1

Introduction

O-Ring seals are already more than 100 years old and were first registered as gas sealing rings in a water-cock patent by Thomas A. Edison in 1882. Other patents for the use of O-Rings were granted in North America in 1930. It was only with the discovery and development of synthetic rubber around 1930 that O-Rings began their successful growth.

Continuous development in the materials sector, in particular the creation of new groups of elastomers, has supported growth in the number of applications for O-Rings. Nowadays this is the most common type of seal, with millions in use in all sectors of industry.

In addition to their excellent sealing properties, O-Rings are simple to mould, easy to mount and maintain and do not require large housings. They can be used both statically and dynamically. The correct choice of material for the fluid and temperatures concerned is also critical. The O-Ring continues to be the sealing element with the best price/performance ratio.

General remarks on O-Rings

An O-Ring is an endless ring with a circular cross-section. It is manufactured to close tolerances, with a high surface finish and can provide an axial or radial seal. Its dimensions are quoted in terms of the inside diameter d_1 and the diameter of the cross-section d_2.

The simple symmetrical shape of the O-Ring makes it the ideal type of dual-action seal for many applications. It is available in a large number of sizes and in a wide range of materials and is used for many several sealing applications.
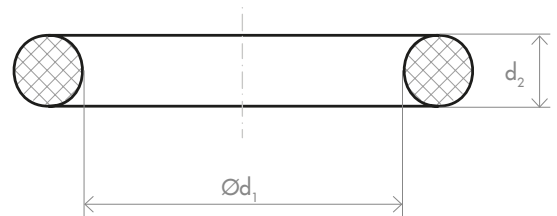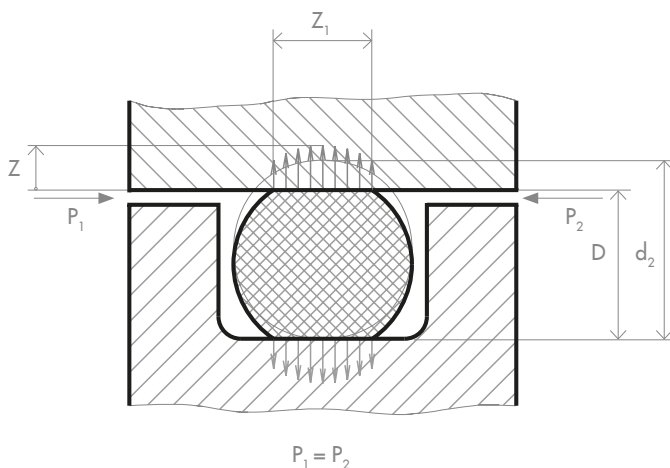
Function

Elastomers behave like highly viscous fluids. Pressure exerted on them is propagated to practically the same degree in all directions (basic law of hydrostatics, Blaise Pascal). The radial and axial forces generated by the O-Ring housing are reinforced by the pressure - use of the fluid to be retained. The total sealing force thus created increases as the pressure of the fluid rises.

Polymers and metals do not react to pressurization, in other words, it is only compression that creates the seal. This means that virgin PTFE O-Rings are designed to be compressed once only and require an enclosed mounting. With metal O-Rings it is possible to provide holes so that the pressure of the fluid is added to the compressive force.

The maximum sealing force z and the O-Ring seating Z_1 are functions of the O-Ring cross-sectional diameter d_2, its hardness, the compression selected $(d_2 - D)$ and the pressure differential $(P_1 - P_2)$.

Where O-Rings and housings are defined in accordance with the data in our catalogues, «mechanical tightness» can be assumed, provided that the following criteria are satisfied:

– Seal between stationary parts:
assume loss-free tightness with liquids and diffusion losses with gases

– Seal between moving parts:
with liquids, a film can build up at the slide face and lead to leakage losses in the long term. With gases there will be a loss at the slide face.

Practical experience has shown that this definition is generally valid. Variable operating conditions, such as temperature and pressure cycles, can lead to leakage under certain circumstances.

Propagation of pressure

$P_1 = P_2$

$P_1 > P_2$
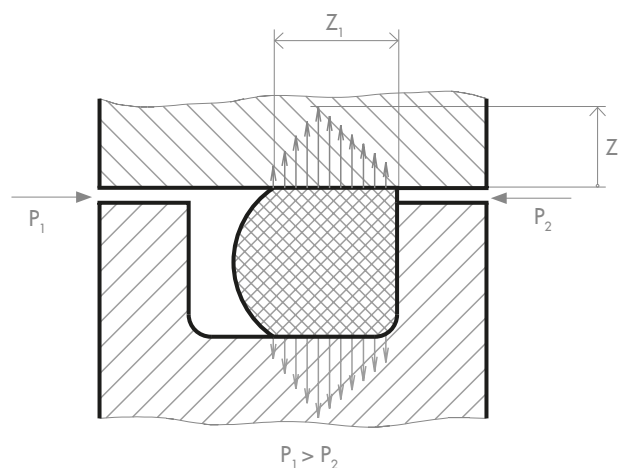
Designation of the elastomer O-Rings

Material name	Trade name	Brief description ISO 1629	Brief description ASTM D-1418
Acrylate elastomer	Europrene AR®	ACM	ACM
	Hytemp®		
Acrylonitrile butadiene elastomer	Europrene®	NBR	NBR
	Krynac®		
	Nipol®		
	Perbunan®		
Butyl elastomer	Esso Butyl®	IIR	IIR
	Polysar Butyl®		
Chloroprene elastomer	Baypren®	CR	CR
	Butador®		
	Neoprene®		
Ethylene acrylate elastomer	VAMAC®	AEM	AEM
Ethylene propylene diene elastomer	Dutral®	EPDM	EPDM
	Keltan®		
	Vistalon®		
Fluoroelastomer	Fluorel®	FKM	FPM
	Tecnoflon®		
	Viton®		
Fluorosilicone elastomer	Silastic®	FVMQ	MFQ
Hydrogenated acrylonitrile elastomer	Therban®	HNBR	HSN
	Tornac®		
	Zetpol®		
Natural rubber	Natsyn®	NR	NR
Perfluorelastomer	Kalrez®	FFKM	FFKM
Polyesther urethane elastomer	Vulcollan®	AU	AU
	Urepan®		
Polyether urethane elastomer	ARCOL®	EU	EU
Silicone elastomer	Elastosil®	VMQ	MVQ
	Rhodorsil®		
	Silastic®		
	Silopren®		
Styrene-butadiene elastomer	Buna S®	SBR	SBR
	Europrene®		
	Polysar S®		
Tetra Fluorethylene Propylene	AFLAS®	FEPM	FEPM

Dimensions

Determination of materials

The internal diameter (d1) is best measured with a graduated plug gauge or, for larger O-Rings, a measuring tape. It is also possible, in emergencies, to determine the developed length by cutting the O-Ring, but this method is susceptible to error.

The cross-sectional diameter (d2) is measured radially and axially with feeler gauges without any spring force. Contactless measurement with a profile projector is also possible.

It is only possible to determine the exact composition of materials in the laboratory and this is relatively expensive. TGA thermal analysis to ASTM E-1131 enables groups of materials to be precisely identified. It is a relatively simple matter to establish the broad definition of the material group using the density, and this can be undertaken with the aid of the table below.

Determination of the material group

Material groups		Density* g/cm^3
ACM	Acrylate Elastomer	1.30 – 1.40
AEM	Ethylene Acrylate Elastomer	1.30 – 1.41
AU	Polyester Urethane Elastomer	1.20 – 1.40
CR	Chloroprene Elastomer	1.30 – 1.50
EPDM	Ethylene-Propylene Elastomer	1.10 – 1.20
EU	Polyeter Urethane Elastomer	1.20 – 1.40
FEPM	Tetra Fluorethylene Propylene	1.90 – 2.00
FFKM	Perfluorelastomer	1.90 – 2.00
FKM	Fluoroelastomer	1.80 – 2.00
FVMQ	Fluorosilicone Elastomer	1.40 – 1.50
HNBR	Hydrogenated Acrylonitrile Elastomer	1.20 – 1.30
IIR	Butyl Elastomer	1.10 – 1.40
NBR	Acrylonitrile Butadiene Elastomer	1.20 – 1.30
NR	Natural Rubber	1.10 – 1.40
SBR	Styrene-Butadiene Elastomer	1.10 – 1.30
VMQ	Silicone Elastomer	1.30 – 1.40

* The exact densities of specific elastomer compounds are available on request.

Resilience

The NBR, FPM and EPDM elastomer groups all have different resilience properties and can therefore be reliably identified using non-destructive tests. They can be used in hardness ranges from 60 Shore A/IRHD to 90 Shore A/IRHD.

Acetone test

The acetone test differentiates between fluoroelastomers and perfluoroelastomers very easily. Perfluoroelastomers show virtually no swelling in acetone, whereas a significant degree of swelling occurs relatively quickly in fluoroelastomers.

Fire response

Given the fire response characteristics and the type of residues, the elastomer group can be determined.

Determination of the elastomer group

Elastomer	Fire response	Type of residues	Characteristics
NBR	- burns well in its own flame, but very unevenly	- friable, very slightly greasy	- flickering, shooting flame
FKM/FFKM	- does not burn in its own flame - light-coloured smoke	- only very slight residues	- very strong pungent odour, as intense as e.g. ammonia
VMQ/FVMQ	- does not burn in its own flame - burning area becomes white - smell not intense	- solid, white	- yellow-white flame, white smoke
EPDM	- burns very well in its own flame - smoking	- very fine-grained, very slightly greasy	- pungent odour
CR	- does not burn in its own flame, (flame-resistant), i.e. the specimen is extinguished when the flame is removed	- solid particles, not greasy	- rather pungent odour
IIR	- burns well with its own flame - yellow smoky flames	- slightly greasy but not as much as natural rubber	- slightly intensive odour
AU/EU	- does not burn in its own flame - strong characteristic odour	- soft and fluid, the specimen drips after an extended burning test	- immediately fluid at the point of burning, a kind of melt
NR	- burns very well in its own flame - uniform fire response - smoky flames	- sticky, greasy, white	- characteristic odour

Compression set

The compression set of an elastomer is a simple method of determining the quality and curing degree of a vulcanised material. An O-Ring is defined by the resilience of its material, which guarantees its sealing function, and this test is therefore very practical.

Compression set is defined as the permanent deformation of an elastomer after the force which changed its shape has been removed. It is tested to DIN 53517 or ASTM D395 method B, after 25% compression by storing in air in a hot cabinet, usually for 24 h at +100° C.

The following is generally valid: the lower the compression set, i.e. the lower the residual deformation, the higher the grade of the compound.

$$\% \text{ compression set} = \frac{d_2 - d_2^*}{d_2 - D} \cdot 100$$

* O-Ring in compressed state

The compression set data shown in our physical data sheet refers to tests with specimen sheets 6 mm thick. Tests on O-Rings, particularly those with a cross-section of less than 6 mm, give slightly inferior results. Compression set values measured on the O-Ring are available on request. The compression set is used as evidence to evaluate the vulcanization degree of a rubber O-Ring and this test procedure is often applied to indicate the proper production process of O-Rings.

Compression/resilience/residual compression set

Compression	Resilience	Residual compression set
I	II	III
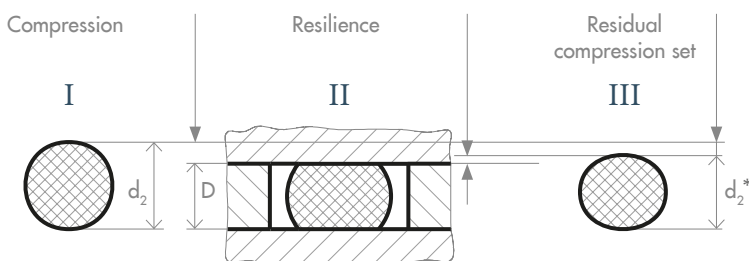
d_2 Nominal cross-section of O-Ring

D   O-Ring in compressed state

d_2^1 O-Ring after removal of stress

Hardness

The hardness of the material is defined as follows: Resistance of an elastomer material to penetration of a specimen with a defined force for a defined time. It is measured as Shore A or IRHD (International Rubber Hardness Degree).

Hardness is tested to:
– Shore A to DIN 53505
– IRHD to DIN 53519/1 or DIN 53519/2

The hardness data given in our physical data sheet refers to tests with 6 mm thick specimens. Hardness tests on O-Rings give different values. The round cross-section means that the results are up to 10 points lower, particularly with smaller cross-sections. Correction values for measurements on O-Rings are available on request.

PTFE-FEP covered O-Rings

These seals provide an ideal combination of the elastic properties of elastomer O-Rings and the chemical resistance of PTFE or FEP. Their function is the same as that of elastomer O-Rings. They are identified by the same sizes as other O-Rings. The transparent FEP coating makes it easy to determine the core material; red means silicon (VMQ) and black is fluoroelastomer (FKM). The hardness cannot be reliably determined because it is affected by the FEP cover.

Virgin PTFE O-Rings

The outstanding property of solid O-Rings made from virgin PTFE is their universal chemical resistance. The disadvantage of non-elastic behavior requires special housing grooves. Tightness is achieved solely by deformation of the cross-section and is not dependent on the properties shown by elastomeric materials.

Metal O-Rings and C-Rings

These are designed for high-temperature and high-pressure use. They require specially designed open housing grooves. Their tightness function is achieved by deforming the cross-section or is improved by adding pressure-reinforcing holes or gas pressure filling, as appropriate.

Design notes

|	
Elastomer O-Rings	Definition of the type of mounting
Static applications	Compression Compression of cord diameter
Axial seals for static applications	Rugosity Special groove profiles
Radial seals for static applications	Surface roughness
Special applications	Use of O-Rings in vacuum applications
Dynamic applications	Compression
Dynamic applications hydraulic	Profiles and surface finish of grooves
Dynamic applications pneumatic	Determination of O-Ring compression and depth of groove Examples of O-Ring compression for pneumatic operation Profile and rugosity of grooves
Special applications	Immersed mounting O-Rings in rotary applications Use as drive belts
General Design notes	O-Ring in rotary applications Force required for cross-sectional deformation Extension and compression Slide face material and surfaces Pressure Material hardness Lubrification Friction Wear Running speed Contamination at the seal
Back-up Rings	General Back-up Ring types Design notes
Virgin PTFE O-Rings	Mounting cavities Limitations Surface finish
Metallic O-Rings/C-Rings	Designs Surface finish

2
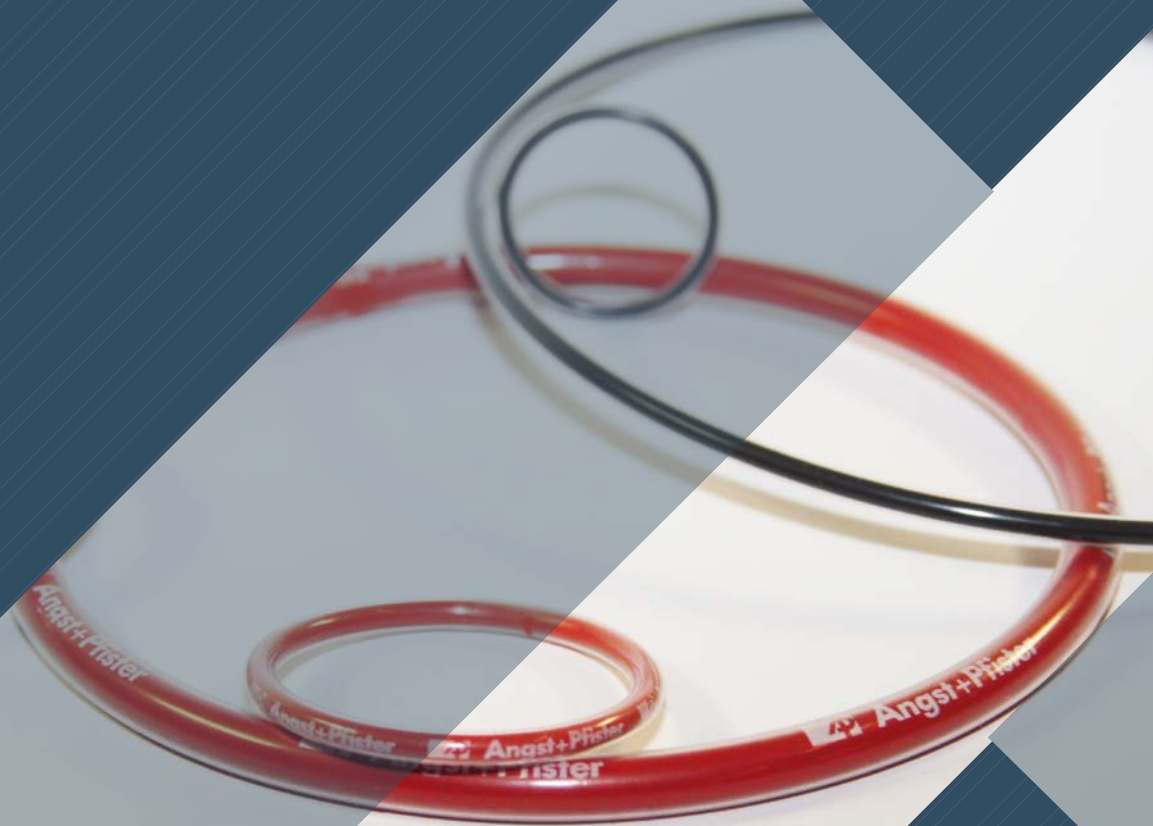
Elastomer O-Rings

Definition of the type of mounting

O-Rings are used in static or dynamic applications. In static applications the O-Ring can be used as a flange or cover seal to provide axial tightness or as a rod or piston packing to provide radial tightness. In dynamic applications the O-Ring is used as a rod or piston packing, mainly on reciprocating parts, to provide radial tightness. In exceptional cases it may be used for tilting movements, in which case special mounting conditions must be taken.
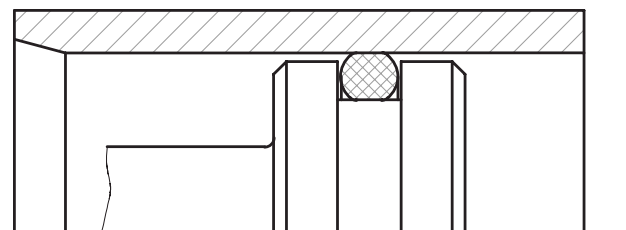
Flange seal, axial compression, static application
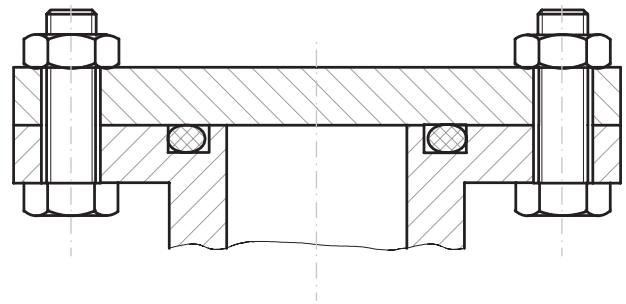
Rod packing, radial compression, static or dynamic applications
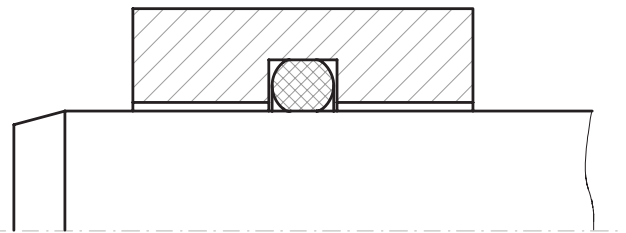
Piston packing, radial compression, static or dynamic applications
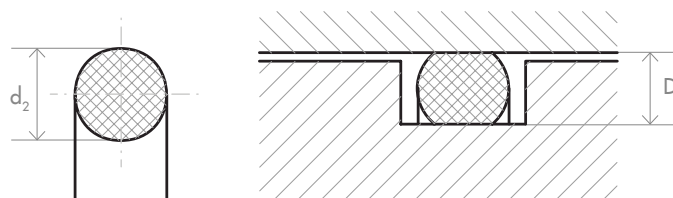
Static applications

In static conditions the O-Ring compression is higher than in dynamic applications. The requirements at the sealing surfaces are different, i.e. coarser machining can be accepted. In general, a seal with the largest possible cross-section should be chosen. Larger cross-sectional diameters are subject to greater compression [mm] and in percentage terms their tolerance deviations are smaller.

