O-ring description
Compression process
Injection moulding

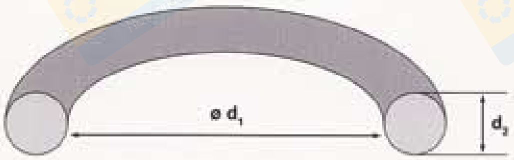
General

An O-ring seal is a means of preventing unwanted lekagae or loss of fluid or gas (i.e. media generally).

The O-ring is the most popular form of seal as it's so easy and simple to install and needs little installation space. Given correct grooving and material/s choice the seal can be used for a very long time within the rubber's temperature limits both as a fixed and as a moving part.

Description

An O-ring is a closed circle usually made of flexible rubber (elastomer). The dimensions are defined by the interior diameter ***d1*** and the cord diameter ***d2***.



O-ring-sizing

O-rings are gaplessly and seamlessly made of various types of natural rubber in hot injection or press moulds by vulcanising (cross-linking).

Manufacturing processes

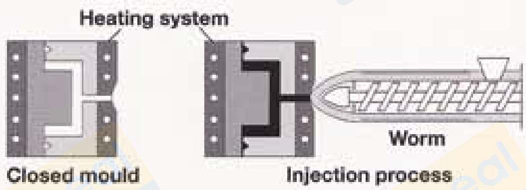
Two manufacturing processes are fundamentally differentiated between in manufacturing O-rings of elastomers.

- Compression process
  (Compression moulding = CM-process)
- Injection moulding
  (Injection moulding = IM-process)

In CM the slug is manually inserted in the tool (mould) before the two mould halves consisting of an upper and a lower part are closed. As this process is very time-consuming it is primarily suitable for manufacturing smaller quantities and larger dimensions.

Picture of CM

In injection moulding the slug is automatically injected in the tool, which consists of several O-ring cavities. This process is particularly suitable for large quantities and small dimensions.



Picture of IM

Elastomers

Seal materials

Elastomers/natural rubber

Cross-linked polymers with typical rubbery characteristics are called elastomers (rubber). The unlinked raw product is called natural rubber and the source is either from rubber plants or of synthetic manufacture.

Picture of the macro molecules of natural rubber

The elasticity of the cross-linked products is a result of cross-linking polymer chains causing elastomers to revert to shape after subjection to load. The number of elastomer qualities available is due to the various natural rubber types that can be used as a basis for a variety of materials by employing appropriate recipes.

Picture of the macro molecules of rubber

Materials

Technical rubber materials are made using recipes whereby the polymer itself is the weakest link in chemical resistance in the chain of mixture ingredients where the media to be sealed are concerned.

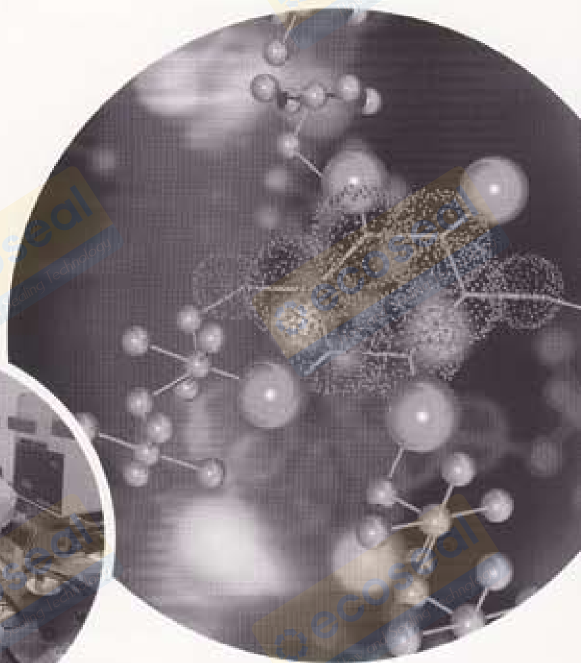
The choice of the right sealant material is often hence restricted to the choice of basic polymer/s. However, in practice other influences due to the recipe used may be of significance such as the type of cross-linking, the quantity of softener/s used and the type of filler employed. Polymer tolerability alone is hence no guarantee of reliable sealing but is a major pre.condition of it.

Ingredients	Quantity in phr
natural rubber (polymer)	100.0
Filler materials	40.0
Softener/s	10.0
Processing aids	3.0
Ageing prevention media	3.0
Activators	2.5
Cross-linking media	2.0
Accelerator/s	1.5

Mixture ingredients in a sample recipe

ⓘNOTE:

Phr is parts per hundred of rubber, i.e. relative to 100 parts of natural rubber.



DIN ISO 1629

ASTM D 1418

Natural rubber nomenclature

Due to the designation of the numerous synthesis natural rubbers a classification has been allocated per IS0 1629 or ASTM D 1418. Natural rubbers in solid form are classified into the following group based on their polymer chain chemical composition.

Group	Chemical name	DIN ISO 1629	ASTM D 1418	COG no.
M	Polyacrylate-natural rubber	ACM	ACM	AC ...
M	Chlorpolyethylene-natural rubber	CM	CM	--
M	Ethylene acrylate-natural rubber	AEM	AEM	--
M	Chlorsulphurated-polyethylene-natural rubber	CSM	CSM	Hy ...
M	Ethylene-propylene-natural rubber	EPM	EPM	EP ...
M	Ethylene-propylene-(dien)-natural rubber	EPDM	EPDM	AP ...
M	Fluoride-natural rubber	FPM	FKM	LT ... Vi ...
		FEPM	FEPM	AF... Vi ...
M	Perfluor-natural rubber	FFPM	FFKM	Perlast®
O	Epichlorhydrine-natural rubber	CO	CO	--
O	Epichlorhydrin-copolymer-natural rubber	ECO	ECO	--
O	Propylenoxide-copolymer-natural rubber	GPO	GPO	--
R	Butadiene-natural rubber	BR	BR	--
R	Chloroprene-natural rubber	CR	CR	NE ...
R	Isobutene-isopropene-natural rubber	IIR	IIR	BT ...
R	Isoprene-natural rubber	IR	IR	--
R	Acrylnitrile-butadiene-natural rubber	NBR	NBR	P ...
R	Hydrated acrylnitrile-butadiene-natural rubber	HNBR	HNBR	HNBR ...
R	Natural rubber	NR	NR	K ...
R	Styrol-butadiene-natural rubber	SBR	SBR	--
Q	Fluor-methyl-silicone-natural rubber	FVMQ	FVMQ	Si ... FL
Q	Methyl-phenyl-silicone-natural rubber	PMQ	PMQ	--
Q	Methyl-phenyl-vinyl-silicone-natural rubber	PVMQ	PVMQ	--
Q	Methyl-vinyl-silicone-natural rubber	VMQ	VMQ	Si ...
Q	Methyl-silicone-natural rubber	MQ	MQ	--
U	Polyesterurethane-natural rubber	AU	AU	PU ...
U	Polyetherurethane-natural rubber	EU	EU	EU ...

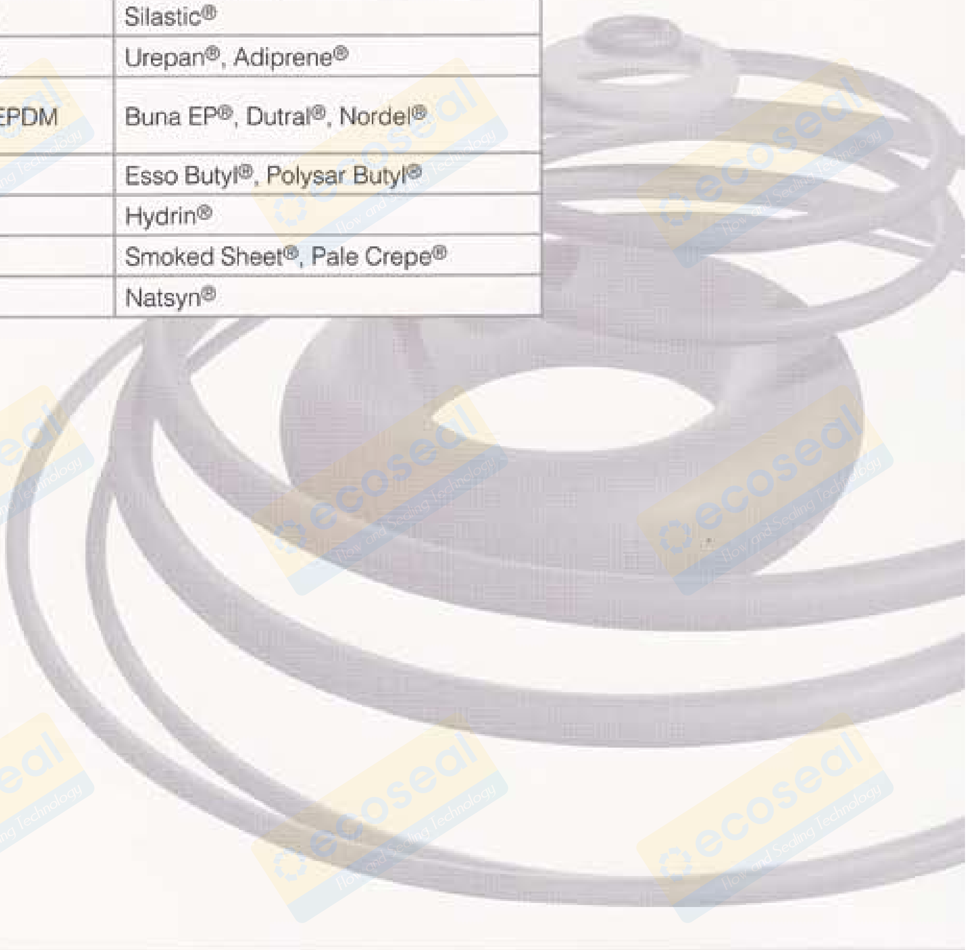
Overview of the major natural rubber types with brief designation and COG no.

The most common natural rubbers with trade names

The table below is an overview of some selected natural rubbers from which elastomer sealant materials are made with their abbreviations and a selection of trade names.

Basic natural rubber	Abbreviation	Trade name (selection)
Acrylnitrile-butadiene-natural rubber	NBR	Perbunan®, Europrene N®, Krynac®
Styrol-butadiene-natural rubber	SBR	Europrene®, Buna-S®
Hydrated acrylnitrile-butadiene-natural rubber	HNBR	Therban®, Zetpol®
Chloroprene-natural rubber	CR	Baypren®, Neoprene®
Acrylate natural rubber	ACM	Nipol AR®, Hytemp®, Cyanacryl®
Ethylene acrylate-natural rubber	AEM	Vamac®
Fluor natural rubber	FPM/FKM	Viton®, Dai-El®, Tecnoflon®
	FEPM	Viton® Extreme, Aflas®
Perfluor natural rubber	FFKM	Kalrez®, Perlast®, Chemraz®
Silicone natural rubber	VMQ	Elastosil®, Silopren®
Fluor-silicone-natural rubber	FVMQ	Silastic®
Polyurethane-natural rubber	AU/EU	Urepan®, Adiprene®
Ethylene-propylene-(dien)-natural rubber	EPM, EPDM	Buna EP®, Dutral®, Nordel®
Butyl rubber	IIR	Esso Butyl®, Polysar Butyl®
Epichlorhydrine-natural rubber	ECO	Hydrin®
Natural rubber	NR	Smoked Sheet®, Pale Crepe®
Polyisoprene-natural rubber	IR	Natsyn®

Overview of some types of natural rubber (incomplete list)



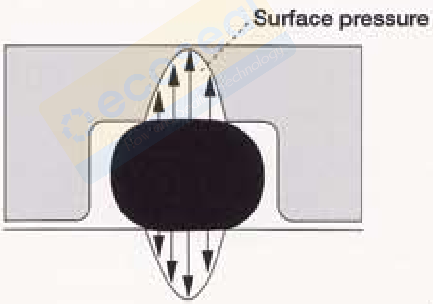
The way they work

O-ring seal effect

O-ring sealant effect is due to the elastic deformation of the cross-section (cord diameterr d2) in an appropriately shaped installation space (groove). The circular cross-section is changed to elliptical in this installation space and seals off a gap in the contact or sealing surface and groove.

Sealing effect is hence due to deformation of the circular O-ring. Its extent is determined by groove depth t. The compression forces that arise due to this deformation make the seal in the system.

ⓘIMPORTANT: The cord diameter d2 must always exceed the depth of the installation space.

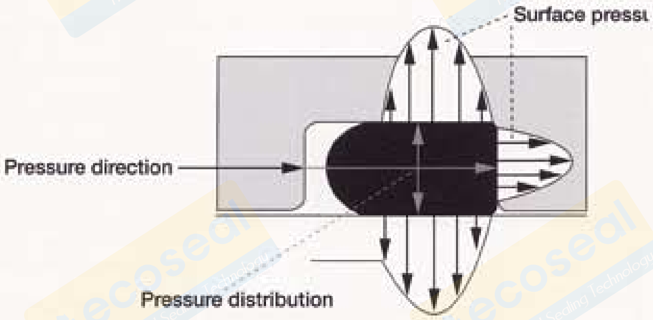


Compressed O-ring in installation space without pressure

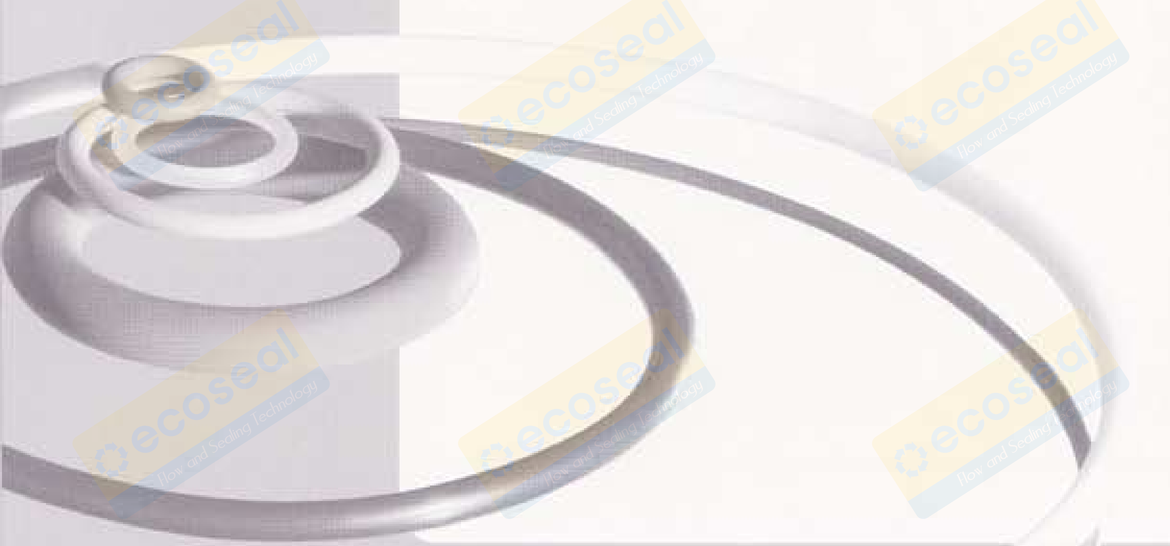
Any pressure of the medium to be sealed tensions the O-ring additionally and this is beneficial to the seal as its effect is increased (surface pressure increase).

The pressure presses the O-ring against the groove flank facing away from that pressure. To avoid the ring being pressed into the seal gap in the process this should be as small as possible. In radial seals a tolerance pairing of H8/f7 should exist, in axial seals H11/h11.

If not, or if higher pressures are anticipated, then the material/s chosen should ensure maximum possible O-ring hardness. Should this not be the case extrusion may occur and the O-ring be destroyed.



Compressed O-ring in installation space under pressure

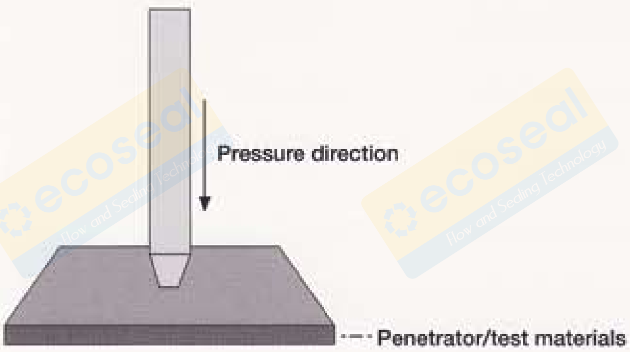


Hardness

Hardness here is the resistance of a body to penetration by a harder body of a specific shape at a specific pressure over a specific time. It is measured in Shore or IRHD (International Rubber Hardness Degree) gemessen. Comparable values are determined using standard samples and given in Shore A units. For measurements on finished products IRHD is usual. Hardness values of finished products deviate from those of standard samples as their thickness, curved surface or values measured at the edges are not comparable and the metrology procedures differ.