Compression force

The mounted O-Ring must be deformed and this is associated with a change in the cross-section. This compression must initiate the sealing load against the counter surfaces. When pressure is applied the compressive force automatically increases. The minimum compression necessary depends on the application, the maximum compression is governed by the requirement for long service life. If the compression is too high this has a negative effect on the compression set.

In static applications a higher compression can be selected because there is no friction or wear. If the surfaces are coarse or slightly worn the compression must be increased (to the maximum permissible) and if possible O-Rings made from softer materials used.

Calculation of compression

$$\text{Compression (\%)} = \frac{d_2 - D}{d_2} \cdot 100$$

The table of mounting dimensions for static applications that is given in the chapter 5 «Groove Dimensions» applies to O-Rings with a hardness of 70 IRHD/Shore A. It fully utilizes the permissible range for compression that is given in the diagram below. Where O-Rings with a hardness of 90 IRHD/Shore A are used, the percentage compression should be reduced somewhat if possible (lower spring resistance means easier mounting).

Compression of cord diameter
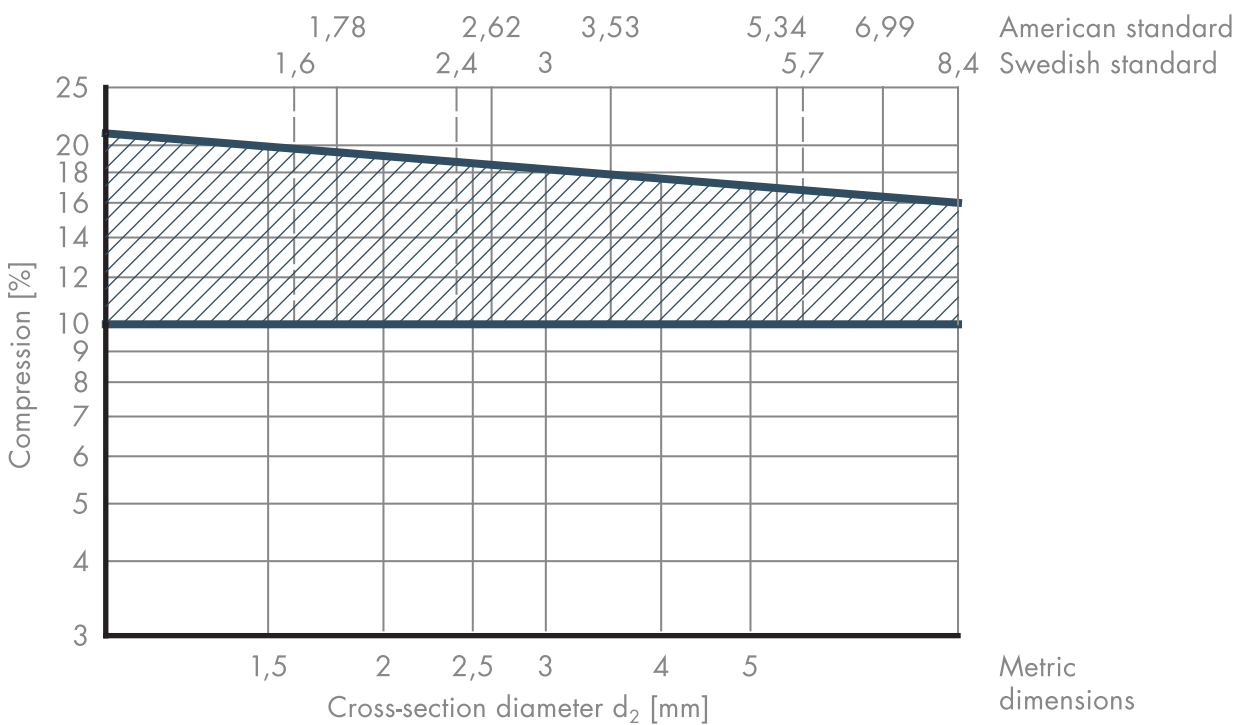
Design and surface finish of grooves

The profile of the groove is largely determined by the type of O-Ring mounting and the most efficient way of manufacturing the groove. The volume of the groove is normally approximately 25% larger than the cross-sectional area of the O-Ring. This is necessary because of the high degree of thermal expansion of the elastomer and the possibility that it might swell. Other rules apply to vacuum.

Axial seals for static applications

Pressure exerted from inside
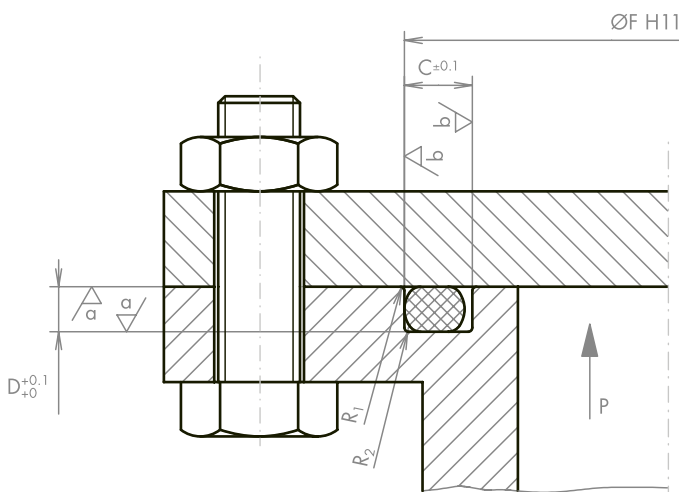

Tolerance C for cross-section Ø > 3 mm = ± 0.2
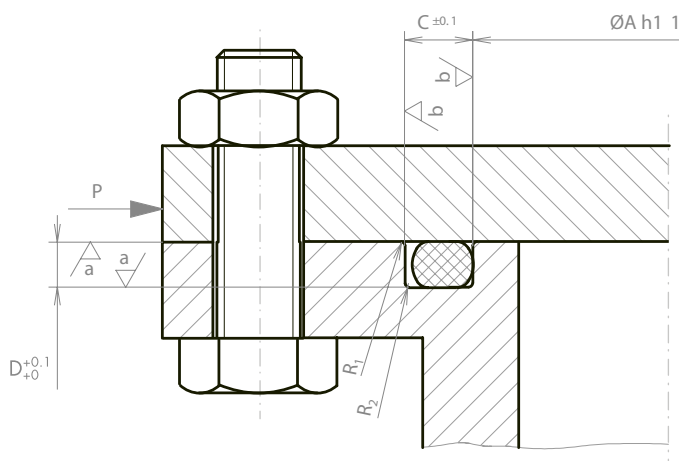
The groove is located in the flange or in the cover. The direction of deformation (elongated by the interference to the groove diameter of the inner grove side wall or pressed by the interference to the outer grove side wall diameter) is critical when determining the dimensions of the groove as the O-Ring carries out relative movement under compressive stress and changes its position inside the groove. It is therefore an advantage if it is supported on the side away from the pressure. When the pressure is applied from inside it is beneficial for the O-Ring to be slightly compressed on its outer diameter. A compression of 1 to 3% is ideal; this also enables tightely compressed.

If the pressure is applied from outside, the O-Ring must press against the internal diameter of the groove. Up to 6% elongation of the O-Ring internal diameter is permitted.
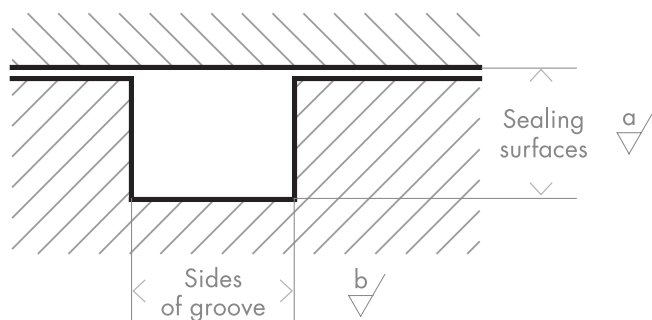
Locating groove
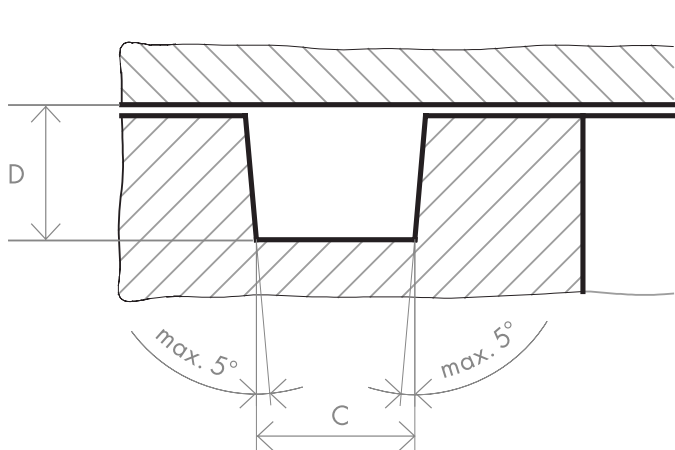
Locating grooves should be basically rectangular in design. However, for production engineering reasons, the walls of the groove may slope by up to 5°.

Roughness

| Surface		Pressure	Roughness			Roughness class
			R_a	R_t	R_z	
			µm	µm	µm	
Contact surface	a	not pulsating	1.60	16.00	6.30	N7
		pulsating	0.80	6.30	3.15	N6
Side of groove	b	not pulsating	3.20	22.00	12.50	N8

The surface finish shown here applies to O-Rings with a hardness of 70 to 90 IRHD/Shore A. If the contact surfaces are less finely machined for reasons of economy, softer O-Rings must be used and the cross-section must be more tightly compressed.
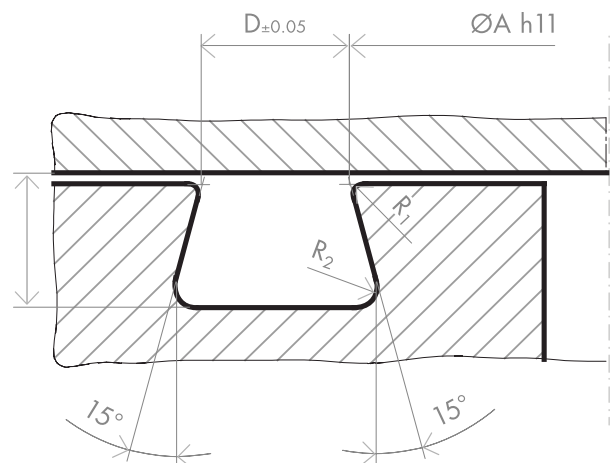
Special groove profiles

Dovetail groove

In certain types of assembly, the O-Ring must be held firmly in the groove (e.g. valve seats) and dovetail grooves should be provided. It is then permissible to apply only slight dynamic stresses to the O-Ring.

Single-sided dovetail groove
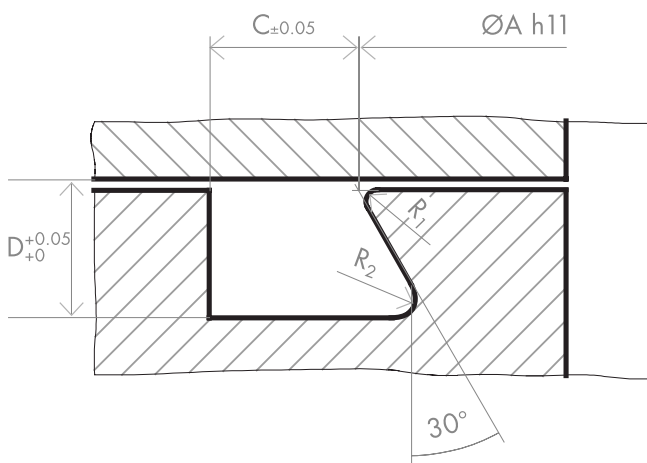
Two sided dovetail groove

Internal diameter of groove =
internal diameter of O-Ring plus 2 to 4 %

$\varnothing A = \varnothing d_1 \times 1.02 \text{ bis } 1.04$

Dovetail groove dimension

Diameter of O-Ring cross-section	Depth of groove	$D^{+0.05}_{+0}$	Width of groove	$C^{+/- 0.05}$	Radius	Radius max.
d_2	D		C		R_1	R_2
mm	mm		mm		mm	mm
3.00	2.40		2.60		0.10 – 0.20	0.75
3.50	2.90		3.00		0.10 – 0.20	0.75
3.53	2.90		3.00		0.10 – 0.20	0.75
3.55	2.90		3.00		0.10 – 0.20	0.75
3.60	3.00		3.10		0.10 – 0.20	0.75
4.00	3.30		3.40		0.10 – 0.20	0.75
5.00	4.10		4.20		0.10 – 0.20	0.75
5.30	4.50		4.50		0.10 – 0.20	0.75
5.34	4.50		4.50		0.10 – 0.20	0.75
5.70	4.85		5.00		0.10 – 0.20	0.75
6.99	6.00		6.20		0.10 – 0.20	1.50
7.00	6.00		6.20		0.10 – 0.20	1.50
8.40	7.50		7.80		0.10 – 0.20	1.50

Where the hardness of the O-Rings > 80 IRHD/Shore A a groove with C approximately 3% larger must be selected

Triangular groove

It is very difficult to check the dimension of the contact surface that is at an angle of < 45%. This type of mounting should not be considered for O-Rings with a cross-sectional diameter d_2 < 3 mm. The O-Ring is subjected to considerable permanent deformation which shortens its service life. Rectangular grooves are preferable.

Triangular groove
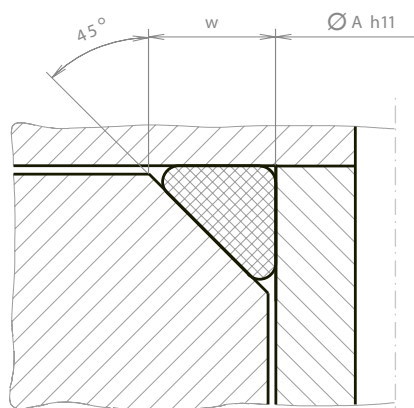
Triangular groove dimensions

| Diameter of O-Ring cross section	Chamfer	
d_2	w	
mm	mm	
3.00	4.10	+0.20/0
3.50	4.70	+0.20/0
3.53	4.70	+0.20/0
3.55	4.70	+0.20/0
3.60	4.90	+0.20/0
4.00	5.50	+0.20/0
5.00	6.80	+0.20/0
5.30	7.30	+0.25/0
5.34	7.30	+0.25/0
5.70	7.80	+0.25/0
6.99	9.50	+0.30/0
7.00	9.50	+0.30/0
8.40	11.50	+0.30/0

Radial seals for static applications

The groove is in a shaft or piston (cylinder packing) or in the cylinder liner (rod packing). In static cylinder and rod packing applications the O-Rings are sprung radially and are subjected to the same percentage compression.

Rod packing, groove in cylinder wall
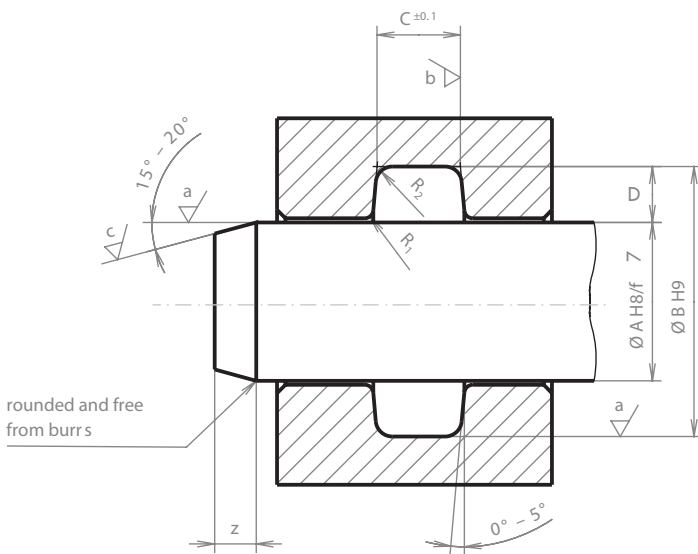
Cylinder packing, groove in piston or shaft
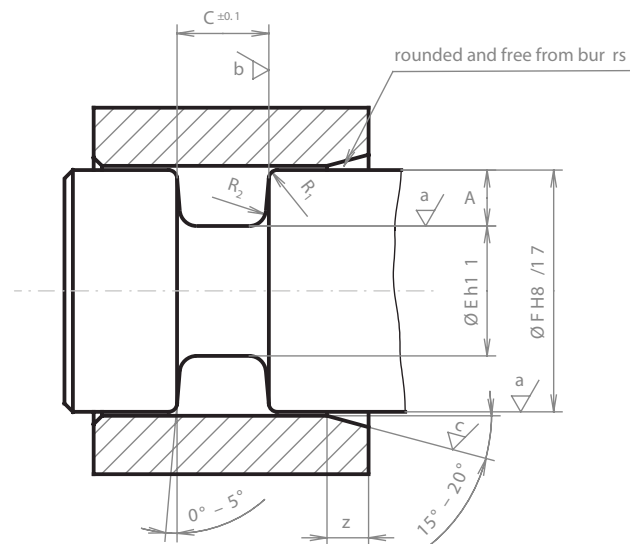
Clearance A from 100 bar and Ø 50 mm = H7/g 6
Tolerance C from cross-sectional Ø > 3 mm = ±0.2

Slope z: see table on page 37

Roughness

The surface finish shown here applies to O-Rings with a hardness of 70 to 90 IRHD/Shore A. If the contact surfaces are less finely machined for reasons of economy, softer O-Rings must be used and the cross-section must be more tightly compressed.