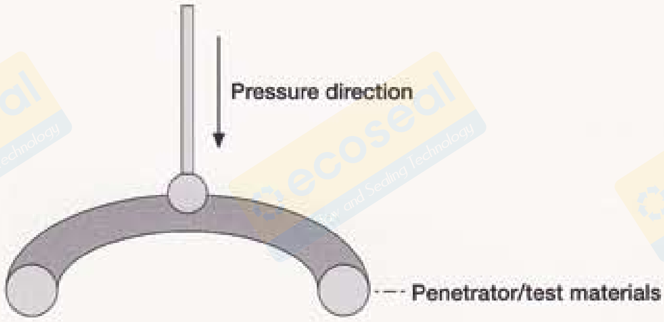
At a cord thickness ≤ 3 mm is meaningful measurement of hardness is only feasible in IRHD (up to a cord thickness. of 1.6 mm).

The picture below shows the penetrating body (a pyramid stump) for hardness measurement in Shore A (DIN 53505).



Hardness measurement in Shore A

The picture below shows the penetrating body (a sphere) for hardness measurement in IRHD (DIN ISO 48 CM).



Hardness measurement in IRHD

Hardness must be adjusted to e.g. pressure burden. The softer the elastomer the easier it is deformed under pressure and pressed into the gap to be sealed. On the other hand softer elastomer seals at low pressures and between uneven surfaces due to its greater flexibility.

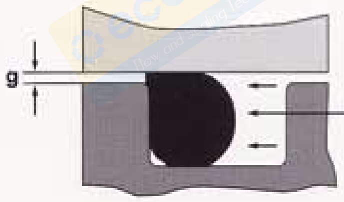
ⓘNOTE:
Hardness is not a quality characteristic but a characteristic that plays a role in sealing.

O-ring behaviour under pressure

Extrusion

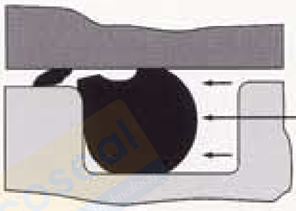
ⓘIMPORTANT:
The gap size should be as small as possible.

The extrusion angle is largely determined by the gap size ***g*** between machinery parts. The play depends on process, manufacturing method, tolerances influencing play, the breathing of the parts under pressure and so on.



O-ring behaviour under pressure

Excessive gaps can e.g. cause elastomer destruction by extrusion.



Extruded O-ring

O-rings of 90 Shore A hardness permit slightly larger gaps than standard-O-rings of 70 Shore A. The table of guide values below of gap sizes for standard elastomers are maximum values if the components are centred.

ⓘNOTE:
All data based on experience and solely intended as guidance.

Cord thickness d2	to 2	2.01–3	3.01–5	5.01–7	over 7.01
O-ring hardness 70 Shore A					
Pressure (bar)			Gap g		
≤ 35	0.08	0.09	0.10	0.13	0.15
≤ 70	0.05	0.07	0.08	0.09	0.10
≤ 100	0.03	0.04	0.05	0.07	0.08
O-ring hardness 90 Shore A					
Pressure (bar)			Gap g		
≤ 35	0.13	0.15	0.20	0.023	0.25
≤ 70	0.10	0.13	0.15	0.18	0.20
≤ 100	0.07	0.09	0.10	0.13	0.15
≤ 140	0.05	0.07	0.08	0.09	0.10
≤ 175	0.04	0.05	0.07	0.08	0.09
≤ 210	0.03	0.04	0.05	0.07	0.08
≤ 350	0.02	0.03	0.03	0.04	0.04

Gap size for O-ring installation spaces depending on pressure (data in mm)

Thermal characteristics

Elastomers display optimal characteristics over a wide temperature range and have a long service life within it. Depending on natural rubber type there are two temperature ranges in which this is not the case.

Below a specific temperature - known as the glass transition temperature - elastomers lose their elasticity and mechanical stress resistance. This process is reversible, i.e. after rewarming the original characteristics return.

The upper temperature limit depends on the media used that influence it. Permanently exceeding this upper limit leads to destruction of elastomer and is irreversible.

Elastomer operating temperatures

Operating temperatures

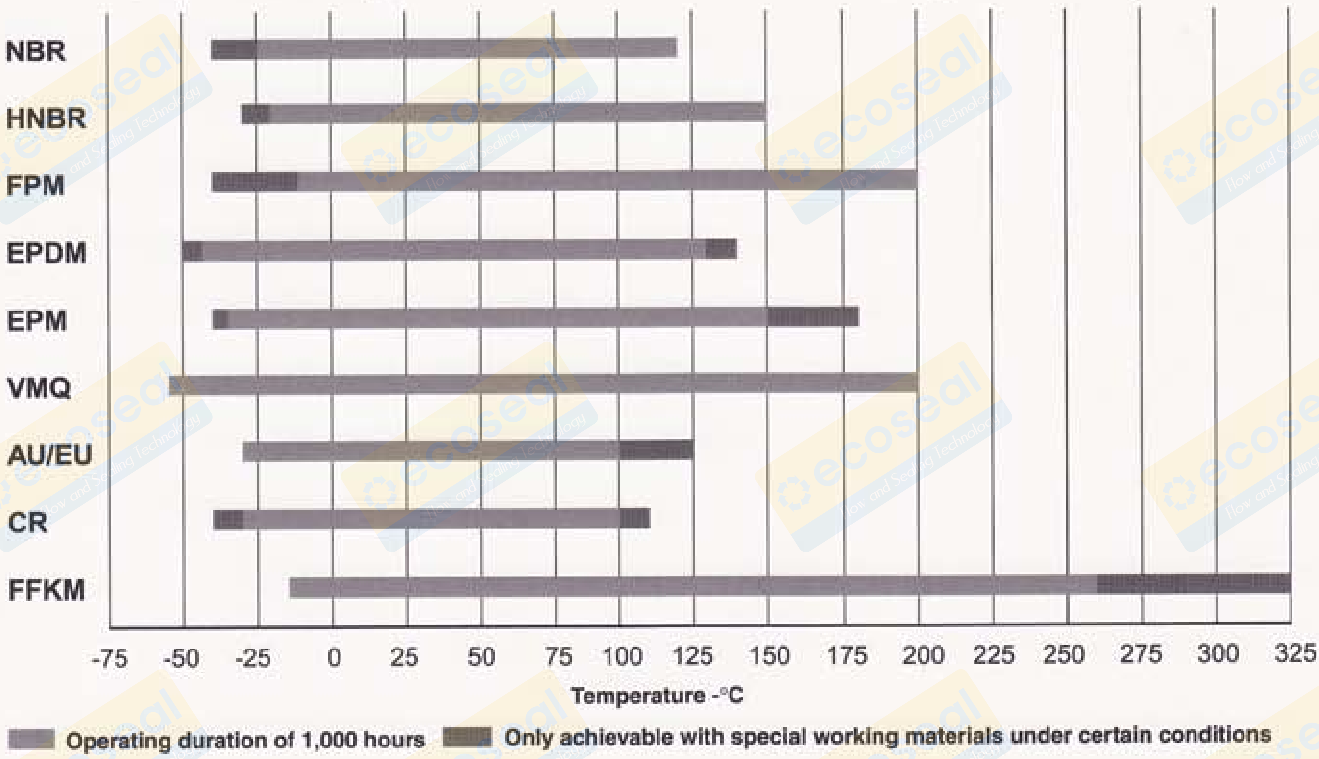
The permissible temperature range depends on the material/s used. Whether temperatures are permanent (constant or operating temperature) or temporary (peak temperature) must be differentiated.

Extreme thermal stress on an O-ring

ⓘIMPORTANT:

Operating temperature depends on the media to be sealed. 100° C air temperature resistance in an O-ring is hence not the same as 100 °C oil resistance.

Temperature ranges of various elastomer materials (medium: air)



▶ Media resistance

Elastomer media resistance

Elastomer resistance to various media is of major significance. Two types of change occur: physical and chemical.

Physical processes

This is primarily volume change (swelling or shrinking) of an elastomer in a medium. In swelling the elastomer soaks up the medium and its technical values therefore change (e.g. lowered tear resistance or hardness). This doesn't mean the seal ceases to function. However, excessive swelling in volume may lead to the installation space (groove) being overfilled and the O-ring being mechanically destroyed. Details of swelling values are given in the literature on the subject (e.g. COG resistance tables) or found by practical experiment, which is better. Please contact us for information.

In shrinking mixture ingredients (e.g. softener) are separated out of the medium (e.g. mineral oil). This may lead to seal pressure being too low or non-existent and result in leakage. This must be prevented at all costs.

Chemical aggression

Contact with the medium here leads to the destruction of the elastomer as the polymer chain is changed. This makes the material hard and brittle and it loses its elastic properties.

Details of chemical resistance can be found either in the materials specifications, the relevant literature or resistance tables (e.g. COG resistance tables). Chemical aggression must also be avoided at all costs.

ⓘIMPORTANT:
Chemical aggression and physical shrinkage of an O-ring must always be prevented/avoided.