Roughness

Surface		Pressure	Roughness			Roughness class
			R_a	R_t	R_z	
		pulsating	µm	µm	µm	
Contact surface	a	not pulsating	1.60	16.00	6.30	N7
		pulsating	0.80	6.30	3.15	N6
Side of groove	b	not pulsating	3.20	22.00	12.50	N8
		pulsating	1.60	16.00	6.30	N7

Sides of groove   b

Sealing surfaces   a
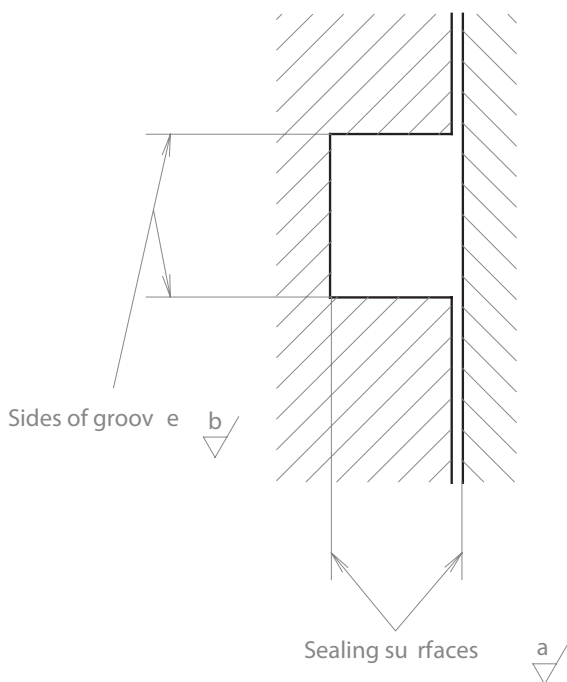
Special applications

Requirements for O-Rings

- High-performance elastomer grades with very low compression set guaranteeing a virtually uniform sealing force over a long service life.

- Tight manufacturing tolerance to guarantee precisely designed sealing load

- Clean sealing faces; the smallest fault or contamination causes leakage

- No impact offset and clean deburring in the radial

Use of O-Rings in vacuum applications

Special guidelines must be observed for the design of O-Rings and their seating grooves when they are used for vacuum applications. The following general design notes apply:

- Extremely clean and finely machined contact surfaces and groove sides

- The degree to which the O-Ring fills the groove is between 90% and 100% (normal mountings have a filling ratio of 75%).

- The O-Ring compression is 30% and therefore higher than in compression mountings.

- For high vacuum from 10^{-6} mbar only FPM, CR and FFKM can be used.

- In the ultra-high vacuum range only FPM and FFKM can be used.

Boxed O-Ring
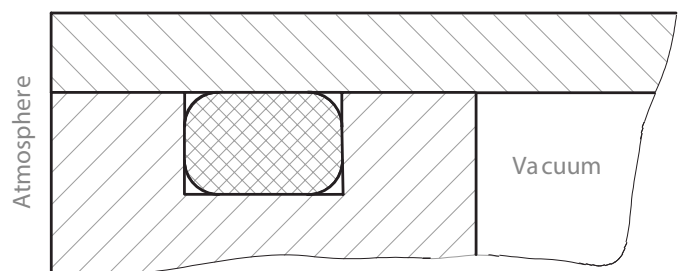
Atmosphere

Vacuum

Groove dimensions: Rectangular groove, radial compression

O-Ring cross-sectional diameter	Depth of groove	Width of groove	Radius		Compressione O-Ring O-Ring compression	Filling ratio of the groove
d_2	D 0/-0.05	C±0.05	R_1	R_2		
mm	mm		mm	mm	%	%
1.78	1.25	2.10	0.10	0.25	29.70	95.00
2.00	1.40	2.15	0.10	0.25	30.00	95.00
2.50	1.75	2.65	0.10	0.25	30.00	95.00
2.62	1.85	3.10	0.10	0.25	29.40	94.00
3.00	2.10	3.20	0.10	0.25	30.00	95.00
3.50	2.45	3.70	0.10	0.25	30.00	95.00
3.53	2.50	4.15	0.10	0.25	29.20	94.00
4.00	2.80	4.25	0.20	0.50	30.00	95.00
5.00	3.50	5.30	0.20	0.50	30.00	95.00
5.34	3.70	6.30	0.20	0.50	30.70	96.00
6.99	4.90	8.20	0.20	0.50	29.90	95.00
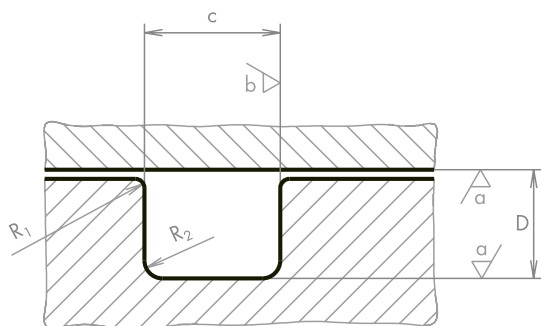
Roughness

Surface		Vacuum	Roughness			Roughness class
			R_a	R_t	R_z	
			µm	µm	µm	
Contact surface	a/▽	Normal	0.80	6.30	3.15	N6
		up to 10 h $^{-8}$ mbar	0.40	3.00	1.60	N5
		up to 10 h $^{-11}$ mbar	0.10	0.80	0.40	N3
Sides of groove	b/▽	generally	1.60	16.00	6.30	N7

Material to be used

For normal vacuums up to 10^{-5} mbar all our standard materials can be used. In the high vacuum area from 10^{-6} to 10^{-9} mbar FPM, CR and FFKM can be used. In the ultra high vacuum area FPM and FFKM must be used.
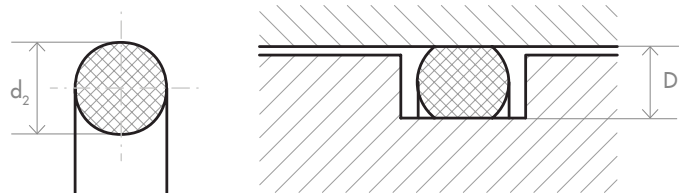
Dynamic applications

In dynamic applications the compression of the O-Ring is lower than in static applications. The contact surface must have a smoother finish in order to keep abrasion resistance and wear within limits. In general, the largest possible cross-section should be selected for the seal. The reasons are two-fold: compression and tolerance. Larger cross-sectional diameters are subject to higher compression (in mm) and in percentage terms their tolerance deviations are smaller.

In contrast with static applications, the deformation of the O-Ring cross-section is kept lower in order to minimize friction, wear and temperature rise. The minimum compression necessary depends on the application (hydraulics or pneumatics). The maximum compression is governed by the requirement for durability.

Determination of compression

$$\text{Compression (\%)} = \frac{d_2 - D}{d_2} \cdot 100$$

# General notes on the use of O-Rings in dynamic applications

- The larger clearances required for dynamic applications mean that at high pressures provision must be made for back-up rings. (see section «Back-up rings», page 57)

- Good lubrication conditions should always prevail in dynamic operation. Where this is not the case, e.g. in pneumatics, the O-Ring compression must be modified. (see section «Dynamic applications, pneumatics» on page 31)

- The resistance to contact fluids, including hydraulic fluids, must be checked. The compatibility of the lubricating greases used must also be checked.

- The temperatures of the fluids to be retained may rise as a result of friction heat. The material used should therefore never be subjected to temperatures at its upper service limit.

- Contaminated fluids and external soiling should be avoided. They damage the seal and this causes leaks.

- It must be kept in mind that peak pressures may be considerably higher than the system pressure (provide back-up rings).

- The relatively high friction that is present, particularly when lubrication conditions are less than ideal, can be partly reduced by reducing the compression. Take care not to go below the minimum compression as this is necessary to initiate the sealing process.

Dynamic applications, hydraulics

The table of groove dimensions in the section «Sets of dimensions» applies to O-Rings with a hardness of 70 IRHD/Shore A. Softer materials are unsuitable for dynamic applications. Where O-Rings with a hardness of 90 IRHD/Shore A are used, slightly higher compressive force and friction must be assumed. In this case the percentage compression can be slightly reduced.

The following diagram shows the permissible bandwidth for compression

Compression of cross-section diameter


Cross-section diameter d_2 [mm]
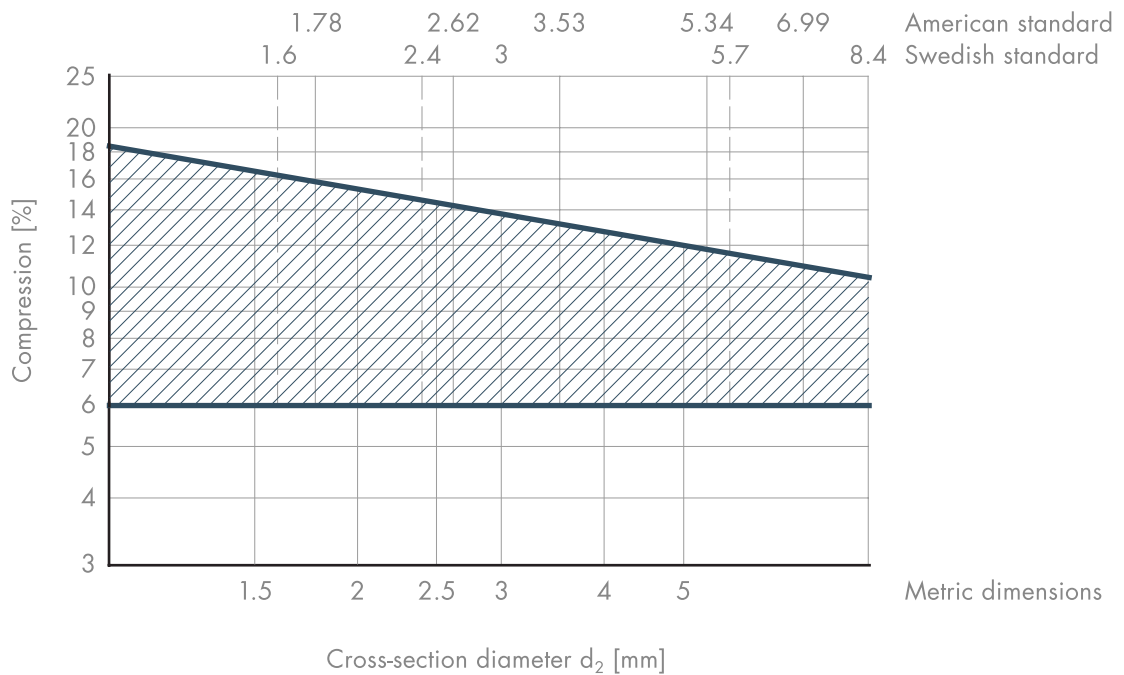
Profiles and surface finish of grooves

Where O-Rings are used in dynamic service the compression must be precisely defined and the lowest possible coefficient of friction is essential. This affects the dimensions and surface finish of the groove. In normal cases the volume of the groove is designed to be 25% larger than the volume of the O-Ring. The radial change in cross-section must be taken up by the axial excess width of the groove. Fully enclosed O-Rings must be avoided because they have a considerably higher compression force. Thermal expansion or possible swelling of the material can lead to failure.

When used as rod packings, O-Rings can be compressed by 1% to 3% at the outer diameter. If mounted in a piston groove, the internal diameter may be extended by up to 6%. This feature is principally used when O-Rings in inch sizes are inserted into metric cavities. With higher pressures and large clearances there is the danger of extrusion of the O-Ring (migration into the gap). Back-up rings are therefore necessary. If one or two back-up rings are used, the width of the groove (dimension C) must be enlarged to the full width of the back-up rings.

(see section on Back-up rings, page 57).

Rod packing, groove in cylinder wall
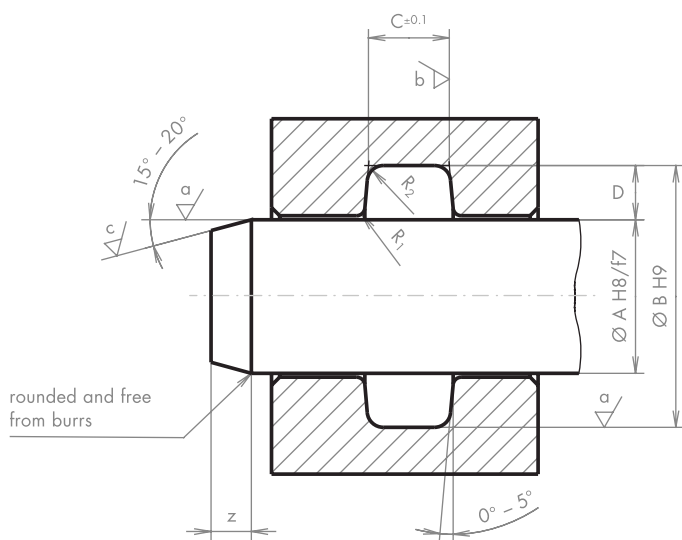
Cylinder packing, groove in piston or shaft
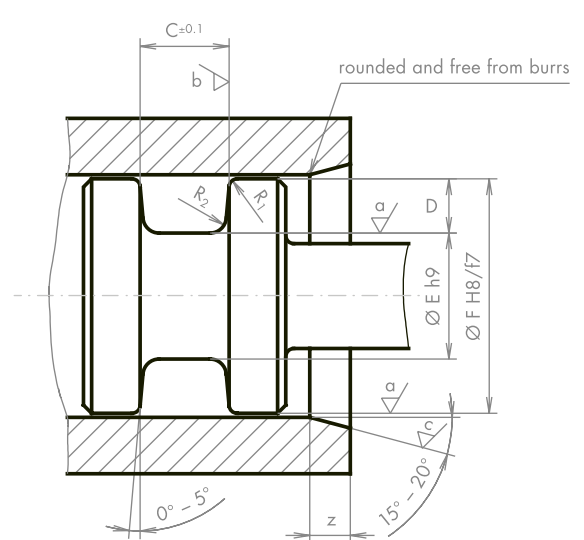
Clearance A from 100 bar = H7/g6
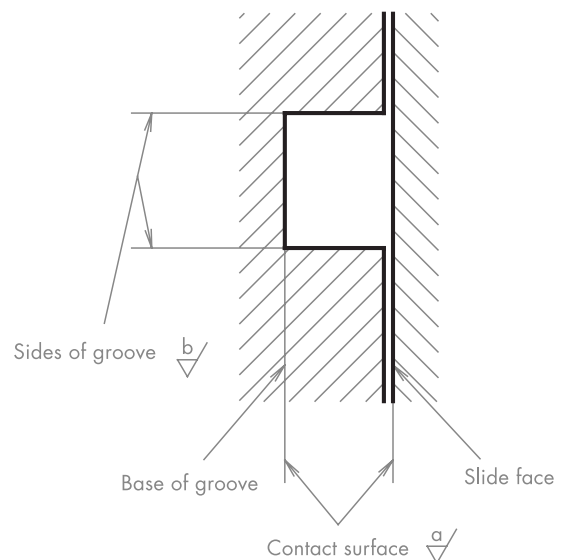Tolerance C from cross-sectional Ø > 3 mm = ± 0.2

Surface finish

Strict compliance with the surface finishes shown here is an important factor for the service life of the O-Ring. A better finish reduces wear and prolongs the life of the O-Ring.

Roughness

Surface		Pressure	Roughness			Roughness class
			R_a	R_t	R_z	
			µm	µm	µm	
Contact surface a	a/	Slide face	0.40	3.00	1.60	N5
		Base of groove	0.80	6.30	3.15	N6
Sides of groove b	b/		0.80	6.30	3.15	N6

Sides of groove b/

Base of groove

Slide face

Contact surface a/

Dynamic applications, pneumatics

The section «Sets of dimensions» does not give any mounting dimensions for dynamic applications in pneumatics because the O-Ring compression is very heavily influenced by the conditions of use.

Factors such as the fluid (oil-free or oiled air), running speed (slow or fast), length of stroke (short or long) and service (heavy or light) greatly affect the spring characteristic of the O-Ring and therefore its sealing capacity and service life.

In general, it can be said that O-Ring compression can be between 4% and 14%.

Compression of cross-section diameter
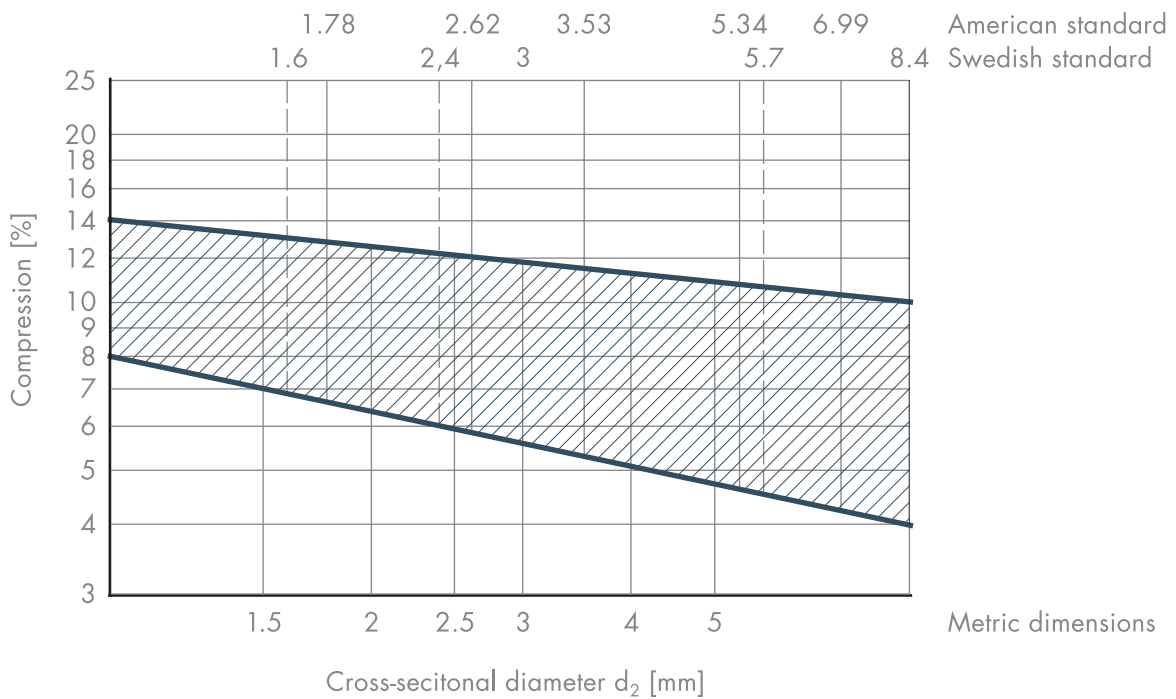
Determination of O-Ring compression and depth of groove

The following criteria must be clarified before determining the O-Ring compression:

- Compressed air: oil-free or oiled

- Stroke speed: fast (≥ 0,5 m/s) or slow (Shall be: <0,5m/s)

- Stroke length: long (≥ 0,1 m) or short (s 0,1 m)

- Service: heavy, continuous service, pulsation frequency shall be: pulsation frequnecy >= 30/min. or light, intermittent stroke, shall be: pulsation frequency <30/min.

Determination of O-Ring compression and depth of groove

Ø Cross sectional diameter	Basic compres-sion	Oil-free air	Oiled air	Fast speed	Slow speed	Long stroke	Short stroke	Heavy service	Light service
mm	%			≥ 0.5 m/s	< 0.5 m/s	≥ 0.1 mm	< 0.1 mm		
1.50 - 3.00	14	*	o	*	o	*	o	*	o
3.01 - 5.00	12	*	o	*	o	*	o	*	o
5.01 - 7.00	10	*	o	*	o	*	o	*	o

* Basic pressure is reduced 1.5 %
o Basic pressure remains the same, no reduction Depth of groove = Ø x (100% – actual compression): 100

Examples of O-Ring compression

Example 1

Diameter of O-Ring cross-section 4 mm
Basic compression 12%

Operating conditions:

- Oil-free air: reduction –1.5%

- Slow speed: no reduction 0.0%

- Long stroke: reduction –1.5%

- Light service: no reduction 0.0%

Total reduction –3.0%

Basic pressure 12% minus 3%
gives an effective compression of 9%.
Determination of groove depth D:

O-Ring cross-sectional
Ø 4.0mm x 0.91 = 3.64mm

Example 2

Cross-sectional 0 of O-Ring 6,99mm
Basic compression 10%

Conditions of service:

- Oiled air: no reduction 0.0%

- Speed 0.7m/s: reduction –1.5%

- Stroke length 0.5m: reduction –1.5%

- Heavy service: reduction –1.5%

Total reduction –4.5%

Basic compression 10% minus 4.5%
gives an effective compression of 5.5%
Determination of groove depth D:

O-Ring cross-sectional
Ø 6.9mm x 0.945 = 6.60mm

Profiles and rugosity of grooves

The use of the O-Ring in dynamic pneumatic applications requires minimum friction. As there is no lubrication, or at best faulty lubrication, wear can be reduced by precisely defining the compression values. The groove width C should be slightly modified since the compression is less than in hydraulic applications i.e. it should be reduced.

When used as rod packings, O-Rings can be compressed 1% to 3% at the outer diameter. If mounted in a piston groove, the inner diameter may be extended by up to 6%. This feature is mainly used when O-Rings in inch sizes are inserted into metric cavities.
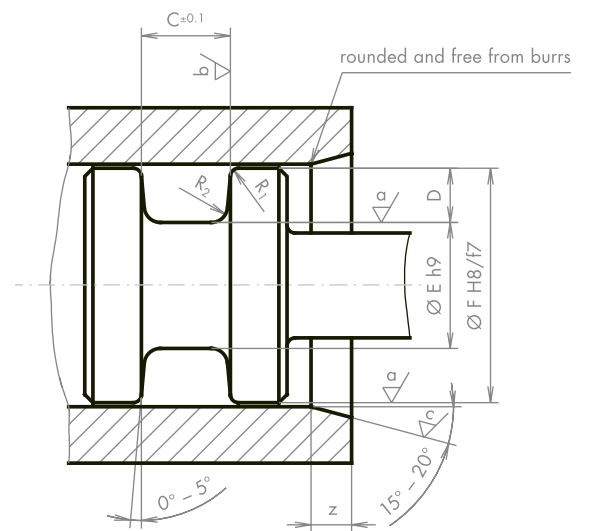
Profiles of grooves

The groove is in a rod instead of rod or piston (cylinder packing) or in the cylinder wall (rod packing). For dynamic cylinder or rod seals the O-Rings are sprung radially. The compression values are between 4% and 14%, depending on the cross-sectional diameter.

Rod packing, groove in cylinder wall
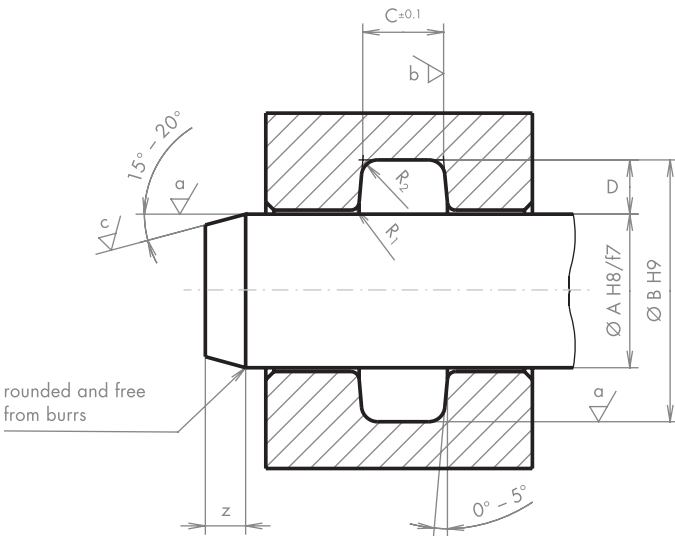
Cylinder packing, groove in piston or shaft

Tolerance C from cross-sectional $\varnothing > 3$ mm = ± 0.2

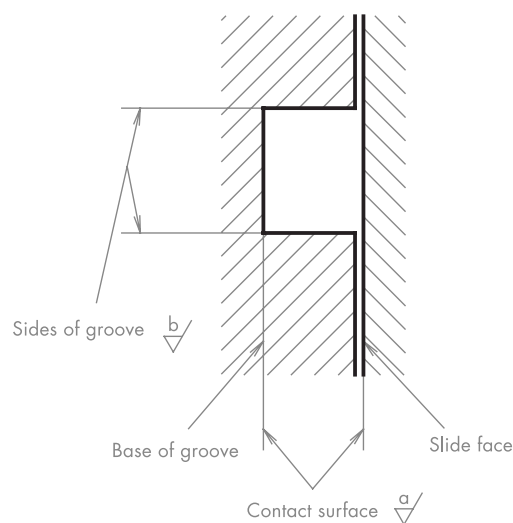## Slope z, radius R_1 / R_2

Cross-sectional diameter	Radius		Chamfer
d_2	R_1	R_2	z
mm	mm	mm	mm
1.50	0.10	0.25	2.00
1.60	0.10	0.25	2.00
1.78	0.10	0.25	2.00
2.00	0.10	0.25	2.00
2.40	0.10	0.25	2.00
2.50	0.10	0.25	2.00
2.62	0.10	0.25	2.00
3.00	0.10	0.25	2.00
3.53	0.20	0.75	3.00
4.00	0.20	0.75	3.00
5.00	0.20	0.75	3.00
5.35	0.20	0.75	3.00
5.70	0.20	0.75	4.00
6.99	0.20	0.75	4.00
7.00	0.20	0.75	4.00

Roughness

Surface		Pressure	Roughness			Roughness class
			R_a	R_t	R_z	
			µm	µm	µm	
Contact surface	a	Slide face	0.40	3.00	1.60	N5
		Base of groove	0.80	6.30	3.15	N6
Sides of groove	b		0.80	6.30	3.15	N6

Sides of groove b

Base of groove   Slide face

Contact surface a

Special applications

Immersed mounting

Cylinder seal, groove in piston

$C_0^{+0.2}$

b

rounded and free from burrs

D

$\varnothing$ F H8/f7

R_2

R_1

a

c

0° – 5°

z

15° – 20°
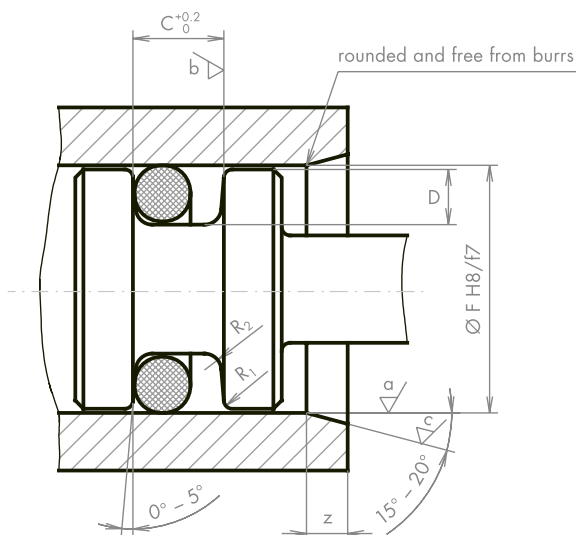
An O-Ring that is mounted below the surface of a liquid is suitable for sealing pneumatic pistons and has the advantage of lower abrasion and thus lower wear. To initiate the sealing process, it requires a pulsed pressure difference of 1 to 2 bar.
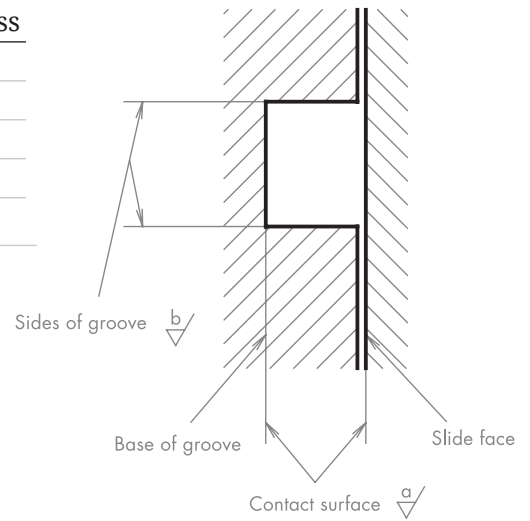
The outer diameter of the O-Ring must be slightly greater than the cylinder diameter (2% to 5%) in order to ensure the sealing function. The inner diameter of the O-Ring d1 must not touch the bottom of the groove. The groove depth must be greater than the O-Ring cord diameter d_2.

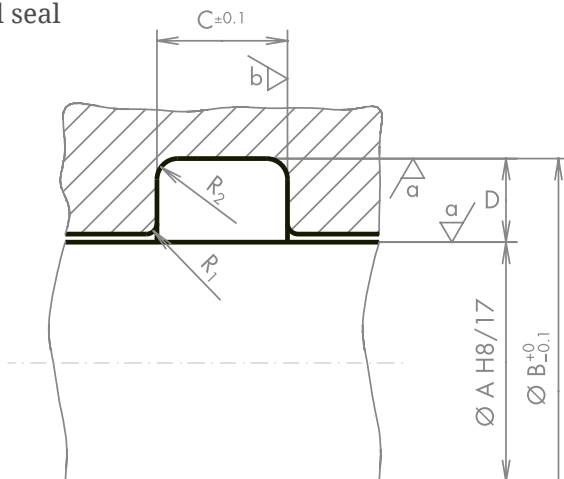Groove dimensions: Rectangular groove, radial compression

O-Ring cross-sectional diameter	Depth of groove	Width of groove	Radius		Chamfer
d_2	D	C	R_1	R_2	z
mm	mm	mm	mm	mm	mm
3.00	3.30	3.50	0.10	0.25	2.00
3.50	3.80	4.00	0.20	0.75	3.00
3.53	3.80	4.00	0.20	0.75	3.00
3.55	3.80	4.00	0.20	0.75	3.00
3.60	3.90	4.10	0.20	0.75	3.00
4.00	4.30	4.50	0.20	0.75	3.00
5.00	5.30	5.60	0.20	0.75	3.00
5.30	5.60	6.00	0.20	0.75	3.00
5.34	5.60	6.00	0.20	0.75	3.00
5.70	6.00	6.50	0.20	0.75	4.00
6.99	7.30	8.00	0.20	0.75	4.00
7.00	7.30	8.00	0.20	0.75	4.00
8.40	8.70	9.50	0.20	0.75	4.00

Roughness

Surface		Pressure	Roughness			Roughness class
			R_a	R_t	R_z	
			µm	µm	µm	
Contact surface a/		Slide face	0.40	3.00	1.60	N5
		Base of groove	0.80	6.30	3.15	N6
Sides of groove b/			0.80	6.30	3.15	N6

Sides of groove b/

Base of groove

Slide face

Contact surface a/

Rod seal

O-Rings in rotary applications

O-Rings can only be used for slow rotary or tilting movements. The O-Ring should always be used as a rod packing in the housing. It must never be stretched over the shaft but should preferably be compressed by 5%. The sliding surface must be hardened (min. 50HRC).

Basis of calculations

Groove depth D = O-Ring cross-sectional Ø:

O-Ring internal diameter d_1 = shaft Ø A + 5%:

Groove width C = O-Ring cross-section diameter d_2 plus 10%

$$D = d_2 \times 0.94$$
$$d_1 = A \times 1.05$$
$$C = d_2 \times 1.10$$

Roughness

Surface	Roughness			Roughness class
	R_a	R_t	R_z	
	µm	µm	µm	
Contact surface	0.40	3.00	1.60	N5
Mounting Chamfer	0.80	6.30	3.15	N8

Use as drive belts

O-Rings can be used as drive elements for low-torque such as those in tape recorders. O-Rings manufactured using a special process must be used for these applications. As a rule an EPDM grade with good ozone resistance and 70 to 80 IRHD/Shore A hardness is used. The extension of the O-Ring at the internal diameter should be between 8% and 12% and the peripheral speed should not exceed 20 m/s.

Limitations:

- Contact with liquids should be avoided as this increases slip

- The smallest bending radius is 3 x cross-sectional diameter d_2

- The thickness d_2 at the cross-section should not be less than 3,00 mm

- The maximum extension is 15% of internal diameter d_1 (preferably an extension from 8% to 2%)

- Tensile strength when mounted is approx. 0,5 to 1,5 N/mm^2

- After extended service times residual tensile deformation is to be expected

- If considerable heat is evolved the O-Ring can be expected to shrink (Joule effect)

General design notes

Compression table for the most common O-Ring cross-sectional diameters

The following table shows the groove depth D [mm] to be selected, depending on the O-Ring cross-sectional diameter d_2 and the compression [%].

Compression
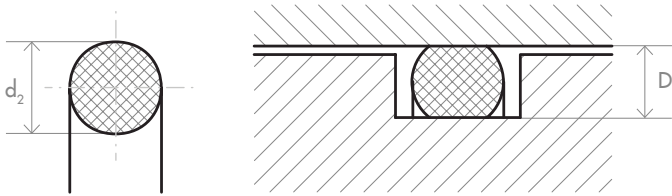
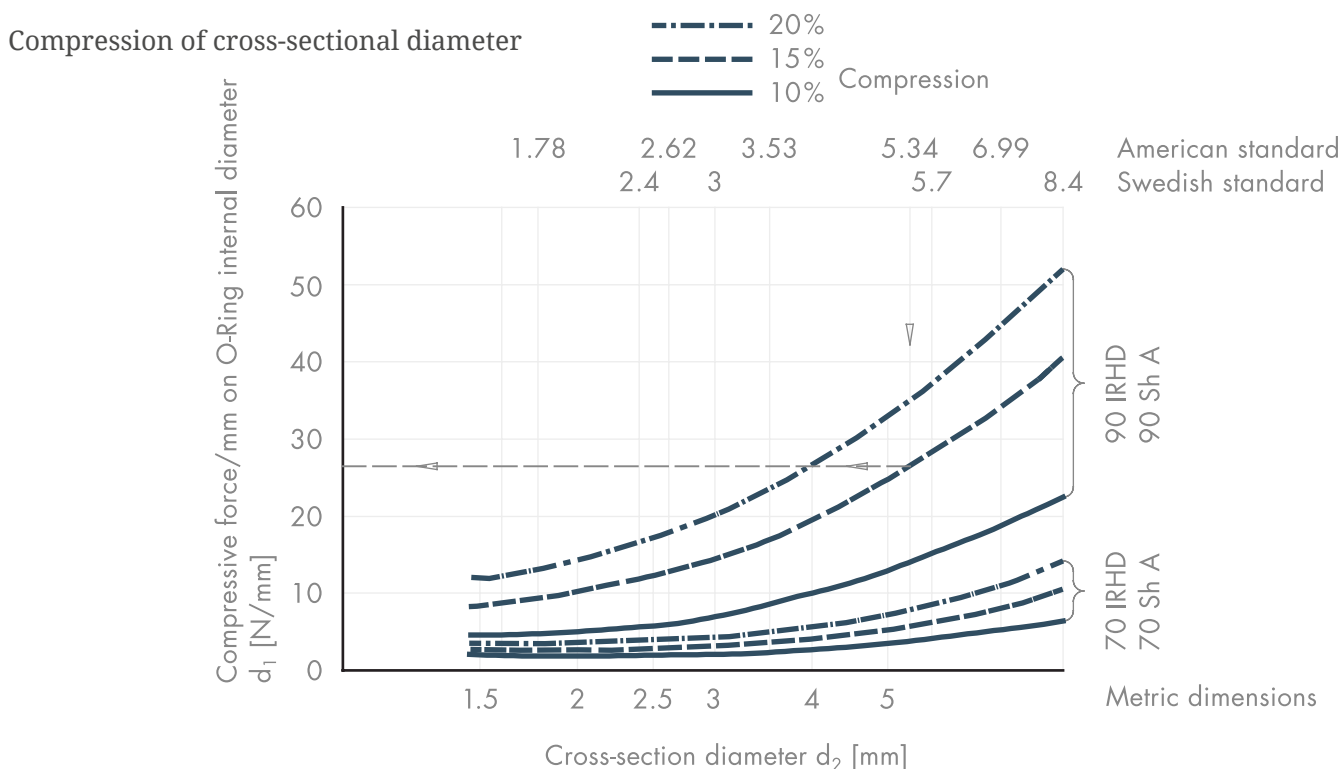$$\text{Compression (\%)} = \frac{d_2 - D}{d_2} \cdot 100$$

Depth of groove D

Com-pression	O-Ring cross-sectional diameter d_2 [mm]														
%	1.50	1.60	1.78	2.00	2.40	2.50	2.62	3.00	3.53	4.00	5.00	5.34	5.70	6.99	8.40
28	1.08	1.15	1.28	1.44											
27	1.10	1.17	1.30	1.46	1.75	1.83	1.91	2.19							
26	1.11	1.18	1.32	1.48	1.78	1.85	1.94	2.22	2.61	2.96					
25	1.13	1.20	1.34	1.50	1.80	1.88	1.97	2.25	2.65	3.00	3.75	4.00	4.28		
24	1.14	1.21	1.35	1.52	1.82	1.90	1.99	2.28	2.68	3.04	3.80	4.06	4.33		
23	1.16	1.23	1.37	1.54	1.85	1.93	2.02	2.31	2.71	3.08	3.85	4.11	4.39	5.39	6.47
22	1.17	1.25	1.39	1.56	1.87	1.95	2.04	2.34	2.75	3.12	3.90	4.17	4.45	5.46	6.55
21	1.19	1.26	1.41	1.58	1.90	1.98	2.07	2.37	2.79	3.16	3.95	4.22	4.50	5.53	6.64
20	1.20	1.28	1.42	1.60	1.92	2.00	2.10	2.40	2.82	3.20	4.00	4.27	4.56	5.60	6.72
19	1.22	1.30	1.44	1.62	1.94	2.03	2.12	2.43	2.86	3.24	4.05	4.33	4.61	5.67	6.80
18	1.23	1.31	1.46	1.64	1.97	2.05	2.15	2.46	2.89	3.28	4.10	4.38	4.67	5.74	6.89
17	1.25	1.33	1.48	1.66	1.99	2.08	2.17	2.49	2.93	3.32	4.15	4.43	4.73	5.81	6.97
16	1.26	1.34	1.50	1.68	2.02	2.10	2.20	2.52	2.97	3.36	4.20	4.49	4.79	5.88	7.06
15	1.28	1.36	1.51	1.70	2.04	2.13	2.23	2.55	3.00	3.40	4.25	4.54	4.85	5.95	7.14
14	1.29	1.38	1.53	1.72	2.06	2.15	2.25	2.58	3.04	3.44	4.30	4.60	4.90	6.02	7.22
13	1.30	1.39	1.55	1.74	2.09	2.18	2.28	2.61	3.07	3.48	4.35	4.65	4.96	6.09	7.31
12	1.32	1.41	1.57	1.76	2.11	2.20	2.30	2.64	3.11	3.52	4.40	4.70	5.02	6.16	7.39
11	1.34	1.42	1.58	1.78	2.13	2.23	2.33	2.67	3.14	3.56	4.45	4.75	5.07	6.23	7.48
10	1.35	1.44	1.60	1.80	2.16	2.25	2.36	2.70	3.18	3.60	4.50	4.81	5.13	6.30	7.56
9	1.37	1.46	1.62	1.82	2.18	2.28	2.38	2.73	3.21	3.64	4.55	4.86	5.19	6.37	7.64
8	1.38	1.47	1.64	1.84	2.20	2.30	2.41	2.76	3.25	3.62	4.60	4.91	5.24	6.44	7.73
7	1.40	1.49	1.66	1.86	2.23	2.33	2.44	2.79	3.28	3.72	4.65	4.97	5.30	6.51	7.81
6	1.41	1.50	1.67	1.88	2.26	2.35	2.46	2.82	3.32	3.76	4.70	5.02	5.36	6.58	7.90
5	1.43	1.52	1.69	1.90	2.28	2.38	2.49	2.85	3.35	3.80	4.75	5.07	5.42	6.65	7.98
4			1.71	1.92	2.30	2.40	2.52	2.88	3.39	3.84	4.80	5.13	5.47	6.72	8.06
3					2.33	2.43	2.54	2.91	3.42	3.88	4.85	5.18	5.53	6.79	8.15
2									3.46	3.92	4.90	5.23	5.59	6.86	8.23