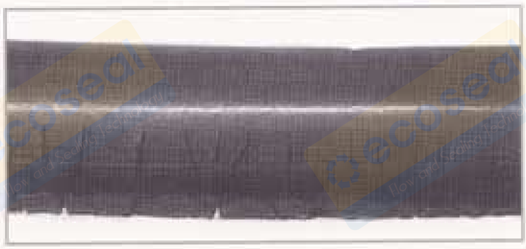


Illustration of chemical aggression on an O-ring

Groove geometry for O-ring installation spaces

O-rings must be laid in grooves made for the purpose if they are to seal properly.
These installation spaces are usually made with a rotary chisel in a shaft or drill hole or with a milling machine in a work piece. Groove geometry is usually rectangular. The illustration below shows a typical rectangular groove with dimensions as recommended in the relevant standards.

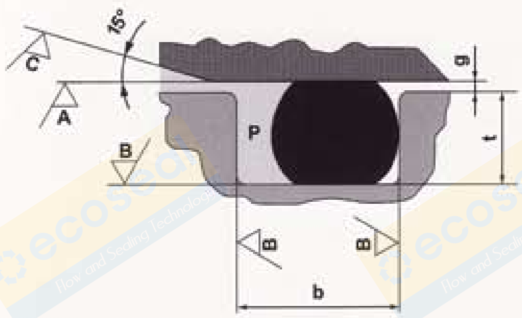


Illustration of a typical rectangular groove

Nomenclature:

t = ***groove depth***
b = ***groove width***
g = ***Gap to be sealed size***
P = ***Media pressure***
A = ***Opposing surface***
B = ***Groove flank surfaces and groove base***
C = ***Surface of installation angle***

Determining groove depth

The relationship of cord thickness ***d2*** of the O-ring to groove depth determins initial compression. Choice of groove depth depends on use. In static use initial compression should be between 15 and 30 %. In dynamic use a larger groove depth and smaller hence compression should be chosen, usually between 6 and 20 %.

ⓘIMPORTANT:
Groove depth is decisive in O-ring pressure.

Groove width b determination

Groove width is determined by O-ring cord thickness d2 and the elliptical shape after compression plus a free space in which the medium can enter to guarantee even pressure on the seal.
In sizing the groove width the primary criterion is avoidance of groove overfill. It is therefore usually assumed in designing the groove that the O-ring should fill it by up to 85 % so that there is space for expansion if needed.

ⓘNOTE:
Groove width needs to be adapted to possible volume increase of the O-ring.

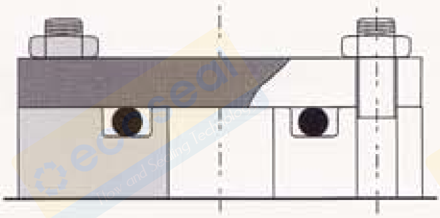
Installation types

Definition of installation types

There are various O-ring installation options. O-ring cross-section deformation directions are differentiated between by axial or radial alignment.
In radial deformation "external seal" (interior groove, piston seal) and "interior seal" (external groove, rod seal) are also differentiated between. Most O-rings are statically stressed seals. If the seal is between machinery parts that move toward one another then the seal is dynamic. O-rings are technically optimal solutions in dynamic sealing only in exceptional cases.

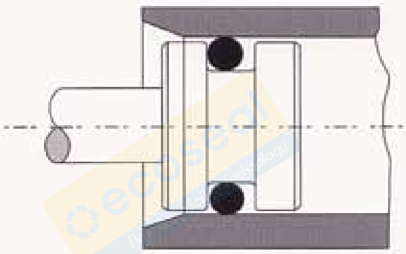
O-ring installation types

Seal type for installation purposes is defined as follows



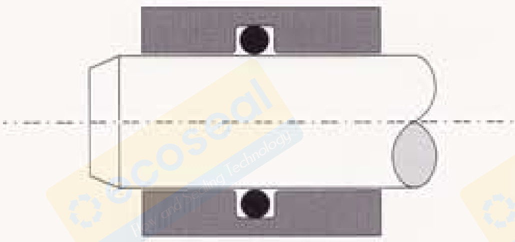
Flange seals

Flange seals
The groove is in the flange and is screwed down by a cover plate.



Piston seals

If the groove is on the interior
the whole is called a „piston seal".



Rod seals

If the groove is on the exterior
the whole is called a „rod seal".

There are also specialised installation situations in specific circumstances such as

- Trapezoidal grooves
- Triangular grooves

Radial, static or dynamic installation external seal (piston seal)

The illustration below is a diagram of a section of the installation space in the case of radial static or dynamic installation of an O-ring in a piston seal.

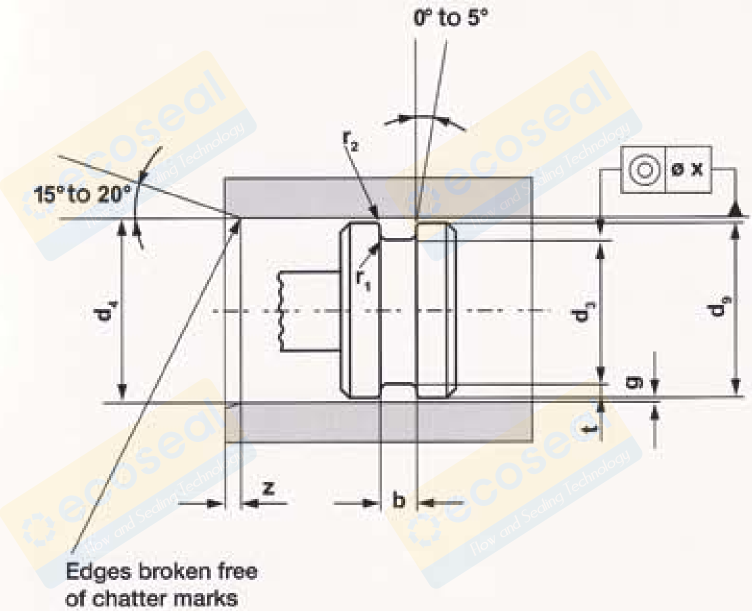


Illustration of the installation space in the case of a static radial piston seal

NOTE:
This seal type is preferable in radial installation.

In the table that follows the names and installation spaces as well as the O-ring are detailed more closely.

Designation	Tolerance	Explanation
d2	DIN 3771	Cord diameter (cord thickness)
d4	H8	Drill hole diameter
d9	f7	Piston diameter (shaft diameter)
d3	h11	Interior diameter of the installation space (groove base diameter)
b1	+0.25	With of the O-ring instillation space (groove width)
g		Gap size
t		Radial depth of the installation space (groove depth)
r1	±0.1 ... 0.2	Radius at the base of the installation space
r2	±0.1	Radius at the edge of the installation space
z		Length of installation angle (> d2/2)

Installation types
Piston seal

The table that follows shows a selection of installation dimensions dependant on cord thickness ***d2***.

d_2	b	t		r_1	r_2	z_{min}
		Static	Dynamic			
0.50	0.70	0.35	0.40	0.2 ± 0.1	0.2	1.1
0.60	0.85	0.40	0.48	0.2 ± 0.1	0.2	1.1
0.75	1.00	0.55	0.60	0.2 ± 0.1	0.2	1.1
0.80	1.10	0.55	0.64	0.2 ± 0.1	0.2	1.1
1.00	1.35	0.70	0.80	0.3 ± 0.1	0.2	1.1
1.20	1.60	0.85	0.95	0.3 ± 0.1	0.2	1.1
1.50	2.00	1.15	1.20	0.3 ± 0.1	0.2	1.1
1.60	2.15	1.20	1.30	0.3 ± 0.1	0.2	1.1
1.80	2.40	1.35	1.45	0.3 ± 0.1	0.2	1.1
2.00	2.70	1.50	1.65	0.3 ± 0.1	0.2	1.1
2.20	2.95	1.65	1.80	0.3 ± 0.1	0.2	1.1
2.40	3.20	1.80	2.00	0.3 ± 0.1	0.2	1.1
2.50	3.35	1.90	2.10	0.3 ± 0.1	0.2	1.3
2.65	3.60	2.05	2.25	0.3 ± 0.1	0.2	1.5
2.80	3.75	2.15	2.40	0.6 ± 0.2	0.2	1.5
3.00	4.00	2.30	2.60	0.6 ± 0.2	0.2	1.5
3.30	4.40	2.60	2.90	0.6 ± 0.2	0.2	1.5
3.55	4.80	2.80	3.10	0.6 ± 0.2	0.2	1.8
3.70	5.00	3.00	3.20	0.6 ± 0.2	0.2	1.9
4.00	5.40	3.20	3.50	0.6 ± 0.2	0.2	2.0
4.30	5.80	3.40	3.75	0.6 ± 0.2	0.2	2.2
4.50	6.10	3.60	3.95	0.6 ± 0.2	0.2	2.3
5.00	6.70	4.10	4.40	0.6 ± 0.2	0.2	2.5
5.30	7.10	4.35	4.70	0.6 ± 0.2	0.2	2.7
5.50	7.40	4.50	4.85	1.0 ± 0.2	0.2	2.8
6.00	8.10	4.90	5.30	1.0 ± 0.2	0.2	3.0
6.50	8.70	5.35	5.75	1.0 ± 0.2	0.2	3.3
7.00	9.50	5.80	6.15	1.0 ± 0.2	0.2	3.6
7.50	10.05	6.25	6.60	1.0 ± 0.2	0.2	3.8
8.00	10.70	6.70	7.10	1.0 ± 0.2	0.2	4.0
9.00	12.00	7.55	8.00	1.0 ± 0.2	0.2	4.5
10.00	13.35	8.40	8.90	1.0 ± 0.2	0.2	5.0
11.00	14.70	9.25	9.80	1.0 ± 0.2	0.2	5.5
12.00	16.10	10.20	10.80	1.0 ± 0.2	0.2	6.0