Force required
for cross-sectional deformation

This graph gives the required compressive force for 10%, 15% and 20% compression of an O-Ring. These are specific guideline values at +20°C. The value found (in N/mm) then only needs to be multiplied by the internal diameter d_1 of the O-Ring.
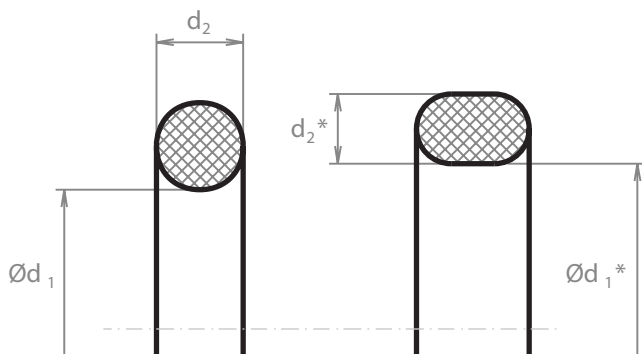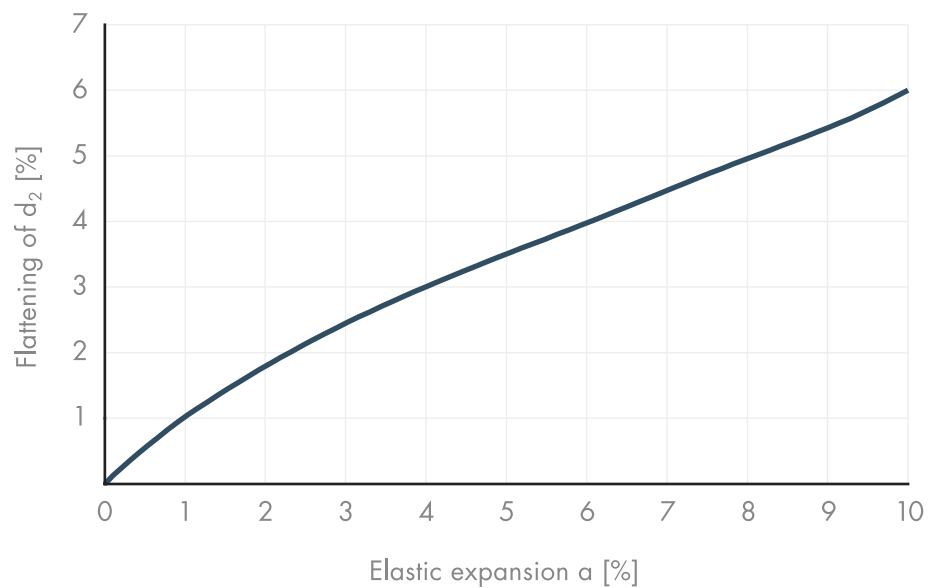
Compression of cross-sectional diameter

- - · - · 20%
- - - - 15%
——— 10%   Compression

Compressive force/mm on O-Ring internal diameter d_1 [N/mm]

1.78   2.62   3.53   5.34   6.99   American standard
      2.4   3   5.7   8.4   Swedish standard

90 IRHD
90 Sh A

70 IRHD
70 Sh A

Metric dimensions

Cross-section diameter d_2 [mm]

Example for O-Ring OR6300, NBR 90
- Internal diameter: d_1 = 75.57 mm
- Cross-sectional diameter: d_2 = 5.34 mm
- Hardness: 90 IRHD/Shore A
- Compression: 15%
- Force (N/mm) x internal diameter d1 (mm) = compressive force (N): 27 N/mm x 75.57 mm = 2040 N

Extension and compression

The internal diameter d_1 of O-Rings should not be extended more than 6% or compressed more than 3% when they have been mounted. The tolerances of the O-Ring cord diameter d_2 are not to be considered. During extension the cross-section, originally circular, becomes oval. In order to achieve the desired compression, this flattening must be taken into account when designing the groove depth.

Elastic expansion

Flattening of d_2 [%] vs. Elastic expansion a [%]

$$\text{Elastic expansion:} \quad \frac{d_1{}^* - d_1}{d_1} \cdot 100$$

d1 * = internal diameter extended or compressed
d2* = cross section flattened

Slide face materials and surfaces

It is only possible to guarantee fault free operation and long service life for a seal if the metal contact surfaces fulfill certain values for rugosity and enable the fluid to wet them. The wettability of a surface is a critical factor in building up a lubricating film. Wettability of the slide face is promoted by, in descending order:

- Soft C steel

- Hardened steel

- Hard chrome-plated surface

- Stainless steel

- Cast iron

- Bronze, brass

- Aluminium / alloys

- Plastics

The rugosity of the contact surface is significant for wear and durability of a seal. The maximum values for R_a, R_t and R_z are given for each sealing element.

The center roughness value R_a is the arithmetic mean value of the absolute of all distances y of the roughness profile from the mean line within the total measuring distance l_m.

The maximum depth of roughness R_t is the vertical distance between the highest and lowest point of the roughness profile within the total measured length l_m.
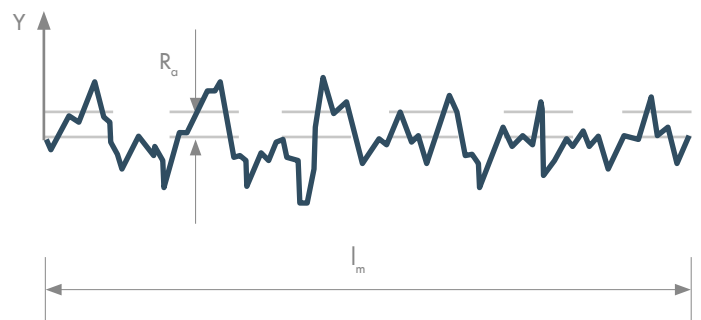
In both tests only the roughness of the surface is taken into account, not its waviness.
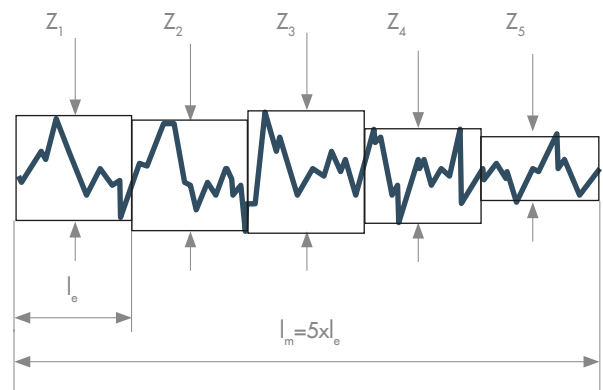
$R_z = \frac{1}{5}(Z_1 + Z_2 + Z_3 + Z_4 + Z_5)$
Average depth of roughness R_z is calculated from 5 consecutive individual measured lengths.

Contact area ratio t_p

Depth of surface smoothness
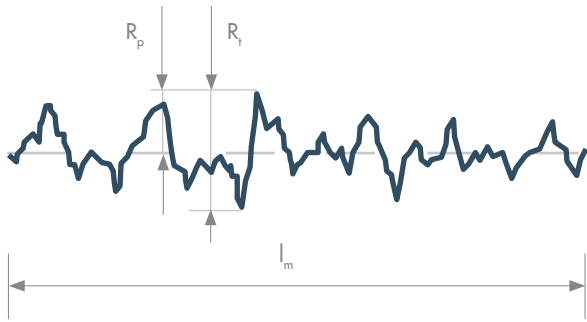
The contact area ratio t_p (%) of a surface is also highly significant when seals are being used. This is the percentage ratio of the bear - in length to the measured length l_m at a certain cut depth (recommended 0,5 R_t). For dynamic contact surfaces a contact area ratio of [3] >50% is recommended for 0,5 R_t (the depth of smoothing is less than 0,5 R_p).

The smoothing depth R_p is the vertical distance between the highest point and the mean line of a roughness profile.

Idealised profile sections for assessment of surface

	R_t	R_a	R_p	Contact area ratio t_P		
				at 0.25 R_t	at 0.5 R_t	at 0.75 R_t
	µm	µm	µm	%	%	%
	1	0.500	0.500	50.0	50.0	50.0
	1	0.250	0.500	25.0	50.0	75.0
	1	0,250	0,500	25.0	50.0	75.0
	1	0.280	0.750	12.5	25.0	37.5
	1	0.280	0.250	62.5	75.0	87.5
	1	0.188	0.785	3.5	14.0	35.0
	1	0.188	0.215	65.0	86.0	96.5
	1	0.390	0.500	43.0	50.0	57.0

Peaks can be removed from the surface by honing, rolling, drawing or rollering; nevertheless the valleys remain as lubricating pockets.

with non-cutting process

R_{p1}

R_{t1}

with cutting process

R_{p2}

R_{t2}
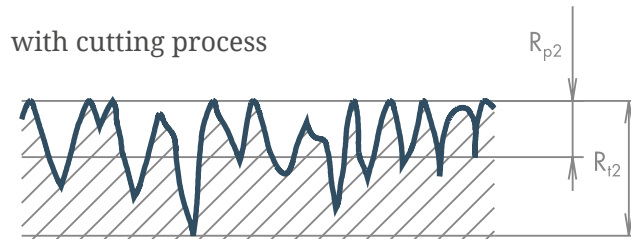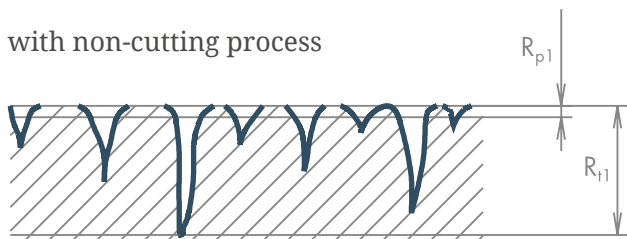
Pressure activated seal load

In static applications where structural parts are sufficiently strong the pressure can rise considerably. It is important that the components to be sealed (e.g. flange, lid, etc.) cannot lift away from each other, for if they do the O-Ring migrates into the gap and when the pressure is released it is caught by the edge of the groove. If the pressure changes many times it peels off.

In dynamic applications (reciprocating movement only) the pressure of the fluid must never exceed 350 bar. Very slow relative movements are an exception to this rule.

In the depressurised condition the O-Ring creates a seal by its elasticity and resilience between the two contact surfaces.

O-Ring without pressure
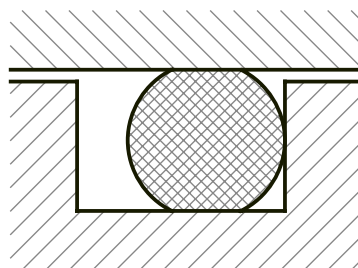
As the pressure rises the O-Ring acts as a highly viscous incompressible liquid. Pressure exerted on the O-Ring is propagated to practically the same degree in all directions (basic law of hydro statics, Blaise Pascal).
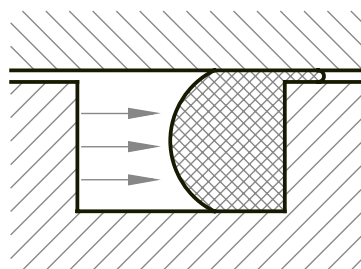
O-Ring under pressure
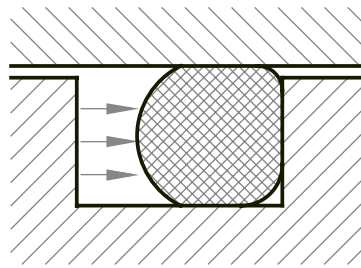
When the pressure rises further the O-Ring is pressed into the gap and shears or peels off.
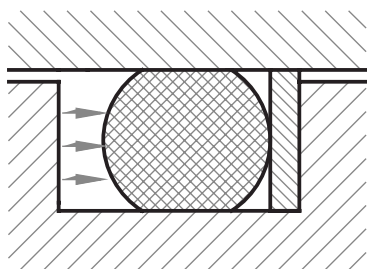
O-Ring in the sealing gap
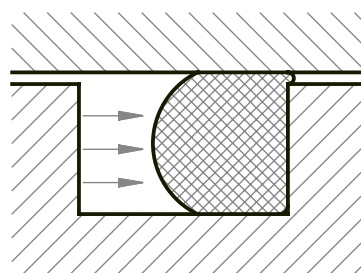
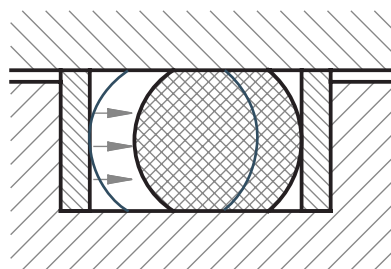Under pulsating pressure the O-Ring is clamped and damaged by the gap of structural

O-Ring clamped

This migration into the gap, which often causes an O-Ring to fail, can be prevented by using back-up rings.

Pressure exerted on one side

Pressure exerted on both sides

Permissible clearance S

Play in the gap on the side of the O-Ring away from the pressure determines whether back-up rings should be used. The degrees of fit should be checked for each pressure and, if the gap is too large, back-up rings must be provided. Otherwise the O-Ring will be destroyed by extrusion of rubber material into the gap. Our recommendations for the selection of fit for static and dynamic applications are given below.

Permissible clearance

Pressure p	Hardness of O-Ring	Fit at
bar	IRHD/Shore A	ØA/ØF
≤ 20	60 ÷ 70	H8/f7
≤ 70	70 ÷ 90	H8/f7
≤ 100	70 ÷ 90 + back-up ring	H8/f7
	70 ÷ 90	H7/g6
≤ 350	70 ÷ 90 + back-up ring	H7/g6

For static flange or cover seals, the structural parts must be designed so that no gaps appear. For a static axially sealing O-Ring, there is no need for back-up rings as the gap is only minimal.
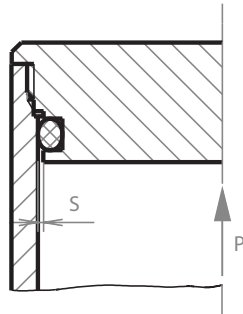
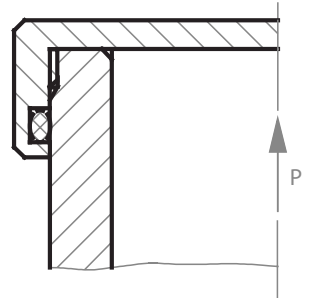With sealing gap (wrong)
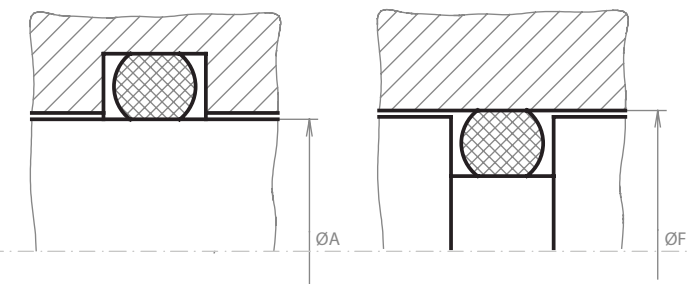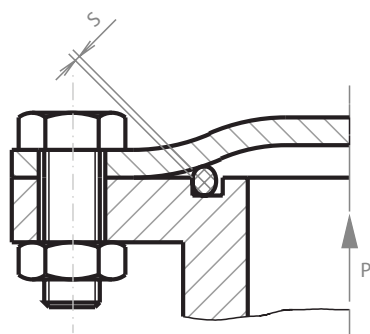
No sealing gap (right)
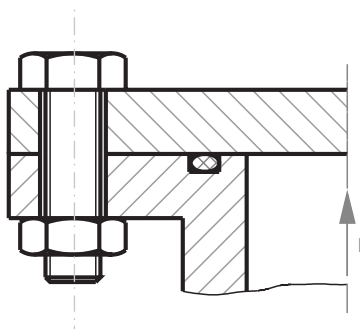
For static radially sealing O-Ring applications the gap should be kept as small as possible.
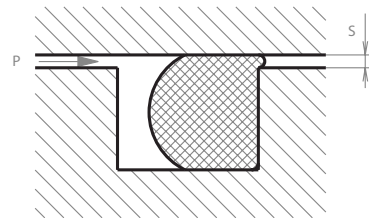
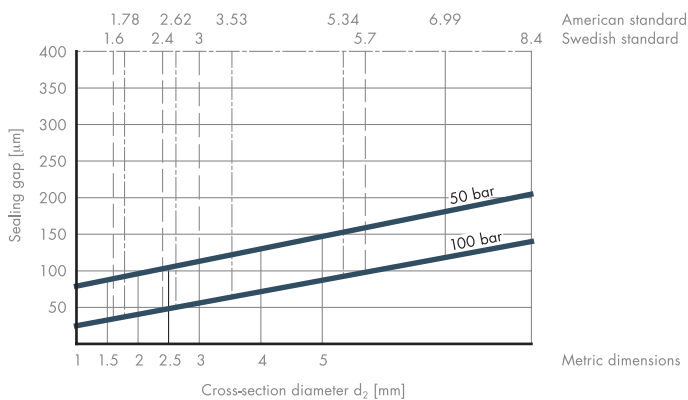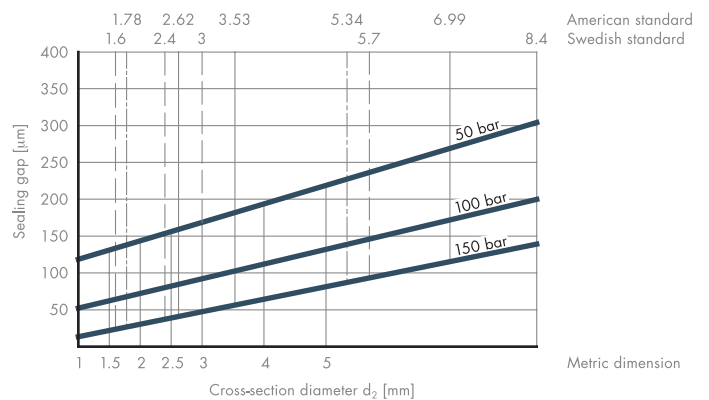High pressure increases sealing gap (wrong)

No sealing gap (right)

For piston and rod seals in static and dynamic applications, the sealing gaps in the high-pressure range, which arise because of tolerance in the fitting, must be very carefully checked. Often back-up-rings are necessary to prevent migration of the O-Ring into the gap.
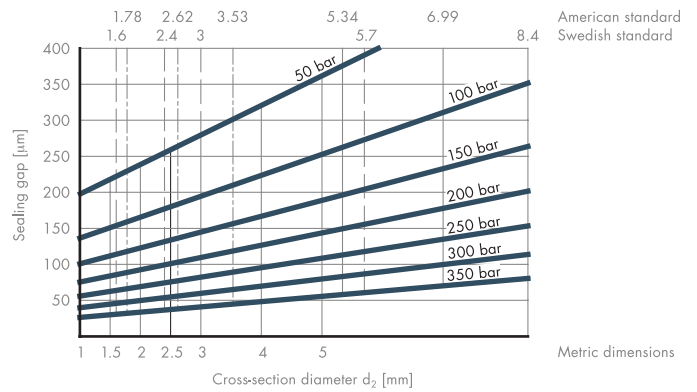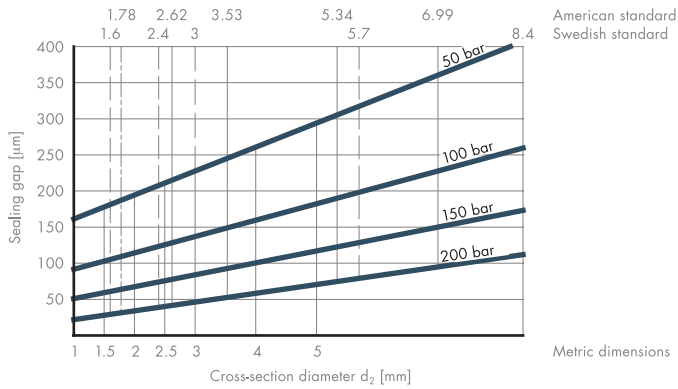

60 IRHD/60 Shore A

70 IRHD/70 Shore A

80 IRHD/80 Shore A

90 IRHD/90 Shore A

The table below gives the permissible allowance S (mm) for the gap for different material hardnesses and working pressures. The different groove widths C for 1 and 2 back-up-rings are also shown.

Allowance gap „s" for cross-section diameter in relation to the hardness of the O-Ring

Allowance gap s for cross-section diameter d_2 (mm)

Pressure		≤ 1.8	>1.8 - ≤2.2	>2.2 - ≤2.7	>2.7 - ≤ 3.2	>3.2 - ≤3.7	>3.7 - ≤4.2	>4.2 - ≤5.0	>5.0 - ≤6.0	>6.0 - ≤8.4
	bar	mm	mm	mm	mm	mm	mm	mm	mm	mm
70 ±5 IRHD/Shore A	< 50	0.12	0.13	0.17	0.18	0.19	0.20	0.22	0.23	0.26
	< 100	0.05	0.07	0.09	0.10	0.11	0.12	0.13	0.14	0.16
	< 150	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10
80 ±5 IRHD/Shore A	< 50	0.17	0.18	0.22	0.23	0.26	0.27	0.30	0.31	0.36
	< 100	0.10	0.11	0.13	0.14	0.15	0.16	0.18	0.19	0.22
	< 150	0.05	0.06	0.07	0.08	0.09	0.10	0.12	0.13	0.13
	< 200	0.02	0.02	0.04	0.04	0.05	0.07	0.08	0.08	0.08
90 ±5 IRHD/Shore A	< 50	0.22	0.23	0.28	0.30	0.35	0.35	0.38	0.40	0.45
	< 100	0.15	0.16	1.18	0.19	0.22	0.23	0.25	0.26	0.30
	< 150	0.08	0.10	0.12	0.13	0.15	0.16	0.18	0.18	0.22
	< 200	0.05	0.06	0.09	0.10	0.11	0.12	0.14	0.14	0.17
	< 250	0.02	0.03	0.07	0.08	0.09	0.10	0.11	0.11	0.13
	< 300	—	—	0.05	0.05	0.06	0.07	0.08	0.08	0.10
	< 350	—	—	0.03	0.03	0.05	0.06	0.07	0.07	0.08

Width of groove C when back-up rings are used

| Number of back-up rings	Cross-sectional diameter d_2		
	≤ 4.2 mm	> 4.2 to ≤ 6.0	> 6.0 to ≤ 8.4
1	With of the groove C + 1.5 mm	With of the groove C + 1.8 mm	With of the groove C + 2.5 mm
2	With of the groove C + 3.0 mm	With of the groove C + 3.6 mm	With of the groove C + 5.0 mm

Material hardness

We introduce this section with a further explanation on hardness testing methods.

The test method to DIN 53519/1/2, ASTM D 1415 e BS 903 A 26 (IRHD = international rubber hardness degree) is the one most commonly used internationally. It calculates the resistance when a ball penetrates the specimen. The values that can be read out are printed out as IRHD normal, soft or micro (depending on the diameter of the ball). For IRHD soft the ball diameter is 5,0 mm, for IRHD normal it is 2,5 mm and for IRHD micro it is 0,4 mm. For IRHD normal and soft tests the specimen must be at least 6 mm thick. For IRHD micro, parts up to 1,5 mm thick can be measured. The IRHD test method measures the penetration of the ball under constant load after the specified test period of 30 seconds has elapsed.

The test method to DIN 53505 (Shore A hardness) measures the resistance of the specimen to penetration by a truncated cone. The results are printed out as Shore A values. Unlike the IRHD test, the specimen must always be at least 6 mm thick. If it is less than these errors occur which can give values up to 10 points higher. For O-Rings with a cord diameter under 6mm, the measuring method according to IRHD micro is far more reliable.

Comparison of different test methods
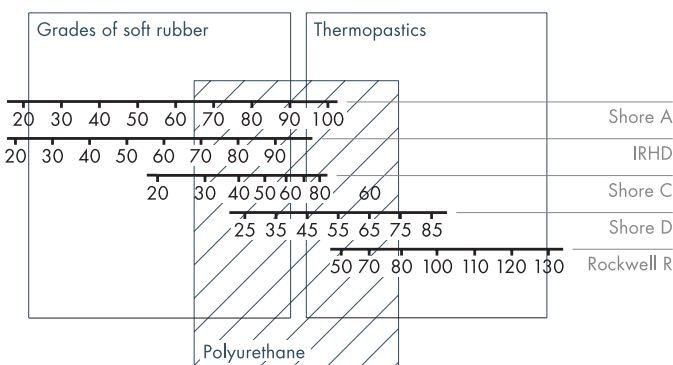
- Softer materials adapt more easily and better to the surface structure of the contact surfaces. The soft materials move more easy into pores and depressions. This behavior is important in the decompressed condition or in the low pressure range, because the additional compression caused by the pressure of the fluid is absent. For this reason, O-Rings with a hardness of 60 IRHD/Shore A are used in the low pressure area where the contact surfaces are rougher. Moderately hard materials are used for dynamic applications. The pressure resistance, wear characteristics and friction require a hardness of 70 to 75 IRHD/Shore A.

- In high pressure applications, harder materials prevent a certain degree of extrusion into the gap. The high compression force means that there are limitations in mounting. The hardness is in the 90 IRHD/Shore A range.

Lubrication

For static applications, the O-Ring can be mounted dry. However, a mineral oil based or oil protects it from ageing and makes it softer during mounting.

Limitations:

- EPDM materials should not come into contact with mineral oil based greaes or mineral oils. Certain synthetic greases or silicone greases are suitable.

- All O-Ring materials except silicone rubber are resistant to silicone grease.

- Please carefully note our recommendations regarding the compatibility of rubber compounds to system medias.

In dynamic applications it is very important to create good lubrification conditions. Good lubrication at the slide faces considerably increases the durability of an O-Ring. In addition to the wettability of the surface (creation of a lubricating film on the sealing face), the lubricating property of the fluid has a considerable effect on the wear of the seal. This depends on its viscosity as well as the general suitability of the fluid.
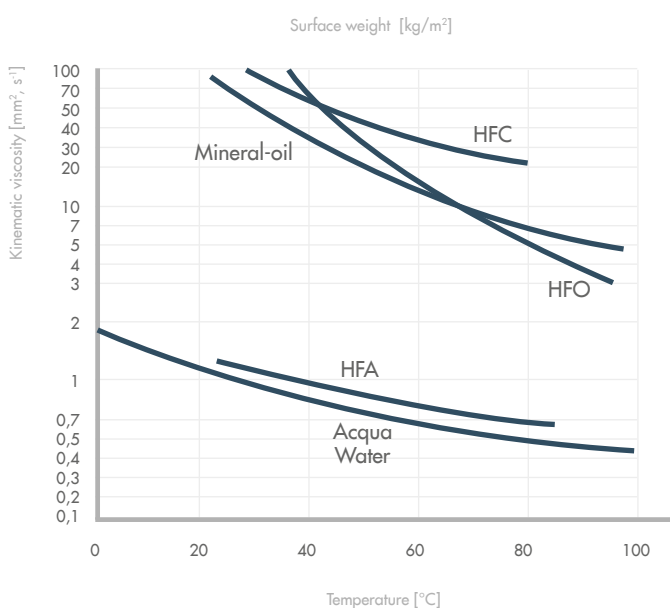
Viscosity

The lubricating fluid always covers the contact surface with a thin film. Storage in the slide face is ensured by the wettability, i.e. the roughness, of the surface. The thickness of the lubricating film is mainly dependent on the type and viscosity of the fluid but is also affected by the compressive force of the dynamic contact surface, the slide face and the stroke speed.

The viscosity of mineral oils depends on pressure and temperature. As the temperature rises a rapid reduction in viscosity can be observed; for this reason, the viscosity-temperature behavior is highly significant. The rise in temperature occurs as a result of the conversion of power losses into heat and this is taken up by the oil. The viscosity-temperature characteristics of mineral oils in different viscosity classes shows a tendency towards a relatively undesirable fall in viscosity. The viscosity index (VI) is the code for the viscosity-temperature characteristic. The higher the VI, the less the viscosity changes with temperature. This means that the operating temperature range is wide. Mineral oils that have been improved by catalysts or other additives, or paraffin-based hydraulic oils have a particularly good viscosity index.

Kinematic viscosity/tempeerature

Fluids with a high viscosity index are characterized by good wear protection and a high sealing effect at high temperature as well as good performance at low temperatures. A high VI extends the service life of sealing that are susceptible to wear.

Friction

Lubrication has a considerable effect on the degree of friction that occurs. With proper lubrication, friction is low. Self-lubricating PTFE seals are an exception to this rule even if they nevertheless do not reject lubricated ratios. High friction not only reduces efficiency, it also increases wear.

Frictional force is affected by the prestressing on the seal, the hardness of the material, the surface finish, the nature and viscosity of the hydraulic fluid, the pressure and the running speed. It can be seen from this that it is not possible to provide precise values for friction. These can only be determined by trials.

We give below the coefficients of friction of elastomer materials when running dry against steel, as determined by the hardness of the material:

• 60 IHRD/Shore   friction coefficient (μ) = 0.9

• 70 IHRD/Shore   friction coefficient (μ) = 0.8

• 80 IHRD/Shore   friction coefficient (μ) = 0.6

• 90 IHRD/Shore   friction coefficient (μ) = 0.5

• For comparison, PTFE friction coefficient (μ) = 0.08

Stick-slip effect

Stick-slip is a phenomenon which adversely affects slow stroke movements. The transition from static friction to sliding friction causes a backwards movement in the reciprocating piston. When stick-slip occurs, the following conditions are combined:

• The static friction must be greater than the sliding friction.

• The seal is not working in the hydro-dynamic friction area but in the mixed friction area.

• The compressible column of oil has a spring effect which stores energy during the transfer of force until it is sufficient to overcome static friction.

Slip velocity/Coefficient of friction
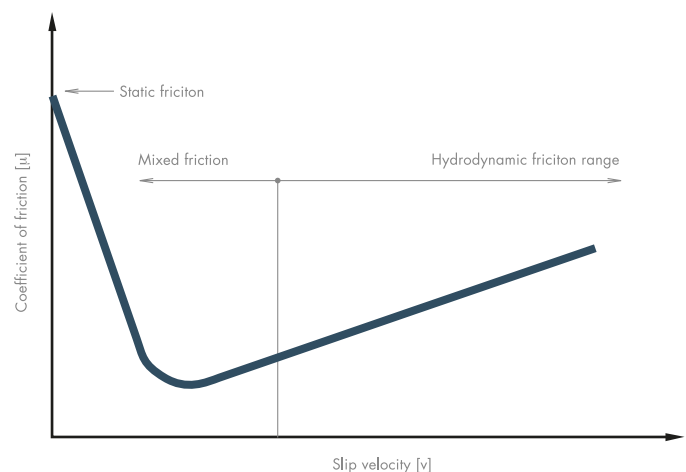
When oils with a low lubricating film resistance are used the result is a greater stick-slip effect. This can be avoided in practice if the wettability of the slide faces is good and an oil with a high viscosity index is used. Stick-slip can also be considerably reduced by selecting an appropriate seal, i.e. a different design of seal and a suitable material.

Wear

Friction and wear are highly interdependent and affect the service life of a seal. It is sometimes very difficult to distinguish normal ageing from wear that should not be tolerated.

Common types of wear

Abrasion:

Frequent causes of failure are excessively rough slide faces, contamination in the oil, insufficient lubrication, excessively high pressure or temperature.

Extrusion:

An excessively large sealing gap on the non-pressurised side, excessively high pressure or the absence of a back-up ring.

Erosion or cavitation (e.g air in the oil):

At high pressure air bubbles are compressed and expand under the sealing face. They cause the seal to be damaged.

These types of wear can be reduced by various means:

- Correct selection of the type of seal and the correct material

- The use of hydraulic fluids with optimum lubricating characteristics

- Optimization of the slide faces involved to reduce wear and promote the formation of a lubricating film

- Checking the general operating conditions such as the pressure and temperature levels, the running speed, etc.

Sliding speed

The service limits for piston and rod speeds cannot be precisely laid down because of the great variety of operating conditions (lubricating fluid, service, temperature). The information in the following graph is only for guidance. It is valid for hydraulic fluids with good lubrication properties and oiled air.
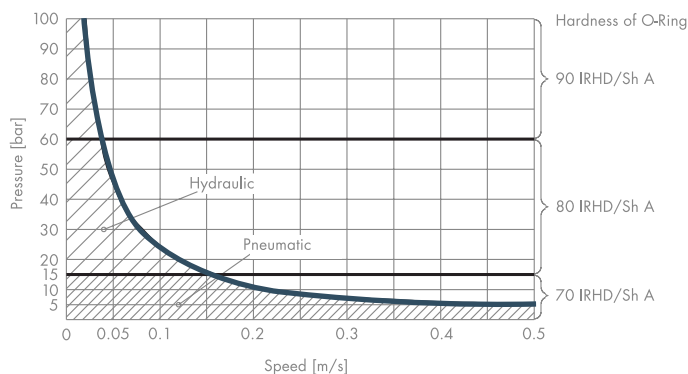

Even higher running speeds are permissible if certain conditions are fulfilled (reduction of compression to a minimum). These cases cannot however be generalized.

Contamination
at the seal area

The fluids to be retained must not be contaminated or contain any solid matter; this causes increased wear. The cleanliness and surface finish of the slide faces must not be adversely affected by any dirt, dust or other solid matter adhering to them. If there is a danger of foreign matter being deposited on the rod, dirt scrapers should be used.

Dirt scrapers are available as standard in NBR, PUR and PTFE.

Dirt scraper
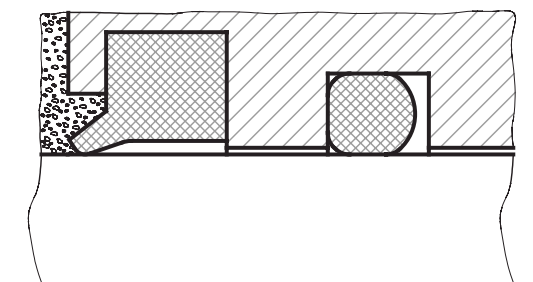
Back-up rings

General

Back-up rings are used in conjunction with O-Rings for static and dynamic applications. Back-up-rings are made of harder material than the O-Ring material – the back-up-ring reduces the gap and prevents migration of the O-Ring into the sealing gap. Back-up rings can be mounted as a single ring behind the O-Ring on the side of lower pressure. For high pressure, two back-up rings can also be fitted from both sides. In case of such a "sandwich" packaging of two back up rings with the O-Ring in the middle, the risk of potential pressure enclosure between the back rings shall be considered in special pressurizing conditions.

Without back-up ring
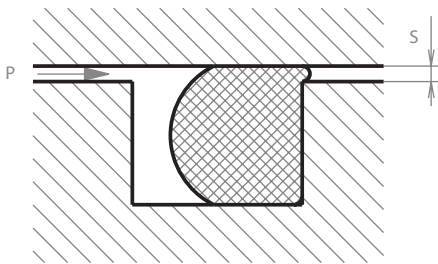
With back-up ring
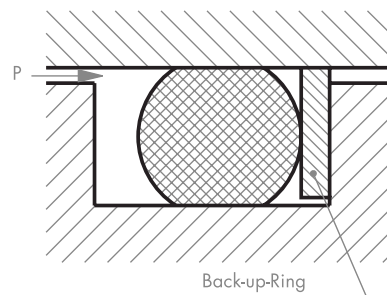
Back-up rings should be used if one of the following operating difficulties arises when O-Rings are used as seals:

- High pressure

- Large sealing gap

- High stroke speed or rapid stroke sequence

- High fluid temperatures

- Large variations in pressure or temperature

- Contaminated fluids

Back-up ring types

Our back-up rings are available in 3 versions.

Type BKW is available from stock for O-Rings in American/British standard sizes. Back-up rings for other O-Ring dimensions are available on request, as are type BKS and BKE. The back-up ring codes are the same as the corresponding O-Ring reference codes.
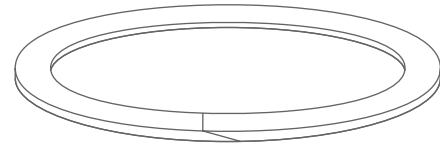
Type BKW (helical) to be used up to 200 bar only
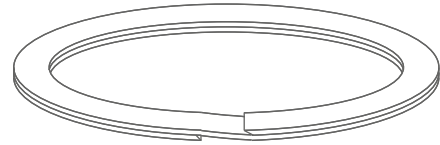
Type BKE (endless)
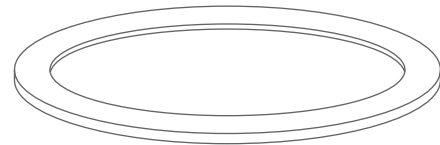
Type BKS (one piece, slotted)

Design notes

Locating grooves should be basically rectangular in design. However, for production engineering reasons, a slope of up to 5° in the walls of the grooves is permissible. The radii of the groove

and the surface finish of the area to be sealed are subject to the same conditions as set out in the section «Profiles and dimensions of grooves".