O-ring installation sizes in a static or dynamic radial piston seal

ⓘNOTE:

Strictly speaking the table values only apply to NBR O-rings with a hardness of 70 Shore A. However, experience shows that they can be used for other materials and hardnesses although the groove depth may need adjusting.

The values are calculated based on a possible swelling of up to 15 %. If the swelling allowed for is less then the groove width can be reduced accordingly.

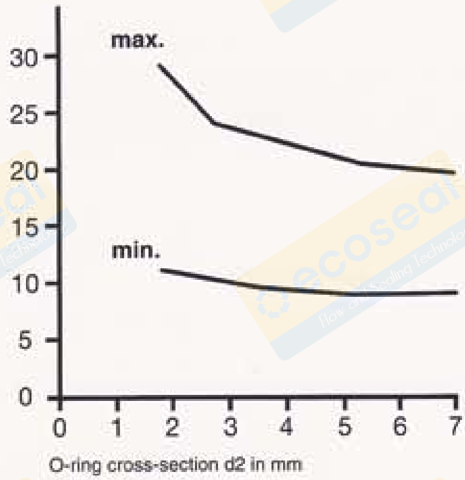
Determining the interior diameter d1

O-ring dimensions for static or dynamic radial external seals must be so chosen that the exterior diameter ***d1*** is approximately 1–3 % smaller than the groove base diameter ***d3***. This means that the O-ring should be installed slightly stretched.

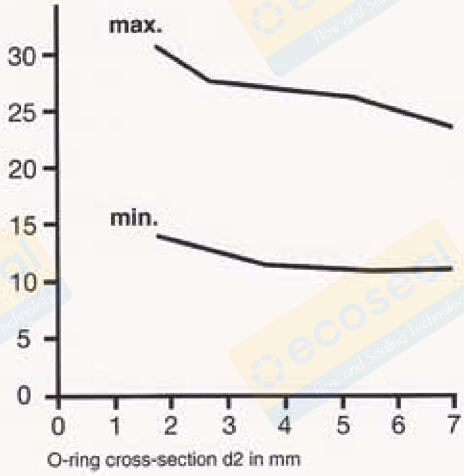
The diagrams opposite show the permissible ranges of the O-ring compression depending on cord diameter ***d2***.

Piston seal interior diameter

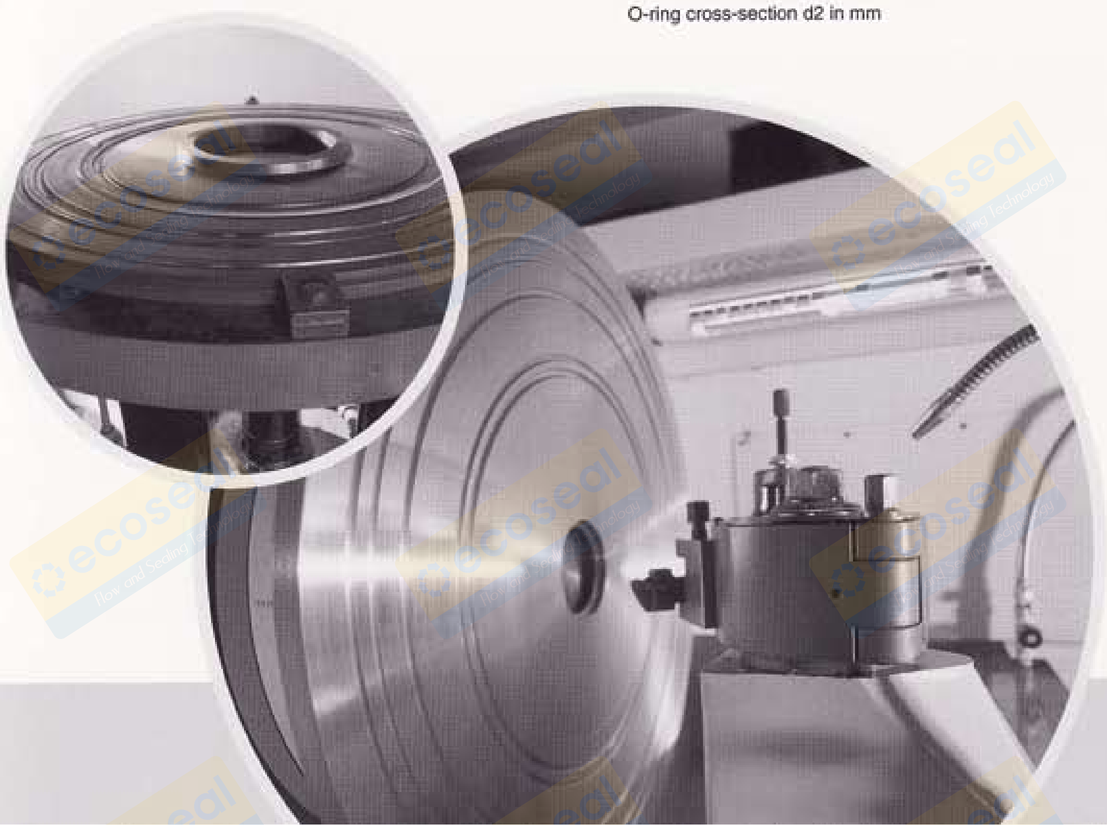
Dynamic seal compression



Static seal compression



ⓘIMPORTANT:
The O-ring should be installed slightly stretched.



Installation types
Rod seal

Radial, static or dynamic installation, interior seal (rod seal)

The illustration below is a diagram of a section of the installation space in the case of radial static or dynamic installation of an O-ring in a rod seal.

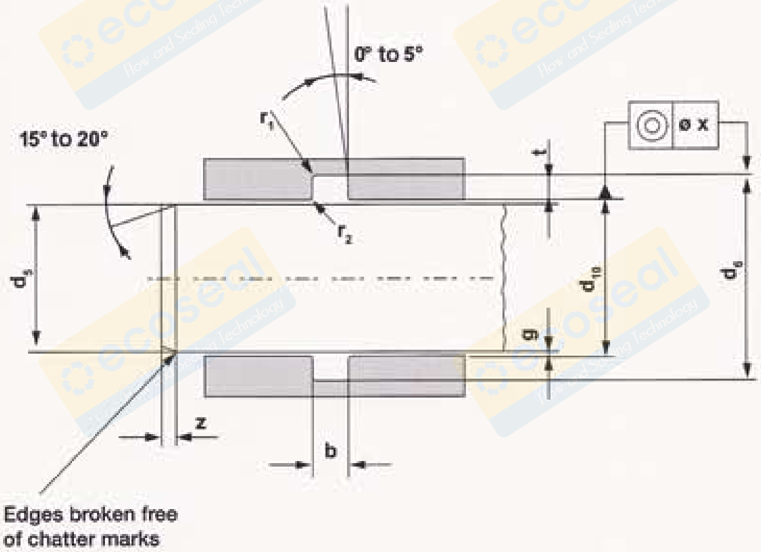


Illustration of the installation space in the case of a static radial rod seal

In the table that follows the names and installation spaces as well as the O-ring are detailed more closely.