1 back-up ring
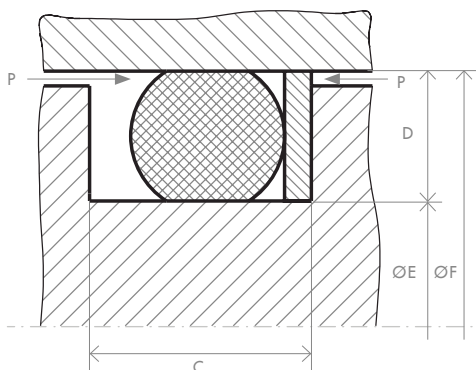
2 back-up rings
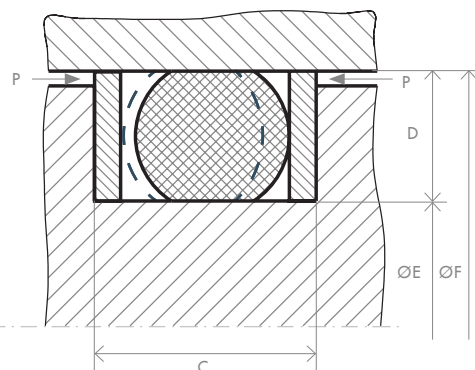
Tolerances:
– ØF: up to 100 bar H8
        100 bar upwards H7
– Ø E: h9
– Width of groove C: ± 0.1 mm
– Cross-sectional Ø ≤3 mm: ±0.1 mm
– Cross-sectional Ø >3 mm: ±0.2 mm

The cylinder diameter F is given in the section «Sets of dimensions» and following sections of Chapter 5 „Groove dimensions for O-Rings". Deviations from the dimensions given there also require specially designed back-up rings. The groove depth D is the standard for dynamic hydraulic applications.

Types BKW and BKS are very simple to mount, even in closed grooves. Type BKE, on the other hand, which satisfies the highest specifications, can only be mounted in open grooves.

Virgin PTFE O-Rings

Mounting cavities

Specially designed O-Ring grooves are required to prevent PTFE O-Rings from migrating (due to the typical cold flow properties of the material). The O-Ring must be completely enclosed, i.e. the width of the groove must be the same as the cross-sectional diameter d_2.

Enclosed O-Ring
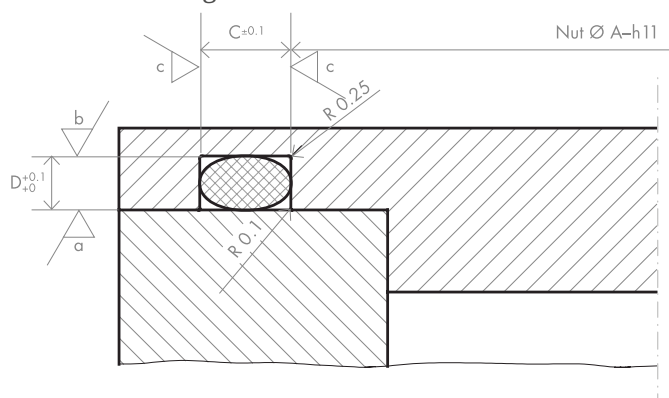
Determination of mounting cavities

Groove Ø	Cross-sectional Ø	With of the groove	Depth of groove
A-h11	d_2	$C^{\pm 0.1}$	$D^{+0.1/0}$
mm	mm	mm	mm
≤ 12	3.00	3.00	2.55
>12 – ≤ 20	4.00	4.00	3.40
>20 – ≤ 25	5.00	5.00	4.25
>25 – ≤ 30	6.00	6.00	5.10
>30 – ≤ 80	7.00	7.00	5.95
>80 – ≤ 120	8.00	8.00	6.80
>120 –≤ 1000	10.00	10.00	8.50

Limitations

- Operating temperature:
  from −200°C to +210°C

- Resistance to fluids: universal

- Except for molten alkaline metals and
 compounds of fluorine

- Pressure resistance

Roughness

Surface			Roughness			Roughness class
			R_a	R_t	R_z	
Contact seals $^a\triangledown$		Uncoated seals	0.40	3.00	1.60	N5
		Coated seals	0.80	6.30	3.15	N6
Base of grove $^b\triangledown$		Uncoated seals	0.40	3.00	1.60	N5
		Coated seals	0.80	6.30	3.15	N6
Sides of grooves $^c\triangledown$			2.50	19.00	10.00	N7/N8

Metal O-Rings, metal C-Rings
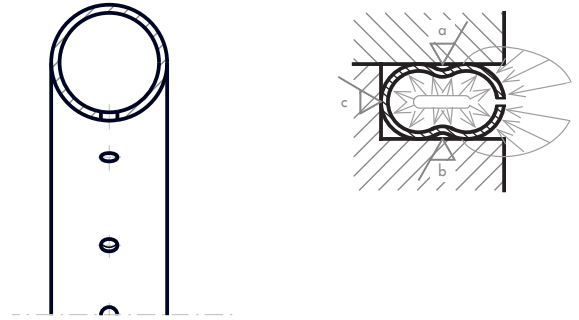
Designs

Standard type

Standard type, made of most metals, from tubing
or solid wire; the favorite type of O-Ring.
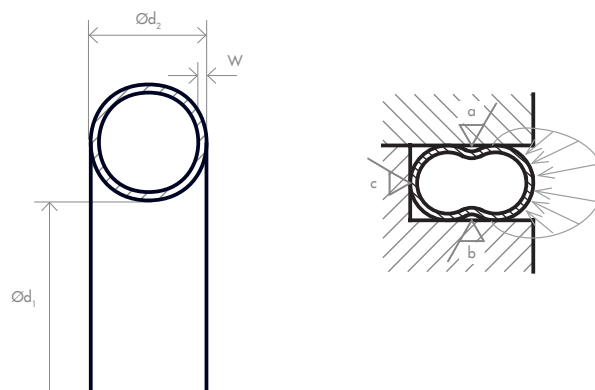
Self-reinforcing

The O-Ring has holes or slots on its inner circumference. This creates internal pressure that matches the pressure in the system. Increasing the internal pressure improves the tightness.

Pressurized

Pressurized for maximum temperatures from +425°C to +980°C (depending on the material). Pressure-filled O-Rings contain a gas at a pressure of at least 40 bar. This pressure increases at elevated temperatures and thus compensates for the loss of pre-stressing in the flange joint and increases the sealing capacity.
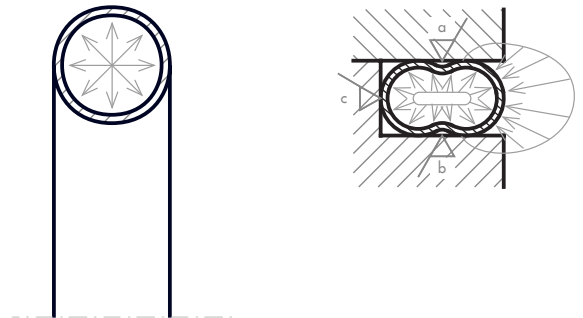
Surface finish

Surface			Surface finish			Roughness class
			R_a	R_t	R_z	
Contact seals		Uncoated seals	0.40	3.00	1.60	N5
		Coated seals	0.80	6.30	3.15	N6
Base of grove		Uncoated seals	0.40	3.00	1.60	N5
		Coated seals	0.80	6.30	3.15	N6
Sides of grooves			2.50	19.00	10.00	N7/N8

For vacuum, gases or low-viscosity liquids (water), the contact surfaces and the base of the groove should always be finished R_a=0.4µm, R_t=≤3.0µm, R_z=1.6µm, N5. If the contact surface has a coarser finish than this, it is advisable to use metal O-Rings and C-Rings with a thicker coating.

Manufacturing tolerances

Manufacturing tolerance for elastomer O-Rings	Cross-sectional diameter d_2
	Inside diameter d_1 tolerances
Defect limits	Definition of quality levels
	Type characteristics N and S to ISO 3601
	Definition of defect types

3

Manufacturing tolerances for elastomer O-Rings

O-Rings are manufactured as rubber mouldings with very close dimensional tolerances. These are specified in Standards ISO 3601/1. O-Rings are normally well within the prescribed tolerances.

The values given in the table below are designed for NBR O-Rings with a hardness of 70 IHRD/Shore A. In the case of different base materials, in particular FPM, MVQ, EPDM and FFKM, different degrees of contraction may result in values that differ from those given in the table. However, such deviations are normally so small that they have no effect on the sealing function of the O-Ring in static applications, for example. Special tooling is required to achieve the tolerances given in the table. Please discuss it with us if you require tighter tolerances.

Tolerances

Cross-sectional diameter d_2	Max. Tolerance	Cross-sectional diameter d_2	Max. Tolerance
mm	mm	mm	mm
≥ 1.00 - ≥ 2.50	± 0.08	> 4.00 - ≤ 5.70	± 0.13
> 2.50 - ≤ 2.70	± 0.09	> 5.70 - ≤ 8.40	± 0.15
> 2.70 - ≤ 4.00	± 0.10		

Inside diameter d_1	Max. Tolerance	Inside diameter d_1	Max. Tolerance
mm	mm	mm	mm
- ≤ 2.50	± 0.13	> 80.00 - ≤ 95.00	± 0.80
> 2.50 - ≤ 4.50	± 0.14	> 95.00 - ≤ 105.00	± 0.90
> 4.50 - ≤ 6.50	± 0.15	> 105.00 - ≤ 120.00	± 1.00
> 6.50 - ≤ 8.50	± 0.16	> 120.00 - ≤ 150.00	± 1.20
> 8.50 - ≤ 10.00	± 0.17	> 150.00 - ≤ 180.00	± 1.40
> 10.00 - ≤ 11.50	± 0.18	> 180.00 - ≤ 200.00	± 1.60
> 11.50 - ≤ 14.00	± 0.19	> 200.00 - ≤ 240.00	± 1.80
> 14.00 - ≤ 16.00	± 0.20	> 240.00 - ≤ 270.00	± 2.00
> 16.00 - ≤ 25.00	± 0.25	> 270.00 - ≤ 325.00	± 2.40
> 25.00 - ≤ 30.00	± 0.30	> 325.00 - ≤ 400.00	± 2.80
> 30.00 - ≤ 35.00	± 0.35	> 400.00 - ≤ 460.00	± 3.20
> 35.00 - ≤ 40.00	± 0.40	> 460.00 - ≤ 530.00	± 3.60
> 40.00 - ≤ 55.00	± 0.50	> 530.00 - ≤ 600.00	± 4.00
> 55.00 - ≤ 70.00	± 0.60	> 600.00 - ≤ 700.00	± 4.40
> 70.00 - ≤ 80.00	± 0.70	> 700.00 - ≤ 800.00	± 4.80

Defect limits

The values given in the table apply to all elastomer O-Rings. They should be regarded as guideline values, as it is often difficult to measure them accurately on elastomers.

Definition of quality levels:

GRADE N (general purpose)

Grade N (general purpose) identifies acceptance criteria for O-Rings intended for general use. The O-Rings we keep in stock are normal grade.

GRADE S (special)

Grade S (special) identifies acceptance criteria for O-Rings intended for applications requiring a higher level of quality and/or precision with respect to dimensional tolerances of surface imperfections. For example, aerospace or critical industrial or automotive applications are covered by this grade. Please contact us if you require different defects limits.

GRADE CS (critical service)

This grade identifies acceptance criteria for O-Rings intended for applications requiring a much higher level of quality and/or precision with respect to dimensional tolerances of surface imperfections. For example, critical service aerospace or medical applications, where the surface of the O-Ring must be near-perfect to perform in a satisfactory manner, are covered by this grade.
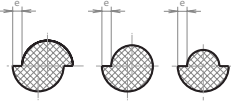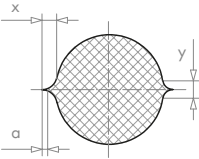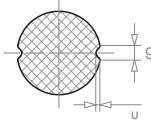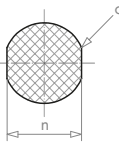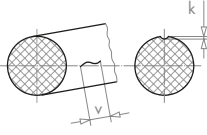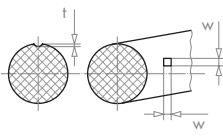
Selection of grade

If the user does not specify the grade at the time of purchase, Grade N will be assumed to be the quality requirement.

Characteristics of grades N (normal), S (special) and CS (critical services) to ISO 3601/3.

Limits of size for surface imperfections

Surface imperfection type	Diagrammatic representation	Limiting dimensions	Maximum limits of imperfections Grade N O-Rings Cross-section d_2					Maximum limits of imperfections Grade S O-Rings Cross-section d_2					Maximum limits of imperfections Grade CS O-Rings Cross-section d_2				
			> 0.8[b]	> 2.25	> 3.15	> 4.50	> 6.30	> 0.8[b]	> 2.25	> 3.15	> 4.50	> 6.30	> 0.8[b]	> 2.25	> 3.15	> 4.50	> 6.30
			≤ 2.25	≤ 3.15	≤ 4.50	≤ 6.30	≤ 8.40[b]	≤ 2.25	≤ 3.15	≤ 4.50	≤ 6.30	≤ 8.40[b]	≤ 2.25	≤ 3.15	≤ 4.50	≤ 6.30	≤ 8.40[b]
Off-register, mismatch (offset)		e	0.08	0.10	0.13	0.15	0.15	0.08	0.08	0.10	0.12	0.13	0.04	0.04	0.06	0.06	0.08
Combined flash (combination of offset, flash and parting line projection)		x	0.10	0.12	0.14	0.16	0.18	0.10	0.12	0.14	0.16	0.18	0.07	0.07	0.10	0.13	0.13
		y	0.10	0.12	0.14	0.16	0.18	0.10	0.12	0.14	0.16	0.18	0.10	0.10	0.13	0.13	0.13
		a	When the flash can be differentiated, it shall not exceed 0.07 mm.					When the flash can be differentiated, it shall not exceed 0.05 mm.					Not permissible				
Backrind		g	0.18	0.27	0.36	0.53	0.70	0.10	0.15	0.20	0.20	0.30	Not permissible				
		u	0.08	0.08	0.10	0.10	0.13	0.05	0.08	0.10	0.10	0.13	Not permissible				
Excessive trimming (radial tool marks not allowed)		n	Trimming is allowed provided the dimension n is not reduced below the minimum diameter d_2 for the O-Ring.					Trimming is allowed provided the dimension n is not reduced below the minimum diameter d_2 for the O-Ring.					Trimming is allowed provided the dimension n is not reduced below the minimum diameter d_2 for the O-ring.				
Flow marks (radial orientation of flow marks is not permissible)		v	0.15[a]	0.15[a]	6.50[a]	6.50[a]	6.50[a]	1.50[a]	1.50[a]	5.00[a]	5.00[a]	5.00[a]	1.50[e]	1.50[e]	1.50[e]	4.56[e]	4.56[e]
		k	0.08	0.08	0.08	0.08	0.08	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Non-fills and indentations (including parting line indentations		w	0.60	0.80	1.00	1.30	1.70	0.15	0.25	0.40	0.63	1.00	0.08 0.13[d]	0.13 0.25[d]	0.18 0.38[d]	0.25 0.51[d]	0.38 0.76[d]
		t	0.08	0.08	0.10	0.10	0.13	0.08	0.08	0.10	0.10	0.13	0.08	0.08	0.10	0.10	0.13

a Or 0.05 times the O-Ring's inside diameter (d_1), whichever is greater.
b Limits of imperfections for cross sections < 0.8 mm or > 8.40 mm shall be agreed upon between manufacturer and customer.
c Round edges.
d Mould deposit indentations only.
e Or 0.03 times the O-Ring's inside diameter (d_1), whichever is greater, subject to a maximum of 30 mm.

Definition of defect types

Excessive trimming

flattened and often roughened area around the inner and/or outer diameters of an O-Ring caused by the trimming process

Flash

film-like material that extends from the parting line projection or inner and/or outer diameters, caused by mould separation or present due to inadequate trimming

Flow mark

thread-like recess, usually curved, of very slight depth in the unflexed state, with normal surface texture and round edge, caused by incomplete flow and knit of the material

Foreign material

any extraneous matter embedded in the surface of the O-Ring, e.g. contamination, dirt, etc.

Indentation

depression, usually irregular in form, caused by the removal of inclusions from the surface or the build-up of hardened deposits on the surface of the mould cavity

Mismatch

cross-sectional radius in one ring half being unequal to that of the other half, caused by dimensional difference in mould halves

Non-fill

randomly spaced, irregularly shaped surface indentation having a coarser texture than the normal O-Ring surface, caused by incomplete filling of, and or the trapping of air in, the mould cavity

Off-register

misalignment of O-Ring halves, caused by the lateral shift of one mould cavity plate relative to other

Offset

mismatch and/or off-register of O-Ring halves

Parting-line indentation

shallow saucer-like recess sometimes triangular in shape, located on the parting line at the inner and/or outer diameters, caused by deformation of the mould edge at the parting line

Parting-line projection

continuous ridge of material situated at the parting line of inner and/or outer diameters caused by worn or excessively rounded edges of the mould cavity

Mounting instructions and accidental damage to the O-Rings

4

Mounting instructions

«Technical tightness» is practically achieved in practice with the correct selection of materials and optimum mounting ratios. If mistakes are made during mounting or if an O-Ring is damaged while being fitted, this leads to loss of tightness.

There should be no sharp-edged transitions, projecting shavings, ghost lines, threads, access holes etc. Even the smallest fault can make the O-Ring leak.
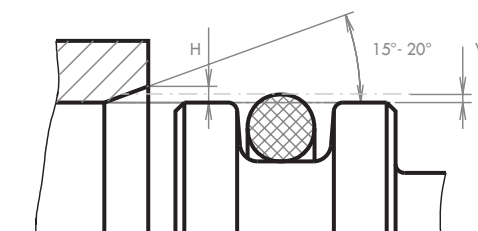
Mounting inclinations

Mounting inclinations ensure that the sealing face of the O-Ring can be mounted without damage. The transition from the taper to the cylindrical surface must be free from burrs.
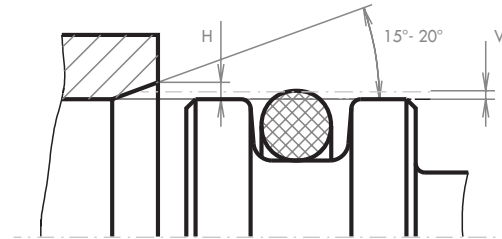
Piston packing

15°- 20°

Rod packing

H   15°- 20°   V
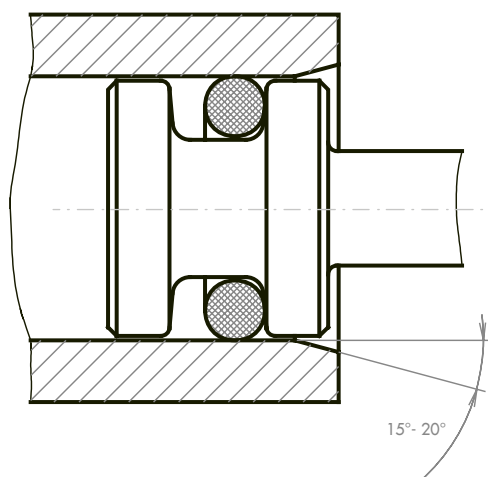
Designing the mounting inclinations

The radial height of the mounting inclination must be greater than the radial compression V. Thus H > V.
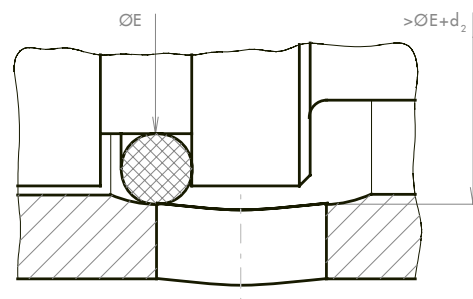
Mounting inclinations

Holes in the mounting area

If transverse holes have to be negotiated during mounting, corresponding recesses must be provided with tapers. The stress in the O-Ring is relieved in the vicinity of the hole and is then compressed again in the taper.
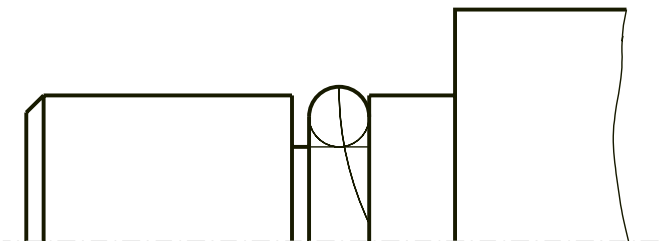
Traverse holes

Stretching during mounting

During mounting the O-Ring should not be stretched by more than approx. 80% of its circumference. Care must be taken to ensure that it remains below the breaking strain quoted in the material data sheet. If elongation reaches the upper elastic limit, the O-Ring must be allowed time to return to its original size.