Designation	Tolerance	Explanation
d10	H8	Drill hole diameter
d5	f7	Rod diameter
d6	H11	Interior diameter of the installation space (groove base diameter)
b	+0.25	With of the O-ring instillation space (groove width)
g		Gap size
t		Radial depth of the installation space (groove depth)
r1	±0.1 ... 0.2	Radius at the base of the installation space
r2	±0.1	Radius at the edge of the installation space
z		Length of installation angle (> d2/2)

The table that follows shows a selection of installation dimensions dependant on cord thickness d2.

d_2	b	t		r_1	r_2	z_{min}
		Static	Dynamic			
0.50	0.70	0.35	0.40	0.2 ± 0.1	0.2	1.1
0.60	0.85	0.40	0.50	0.2 ± 0.1	0.2	1.1
0.75	1.00	0.55	0.60	0.2 ± 0.1	0.2	1.1
0.80	1.10	0.55	0.65	0.2 ± 0.1	0.2	1.1
1.00	1.35	0.70	0.80	0.3 ± 0.1	0.2	1.1
1.20	1.60	0.85	0.95	0.3 ± 0.1	0.2	1.1
1.50	2.00	1.15	1.20	0.3 ± 0.1	0.2	1.1
1.60	2.15	1.20	1.30	0.3 ± 0.1	0.2	1.1
1.80	2.40	1.35	1.45	0.3 ± 0.1	0.2	1.1
2.00	2.70	1.50	1.65	0.3 ± 0.1	0.2	1.1
2.20	2.95	1.65	1.85	0.3 ± 0.1	0.2	1.1
2.40	3.20	1.80	2.05	0.3 ± 0.1	0.2	1.1
2.50	3.35	1.90	2.10	0.3 ± 0.1	0.2	1.3
2.65	3.60	2.05	2.25	0.3 ± 0.1	0.2	1.5
2.80	3.75	2.15	2.40	0.6 ± 0.2	0.2	1.5
3.00	4.00	2.30	2.60	0.6 ± 0.2	0.2	1.5
3.30	4.40	2.60	2.90	0.6 ± 0.2	0.2	1.5
3.55	4.80	2.80	3.10	0.6 ± 0.2	0.2	1.8
3.70	5.00	3.00	3.20	0.6 ± 0.2	0.2	1.9
4.00	5.40	3.20	3.50	0.6 ± 0.2	0.2	2.0
4.30	5.80	3.40	3.75	0.6 ± 0.2	0.2	2.2
4.50	6.10	3.60	3.95	0.6 ± 0.2	0.2	2.3
5.00	6.70	4.10	4.40	0.6 ± 0.2	0.2	2.5
5.30	7.10	4.35	4.70	0.6 ± 0.2	0.2	2.7
5.50	7.40	4.50	4.85	1.0 ± 0.2	0.2	2.8
6.00	8.10	4.90	5.30	1.0 ± 0.2	0.2	3.0
6.50	8.70	5.35	5.75	1.0 ± 0.2	0.2	3.3
7.00	9.50	5.80	6.15	1.0 ± 0.2	0.2	3.6
7.50	10.05	6.25	6.60	1.0 ± 0.2	0.2	3.8
8.00	10.70	6.70	7.10	1.0 ± 0.2	0.2	4.0
9.00	12.00	7.55	8.00	1.0 ± 0.2	0.2	4.5
10.00	13.35	8.40	8.90	1.0 ± 0.2	0.2	5.0
11.00	14.70	9.25	9.80	1.0 ± 0.2	0.2	5.5
12.00	16.10	10.20	10.80	1.0 ± 0.2	0.2	6.0

O-ring installation sizes in a static or dynamic radial piston seal

ⓘ NOTE:

Strictly speaking the table values only apply to NBR O-rings with a hardness of 70 Shore A. However, experience shows that they can be used for other materials and hardnesses although the groove depth may need adjusting.

The values are calculated based on a possible swelling of up to 15 %. If the swelling allowed for is less then the groove width can be reduced accordingly.

Interior diameter
Rod seal

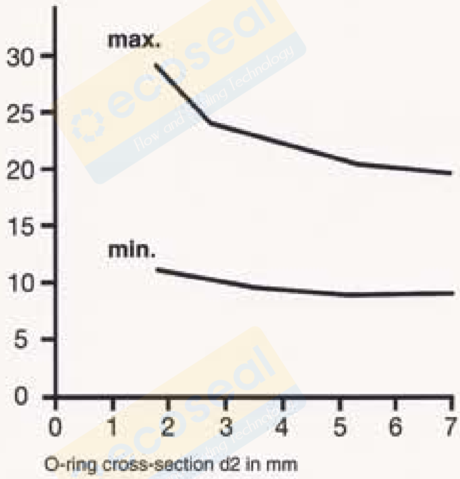
Installation types
Flange seals

Determining the interior diameter d1

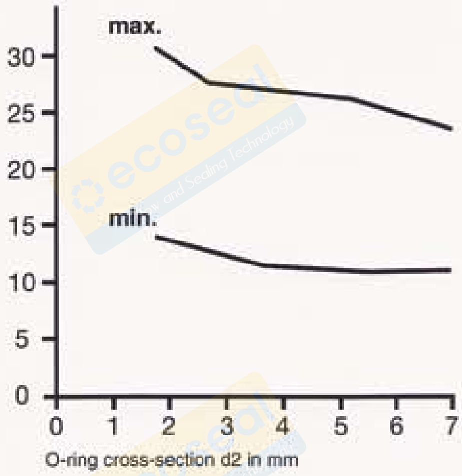
O-ring dimensions for static or dynamic radial internal seals must be chosen that the interior diameter ***d1*** is approximately 1–3 % larger than the external diameter ***d6*** of the installation space. This means that the O-ring should be installed slightly stretched.

The diagrams below show the permissible ranges of the O-ring compression depending on cord diameter ***d2***.

Dynamic seal compression



Static seal compression



IMPORTANT:
The O-ring should be installed slightly compressed.

Axial, static installation (flange seal)

The illustration below is a sectional diagram of the installation space in axial flange seals.

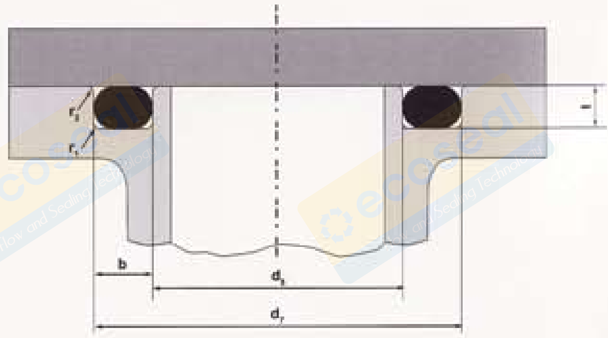


Illustration of axial seal installation space

In the table that follows the names and installation spaces as well as the O-ring are detailed more closely.

Designation	Tolerance	Explanation
d2	DIN 3771	Cord diameter (cord thickness)
d7	H11	External axial diameter
d8	h11	Internal axial diameter
b	+0.25	With of the O-ring instillation space (groove width)
t	+0.1	Radial depth of the installation space (groove depth)
r1	±0.1... 0.2	Radius at the base of the installation space
r2	±0.1	Radius at the edge of the installation space

The table that follows shows a selection of instillation dimensions dependant on cord thickness d2.

d_2	b	t	r_1	r_2
0.50	0.80	0.35	0.2 ± 0.1	0.1
0.60	1.00	0.40	0.2 ± 0.1	0.1
1.00	1.50	0.70	0.3 ± 0.1	0.2
1.50	2.20	1.05	0.3 ± 0.1	0.2
1.80	2.60	1.30	0.3 ± 0.1	0.2
2.00	2.85	1.45	0.3 ± 0.1	0.2
2.50	3.55	1.90	0.3 ± 0.1	0.2
2.65	3.80	2.00	0.3 ± 0.1	0.2
3.00	4.20	2.30	0.6 ± 0.2	0.2
3.55	5.00	2.75	0.6 ± 0.2	0.2
3.70	5.15	2.90	0.6 ± 0.2	0.2
4.00	5.55	3.20	0.6 ± 0.2	0.2
4.30	5.90	3.30	0.6 ± 0.2	0.2
4.50	6.20	3.60	0.6 ± 0.2	0.2
5.00	6.90	4.00	0.6 ± 0.2	0.2
5.30	7.30	4.25	0.6 ± 0.2	0.2
5.50	7.50	4.50	1.0 ± 0.2	0.2
6.00	8.20	4.90	1.0 ± 0.2	0.2
6.50	8.90	5.45	1.0 ± 0.2	0.2
7.00	9.70	5.70	1.0 ± 0.2	0.2
7.50	10.20	6.20	1.0 ± 0.2	0.2
8.00	10.90	6.60	1.0 ± 0.2	0.2
9.00	12.20	7.50	1.0 ± 0.2	0.2
10.00	13.60	8.40	1.0 ± 0.2	0.2
11.00	14.90	9.30	1.0 ± 0.2	0.2
16.00	21.70	13.60	2.0 ± 0.2	0.2

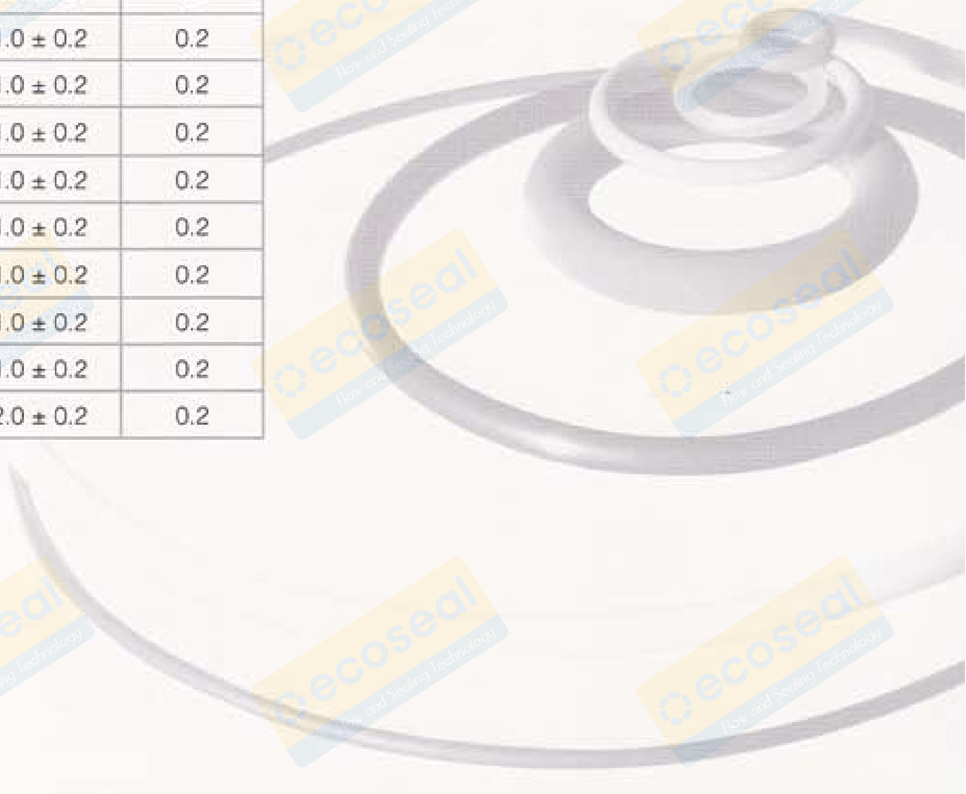
O-ring installation dimensions in an axial flange seal

ⓘNOTE:

Strictly speaking the table values only apply to NBR O-rings with a hardness of 70 Shore A. However, experience shows that they can be used for other materials and hardnesses although the groove depth may need adjusting.

The values are calculated based on a possible swelling of up to 15 %. If the swelling allowed for is less then the groove width can be reduced accordingly.

In axial-static installation the pressure direction should be considered in selecting the O-ring.



Interior diameter
Flange seals

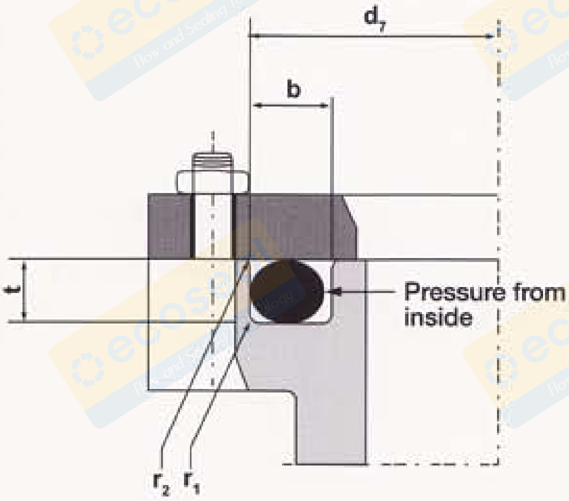
Determining interior diameter given internal pressure

In cases of internal pressure the external diameter of the O-ring (d1 + 2d2) should be approximately 1–3 % greater than the external groove diameter ***d7***. This means that the O-rings are installed slightly compressed and should hence have a similar external diameter to that of the installation space ***d7***.

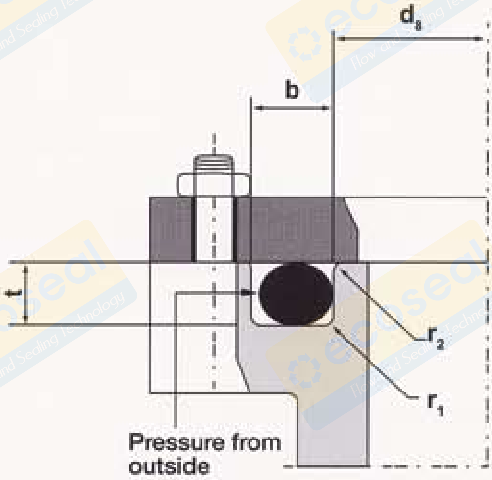
Determining interior diameter given external pressure

In the event of external pressure the interior diameter ***d1*** of the O-ring should be approximately 1–4 % less than the groove internal diameter ***d8***. This means that the O-rings are installed slightly stretched and should hence have a similar external diameter to that of the installation space ***d8***.

ⓘ**IMPORTANT:**
Observe pressure direction!



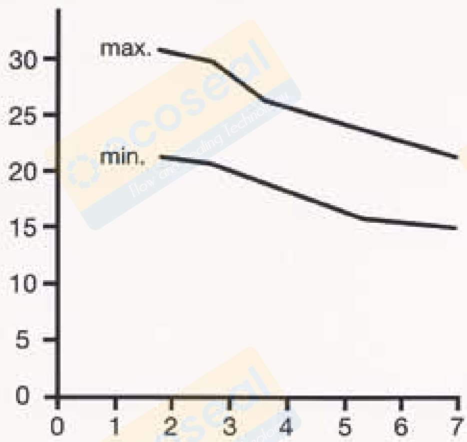
Flange seal – internal pressure



Flange seal – external pressure

The diagram below shows the permissible range of O-ring compression dependant on the cord diameter ***d2***.

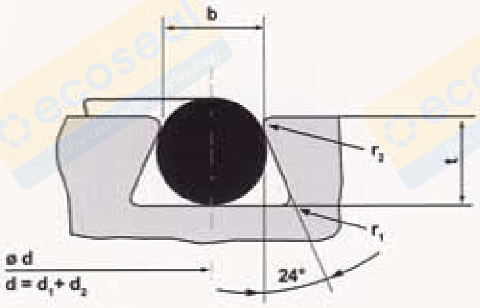
Static seal compression



Trapezoidal groove
Triangular groove

Static seal – trapezoidal groove

This groove shape is desirable if the O-ring has to be held during maintenance, service or starting and stopping tools and machinery. It can also be considered a form of valve seat seal if gasses or fluids e.g. flow in such a way as to create a vacuum pressing the seal out of the groove. Groove processing here is costly and time-consuming. We therefore recommend its use only from a cord thickness of d2 ≥ 2.5 mm.



Picture of a trapezoidal groove

d2	b ± 0.05	t ± 0.05	r2	r1
2.50	2.05	2.00	0.25	0.40
2.62	2.15	2.10	0.25	0.40
3.00	2.40	2.40	0.25	0.40
3.55	2.90	2.90	0.25	0.80
4.00	3.10	3.20	0.25	0.80
5.00	3.90	4.20	0.25	0.80
5.33	4.10	4.60	0.40	0.80
6.00	4.60	5.10	0.40	0.80
7.00	5.60	6.00	0.40	1.60
8.00	6.00	6.90	0.40	1.60

Trapezoidal groove installation dimensions

Seal using a triangular groove

This groove shape is used in flange and cover seals. The O-ring has contact on three sides using this installation space. A defined O-ring contact pressure is not guaranteed, however. There are also problems in manufacture as the tolerances specified are difficult to meet and the seal function not always ensured. The groove offers little space for any swelling of the O-ring.

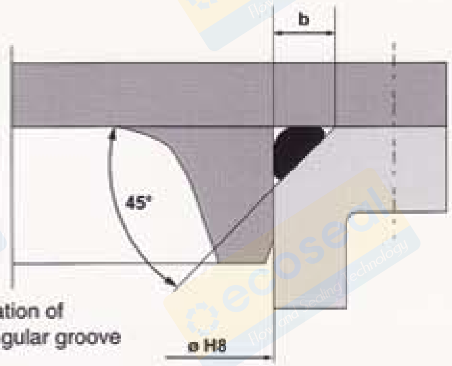


Illustration of a triangular groove

If this groove shape is unavoidable then the dimensions and tolerances in the table that follows should be adhered to. The O-ring cord thickness d2 should exceed 3 mm if at all possible.

d2	b	r
1.80	2.40 +0.10	0.3
2.00	2.70 +0.10	0.4
2.50	3.40 +0.15	0.6
2.62	3.50 +0.15	0.6
3.00	4.00 +0.20	0.6
3.53	4.70 +0.20	0.9
4.00	5.40 +0.20	1.2
5.00	6.70 +0.25	1.2
5.33	7.10 +0.25	1.5
6.00	8.00 +0.30	1.5
7.00	9.40 +0.30	2.0
8.00	10.80 +0.30	2.0
8.40	11.30 +0.30	2.0
10.00	13.60 +0.35	2.5

Triangular groove installation dimensions

ⓘNOTE:

Groove width b in trapezoidal grooves is measured at the edges before deburring. The radius r2 is to be so chosen that the O-ring isn't damaged during installation in the groove and there is no gap extrusion at high pressure.