Torsion while fitting in

Fitting into the groove

O-Rings that are deformed during mounting have a tendency to develop surface cracks as a result of the considerable elastic expansion they have undergone (the internal diameter becomes the external diameter). The O-Rings with the highest risk are those with a poor ratio of inner diameter to cross-section diameter ratio.
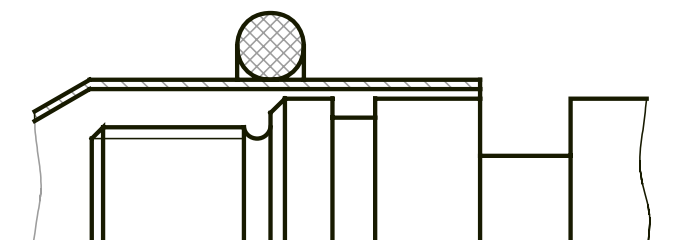
Mounting sleeve

By-passing shoulders of shafts

O-Rings must be protected from sharp edges during mounting. Threads, splines, gear teeth, holes etc. must be covered with a mounting sleeve.

Sliding the O-Ring above rod surface

Prevent the risk of drilling the O-Ring cross section while sliding above the rod surface. Reduce sliding distance and ensure good lubrication while assembly (in doubt lubricating coating of the O-Ring can help here).

Accidental damage to O-Rings

If mounting guidelines or the operating limits of the material are not observed, O-Rings can rapidly fail.

The main types of failure are:

- Working temperatures too high

- Poor compatibility with fluids

- Pressure too high

- Sealing gap too large

- Excess wear

- Compression set too high

- Rapid decompression in the case of gas seals

- Excessive elongation

- Wrongly designed housing

Working temperatures too high

Operating temperatures in excess of those recommended result in secondary curing in the O-Ring and hardening of the material. This can make it brittle. Overheating can also be caused by dynamic friction.

Poor compatibility with fluids

In aggressive fluids, poorly chosen materials may swell or shrink. If the material swells, it softens and loses its compressive force. If it shrinks, the compression is reduced. Resistance to pressure also decreases.

Pressure too high

If the pressures are high and the sealing gap is large and there is no back-up ring to support the O-Ring on the side away from the pressure, the ring will extrude into the gap. The result is mechanical damage such as peeling, explosion or cracking. Under pulsating pressure and with «breathing» structural parts the O-Ring can become caught when the pressure drops.

Excess wear

Excessively high dynamic loads, absence of lubrication, rough surfaces or excessive compression cause undesirable wear. Under pulsating pressure, the O-Ring moves in the groove and this can lead to wear. Contaminants in the fluid can promote wear.

Compression set too high

High compression set automatically means loss of sealing power. It occurs when operating temperatures are too high, if the material is of poor quality or if the groove is badly designed. Compression set can be explained as follows: In the sprung condition the elastomer undergoes secondary curing as a result of heating. It is therefore moulded once more. Temperature and duration are factors that greatly affect flattening. Poor quality materials are more susceptible to compression set. A slight degree of compression set can nevertheless be observed in every O-Ring, i.e. no O-Ring, once mounted and used, will revert to its original circular.

Rapid decompression (Permeation)

Extremely rapid release of pressure causes bubbles or crack formation on the surface of gas seals. Gas permeates into the O-Ring at high pressure and if the pressure drops rapidly it expands and escapes at the surface. This explosive decompression destroys the surface. Thin and/or light gases, such as CO_2 or helium, permeate the elastomer more easily.

Damage can be avoided by reducing the area in contact with the gas (using a small cross-section diameter) or by allowing the pressure to drop more slowly.

Excessive elongation

Excessive stretching (more than 6% to 10% of the inner diameter depending on the material) causes cracks to form on the O-Ring surface. These ozone cracks form more quickly under tension and are mainly observed in materials that are not resistant to ozone and weathering (e.g. NBR).
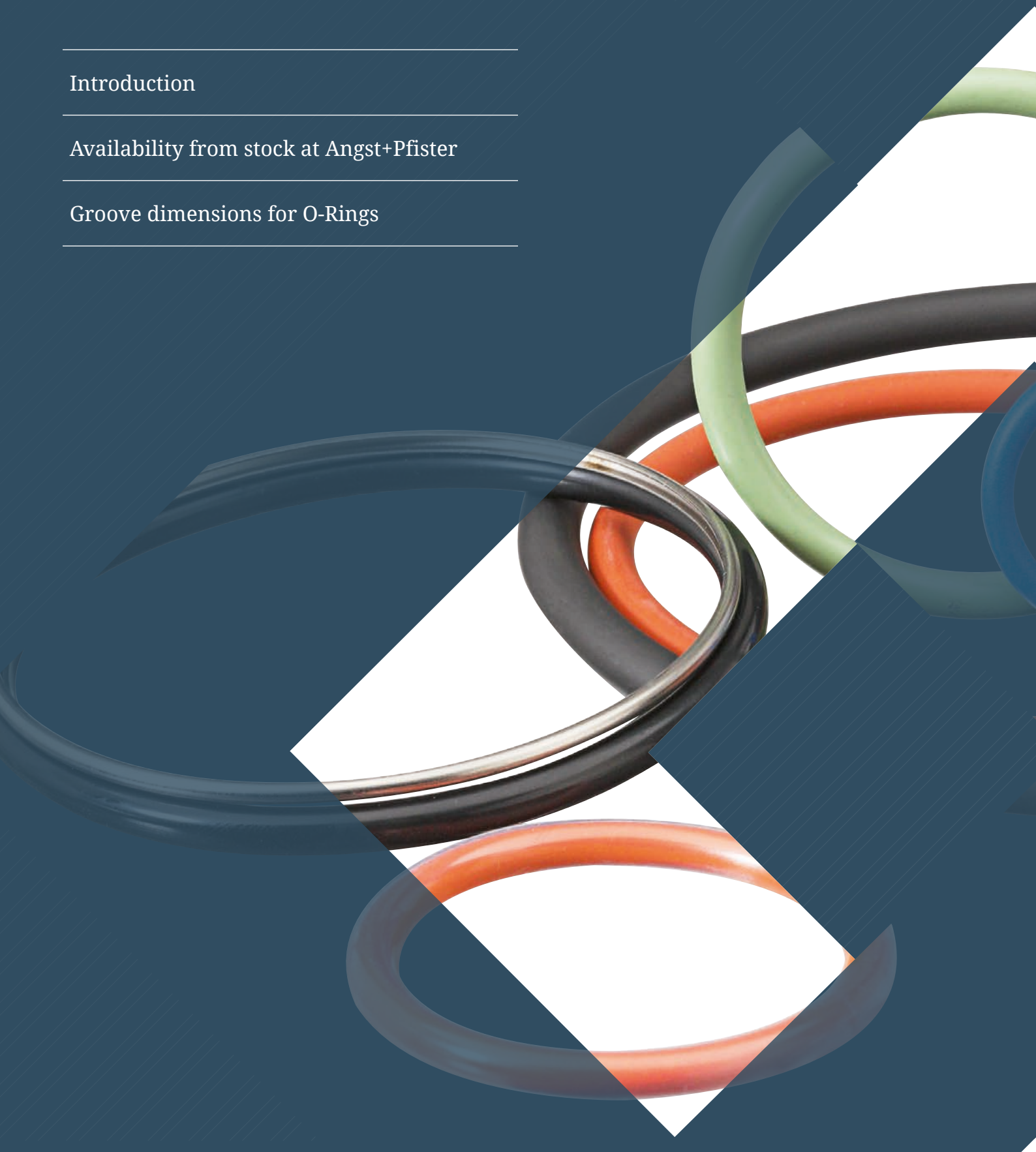
When distorted O-Rings are mounted, too much stretch in the area of the distortion can also cause crack formation. Elevated temperatures and high concentrations of oxygen or ozone accelerate this.

Groove dimensions

Introduction

Availability from stock at Angst+Pfister

Groove dimensions for O-Rings

5

Introduction

The groove dimensions given are general recommendations for the use of elastomer O-Rings with a hardness of 60 to 90 IHRD/Shore A. In certain cases (inadequate lubrication, use in a vacuum, pneumatic applications, extreme dynamic loads) the groove dimensions need to be adapted or altered.

For vacuum applications the section «Use of O-Rings in vacuum applications» in the chapter «Technical notes on the use of elastomer O-Rings» can be used for groove calculations. For pneumatics, the section «Dynamic seals in pneumatics» in the same chapter should be consulted to enable the O-Ring compression to be accurately determined. For other more unusual O-Ring applications it is advisable to contact us for advice.

Availability from stock at Angst+Pfister

- High Performance O-Rings
- PERTEC® O-Rings
- HITEC® Precision O-Rings
- NORMATEC® O-Rings
- Precision O-Rings

The availability of the various O-Ring types from stock is indicated in the respective product catalogs or on our website/webshop.

These also show the physical characteristics and the precise operating limits for the materials concerned.

Special O-Ring dimensions and materials

We are, of course, able to produce special O-Rings tailor-made for your application. Just ask us if you need special dimensions or a particular compound. Special orders are, however, subject to minimum quantities.

Groove dimensions
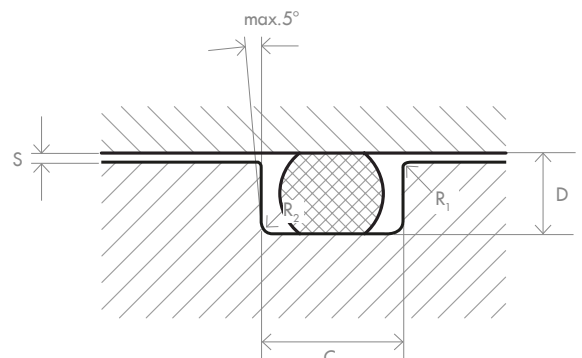
Groove dimensions for O-Rings

The following table gives a quick guide to groove dimensions. If FFKM O-Rings are to be used, we have access to a program for calculating the groove design. This can, under certain circumstances, vary from the standard dimensions.

Determination of O-Ring groove

Cross-sectional diameter	Dynamic radial applications					Static radial/axial applications			Radii	
	Depth of groove, hydraulic		Width of groove			Depth of groove		Width of groove		
d_2	D*		C	C_1	C_2	D $^{+0,1/0}$		C	R_1	R_2
mm	mm	%	mm	mm	mm	mm	%	mm	mm	mm
1.00	–	–	–	–	–	0.70	30	1.50 ±0.1	0.10	0.25
1.02	–	–	–	–	–	0.70	30	1.50 ±0.1	0.10	0.25
1.27	–	–	–	–	–	0.90	28	1.80 ±0.1	0.10	0.25
1.50	–	–	–	–	–	1.10	26	2.20 ±0.1	0.10	0.25
1.52	–	–	–	–	–	1.10	26	2.30 ±0.1	0.10	0.25
1.60	–	–	–	–	–	1.20	25	2.30 ±0.1	0.10	0.25
1.78	1.45	19	2.50 ±0.1	4.00 ±0.1	5.50 ±0.1	1.30	26	2.50 ±0.1	0.10	0.25
1.80	1.50	17	2.50 ±0.2	4.00 ±0.2	5.50 ±0.2	1.30	27	2.50 ±0.1	0.10	0.25
1.90	1.60	16	2.50 ±0.3	4.00 ±0.3	5.50 ±0.1	1.50	21	2.50 ±0.1	0.10	0.25
2.00	1.70	15	2.60 ±0.1	4.10 ±0.1	5.60 ±0.1	1.60	20	2.60 ±0.1	0.10	0.25
2.40	2.00	16	3.20 ±0.1	4.70 ±0.1	6.20 ±0.1	1.80	25	3.20 ±0.1	0.10	0.25
2.50	2.15	14	3.30 ±0.1	4.80 ±0.1	6.30 ±0.1	1.90	24	3.30 ±0.1	0.10	0.25
2.62	2.20	16	3.50 ±0.1	5.00 ±0.1	6.50 ±0.1	2.05	22	3.50 ±0.1	0.10	0.25
2.65	2.20	17	3.50 ±0.1	5.00 ±0.1	6.50 ±0.1	2.05	23	3.50 ±0.1	0.10	0.25
2.70	2.25	16	3.60 ±0.1	5.10 ±0.1	6.60 ±0.1	2.15	20	3.60 ±0.1	0.10	0.25
3.00	2.60	13	4.00 ±0.1	5.50 ±0.1	7.00 ±0.1	2.40	20	4.00 ±0.1	0.10	0.25
3.50	3.05	13	4.50 ±0.2	6.00 ±0.2	7.50 ±0.2	2.90	17	4.50 ±0.2	0.20	0.75
3.53	3.05	13	4.50 ±0.2	6.00 ±0.2	7.50 ±0.2	2.90	18	4.50 ±0.2	0.20	0.75
3.55	3.05	14	4.50 ±0.2	6.00 ±0.2	7.50 ±0.2	2.90	18	4.50 ±0.2	0.20	0.75
3.60	3.10	14	4.60 ±0.2	6.10 ±0.2	7.60 ±0.2	3.00	17	4.60 ±0.2	0.20	0.75
4.00	3.50	12	5.00 ±0.2	6.50 ±0.2	8.00 ±0.2	3.30	17	5.00 ±0.2	0.20	0.75
5.00	4.40	12	6.50 ±0.2	8.30 ±0.2	10.10 ±0.2	4.10	18	6.50 ±0.2	0.20	0.75
5.30	4.70	12	7.00 ±0.2	8.80 ±0.2	10.60 ±0.2	4.50	15	7.00 ±0.2	0.20	0.75
5.34	4.70	12	7.00 ±0.2	8.80 ±0.2	10.60 ±0.2	4.50	16	7.00 ±0.2	0.20	0.75
5.70	5.00	12	7.50 ±0.2	9.30 ±0.2	11.10 ±0.2	4.85	15	7.50 ±0.2	0.20	0.75
6.99	6.20	11	9.50 ±0.2	12.00 ±0.2	14.50 ±0.2	6.00	14	9.50 ±0.2	0.20	0.75
7.00	6.20	11	9.50 ±0.2	12.00 ±0.2	14.50 ±0.2	6.00	14	9.50 ±0.2	0.20	0.75
8.40	7.50	10	11.00 ±0.2	13.50 ±0.2	16.00 ±0.2	7.25	13	11.00 ±0.2	0.20	0.75

* The groove depth D in dynamic hydraulic applications is a theoretical value.
  The tolerance is derived from the clearances given in the groove dimension tables.

C_1 Width of groove with 1 back-up ring (also applies to static use)
C_2 Width of groove with 2 back-up rings (also applies to static use)
s   dimension of gap (not available in static axial use)
% percent compression

Support
all over
the world
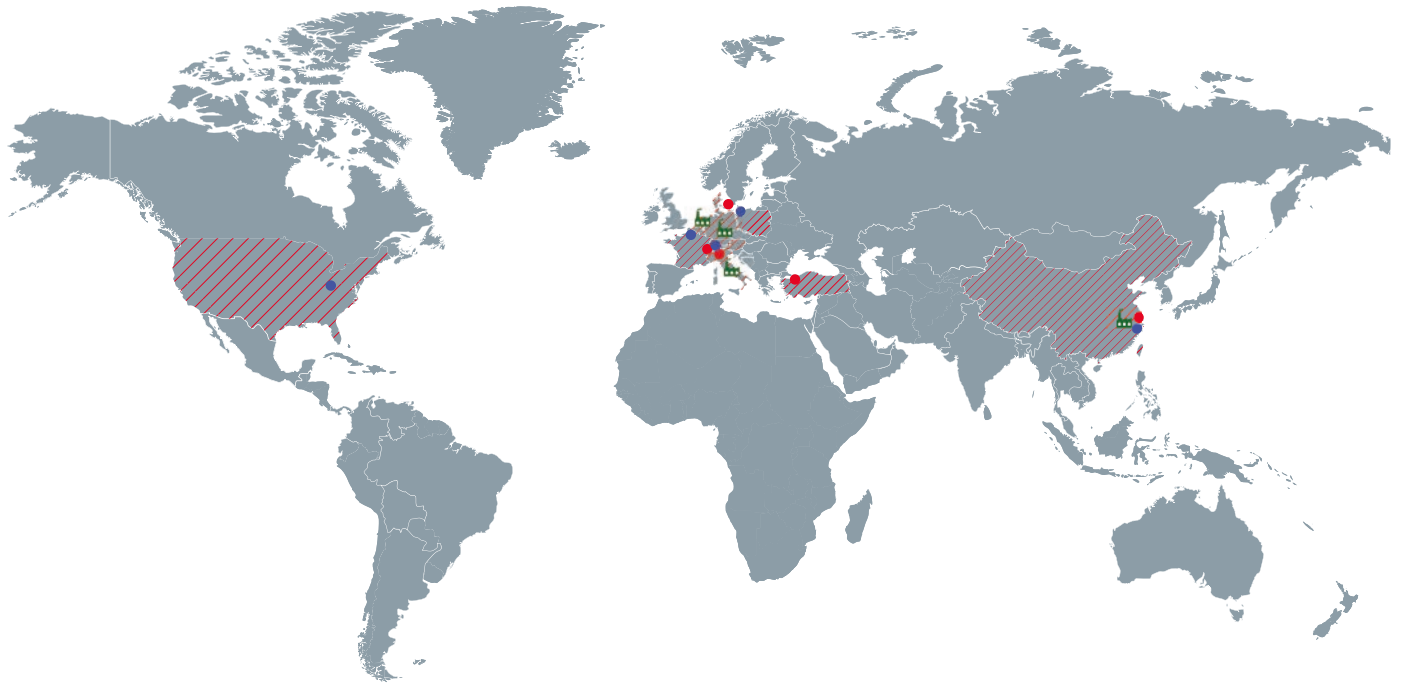
Angst+Pfister serves more than 20,000 customers per year in over 50 countries, through local sales and technical organizations supported by state-of-the-art engineering development centres.

Sales and engineering units
Development Centre
Global Logistics Centre
Production Site

If you have any questions, simply write to us:

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