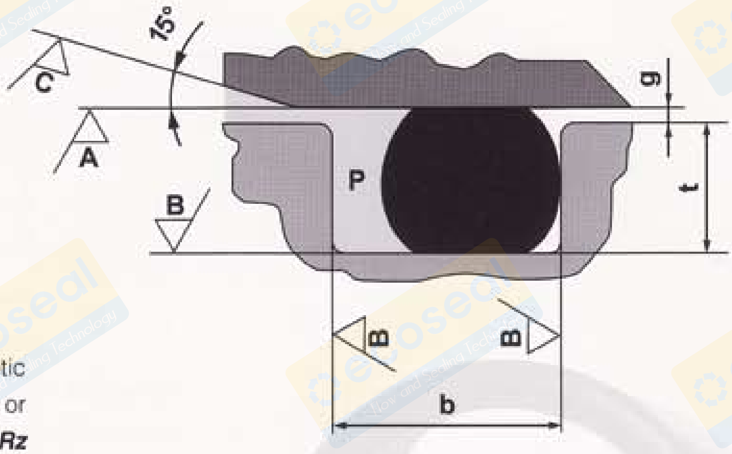
Surface roughness

Surface specifications depend above all on use/s and no generally valid limiting values for roughness can hence be given.

The table below gives values for surface roughness that cover most possible sealing uses. They are only to be considered as recommendations.

Surface	Pressure	Rz (µm)	Ra (µm)
Groove base (B)	Static	6.3	1.6
Groove flanks (B)	Static	6.3	1.6
Seal area (A)	Static	6.3	1.6
Groove base (B)	Dynamic	6.3	1.6
Groove flanks (B)	Dynamic	6.3	1.6
Seal area (A)	Dynamic	1.6	0.4
Installation angle (C	--	16	1.6

Surface roughness values



Installation space design illustration

Explanations

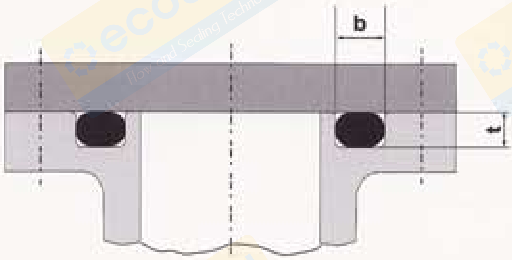
The central roughness value Ra is the arithmetic average of all profile deviation from the centre or reference line. The average roughness depth ***Rz*** is the arithmetic average of the individual roughnesses (profile heights) of five adjacent individual measurement lengths Z1 to Z5.

In specifying surface roughness in sealing technology the characteristic values Ra and Rz are normally used. As these are insufficient by themselves the material proportion of the roughness profile Rmr should also be determined. The material proportion Rmr should be approximately 50 to 70 % measured at a section depth c = 0.25 x Rz, based on a reference line of C0 = 5 %.

Installation space for PTFE O-rings

Installation space design for O-rings of thermoplastic PTFE material is detailed below.

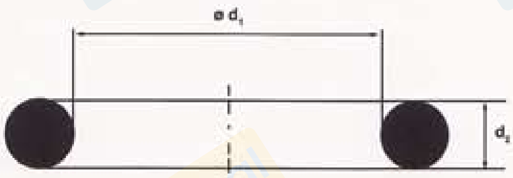
The illustration that follows shows the diagrammatic section of the installation space for static axial installation.



Sectional illustration of an installation space for PTFE O-rings

ⓘNOTE:
PTFE-O-rings have little elasticity. O-ring dimensions are hence to be selected identical with the nominal dimensions to be sealed. Installation ought preferably to be in axially easily accessible grooves.

PTFE O-rings are closed rings of circular cross-section. Dimensions are characterised by the interior diameter ***d1*** and the cord diameter ***d2***. PTFE O-rings are not form-compressed but manufactured under tension and differ in this from elastomer O-rings. They can hence be made in any size.



PTFE O-ring sectional illustration

In the table that follows the names and installation spaces as well as the O-ring are detailed more closely.

Designation	Explanation
d1	O-ring interior diameter
d2	Cord diameter (cord thickness)
b	With of the O-ring instillation space (groove width)
t	Radial depth of the installation space (groove depth)
r1	Radius at the base of the installation space

The table that follows shows a selection of dimensions for groove width ***(b)*** and depth ***(t)*** dependant on cord thickness ***d2***.

d2	b +0.1	t +0.05	r1
1.00	1.20	0.85	0.2
1.50	1.70	1.30	0.2
1.80	2.00	1.60	0.4
2.00	2.20	1.80	0.5
2.50	2.80	2.25	0.5
2.65	2.90	2.35	0.6
3.00	3.30	2.70	0.8
3.55	3.90	3.15	1.0
4.00	4.40	3.60	1.0
5.00	5.50	4.50	1.0
5.30	5.90	4.80	1.2
6.00	6.60	5.60	1.2
7.00	7.70	6.30	1.5
8.00	8.80	7.20	1.5

Installation dimensions for PTFE O-rings

O-ring storage

Lagerung

Seals stored for long periods may change their physical characteristics. Such changes may include hardening, softening, cracking and other forms of surface degeneration. This is due to one or more influences such as deformation, oxygen, light, ozone, heat, damp, oil or solvent. Basic instructions on storage, cleaning and preservation of elastomer seals are laid down in the DIN 7716 and ISO 2230 standards.

ISO 2230 contains advice on storing rubber items. The table below gives the maximums storage periods split into three groups.

Natural rubber base	Maximum storage period	Extension
BR, NR, IR, SBR, AU, EU	5 years	2 years
NBR, XNBR, HNBR, CO, ECO, ACM, CR, IIR, BIIR, CIIR	7 years	3 years
CM, CSM, EPM, EPDM, FPM, VMQ, PVMQ, FVMQ	10 years	5 years

Elastomer storage periods

When storing rubber products certain conditions must be met.

Heat
Storage temperature for elastomers should preferably be in the +5 °C to +25 °C range. Avoid direct contact with heat sources such as radiators or sunlight.

Moisture
Relative humidity should be below 70 % in the storage space. Extremely damp or dry conditions should be avoided.

Light
Elastomer seals should be protected against light when stored. Direct sunlight and strong artificial light with a UV content in particular are to be avoided. We recommend covering windows in storage spaces with red or orange materials.

Oxygen and ozone
If possible elastomers should be packaged or put in airtight containers to protect them against circulating air.

Deformation
Elastomers should be stored in untensioned condition if possible. Large O-rings can be stored coiled to save space.

Surface treatment

„Labs-free" O-rings

Surface treatment

O-rings can be subjected to special surface treatment e.g. to percent adhesion, reduce friction or simplify installation.

Depending on individual case and coating procedure the following benefits may accrue:

- Better separation
- Assembly simplification
- Anti-adhesion effect/s
- Friction reduction
- Silicone and paint cross-linking malfunction freedom
- Improvement in lubrication characteristics
- Stick-slip reduction
- Reduction of breakaway force
- Simplification of automated installation

„Labs-free" O-rings

"Labs-free" O-rings are O-rings free of sub-stances causing paint cross-linking malfunctions. Such O-rings are particularly suited for use in compressed air systems used in painting engineering, above all in the automotive industry. Elastomers may contain substances causing paint cross-linking to malfunction. The causatory substances can be released into the air or by contact by elastomers and then land on the surface/s to be painted and there cause craters on the painted surface/s. The O-rings intended for this use are hence subjected to special treatment to ensure they are free of such substances.

Designation	Type of coating	Coating purpose
PTFE-ME	PTFE transparent	Installation simplification
PTFE-FDA	PTFE milky-white	Mounting aid
PTFE transparent	PTFE transparent	Conditionally dynamic use
PTFE-black	PTFE-black	Dynamic use
PTFE-grey	PTFE-grey	Dynamic use
Polysiloxane	Silicone resin	Mounting aid
Siliconise	Silicone oil	Installation simplification
Talcum powder	Talcum powder	Installation simplification
Molycoting	MoS2 powder	Installation simplification
Graphiting	Graphite powered	Installation simplification

Coating options and their typical uses