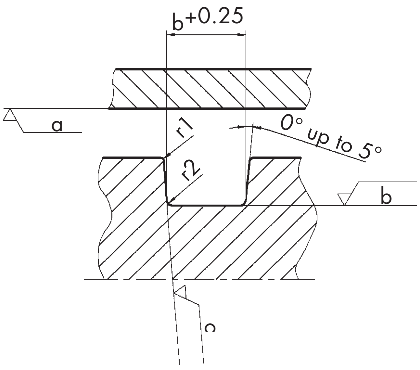
Design guidelines



Once the dimensions and geometric shape of the installation housing have been determined, the following details must be observed for a correct function.

- Any component edges and transition points that come into contact with the O-ring should be burr-free, rounded and polished if necessary.

- The transition point between the groove flank and groove base r2, and the transition between the groove flank and component surface r1, must be slightly rounded.

The radii relating to the cross section are given in the following table:

d2	r1	r2
1 – 2	0.1	0.3
2 – 3	0.2	0.3
3 – 4	0.2	0.5
4 – 5	0.2	0.6
5 – 6	0.2	0.6
6 – 8	0.2	0.8
8 – 10	0.2	1
10 – 12	0.2	1
12 – 15	0.2	1.2

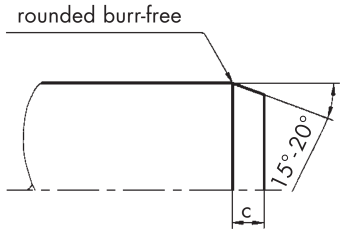
- The surface quality is to be designed for the particular application. For dynamic applications, the surface must be finer than for a static one; the same also applies for pulsating pressures.

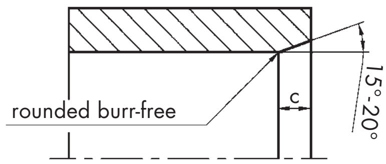
- Avoid marks, holes and scratches on the surface.

- Roughness values are classified to DIN 4768 with various parameters. In many cases, simply stating the average roughness value R_a is not sufficient for classifying the surface quality, and so the average roughness depth R_z, maximum roughness depth R_{max} and the contact area percentage t_p are also quoted. The contact area percentage should be more than 50% if at all possible.

Surface qualities

Type of sealing application	Surface	Pressure	R_a [µm]	R_z [µm]	R_{max} [µm]
dynamic radial	counter surface a		≤ 0.4	≤ 1.2	≤ 1.6
	groove base b		≤ 1.6	≤ 3.2	≤ 6.3
	groove flanks c		≤ 3.2	≤ 6.3	≤ 10
static radial / axial	sealing surface a	not pulsating	≤ 1.6	≤ 6.3	≤ 10
	groove base b		≤ 3.2	≤ 10	≤ 12.5
	groove flanks c		≤ 6.3	≤ 12.5	≤ 16
	sealed surface a	pulsating	≤ 0.8	≤ 1.6	≤ 3.2
	groove base b		≤ 1.6	≤ 3.2	≤ 6.3
	groove flanks c		≤ 3.2	≤ 6.3	≤ 10





Lead-in chamfers

Lead-in chamfers should be used to prevent damage to the O-ring and ensure correct installation.

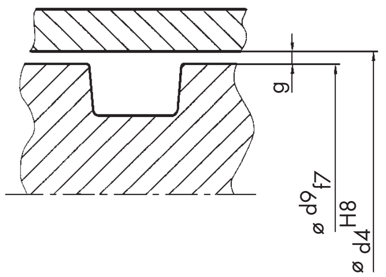
The angles between the lead-in chamfers and the level should be between 15° and 20°. Chamfer lengths C are given in the groove dimension tables.

Sealing gap

The gap that is to be sealed should be as small as possible, so the fits and tolerances shown on installation tables and drawings should be observed.

However, do not forget that working loads, such as those exerted on a cylindrical tube under high pressure, will cause the gap to expand. If the gap is too big, there is a strong risk of gap extrusion. This means that the O-ring migrates into the gap as pressure is applied, where it will soon be destroyed.

In cases of dynamic sealing, the O-ring is destroyed by ripping and peeling. We recommend the use of back-up rings to protect the O-ring against gap extrusion.



Maximum permitted values for radial sealing gap g [mm]

The permitted values for the sealing gap are determined by the pressure, material hardness and diameter.

Type of sealing application	Pressure [bar]	Material hardness [Shore A] 70	80	90
static	≤ 60	0.2	0.25	0.3
	> 60 – 100	0.1	0.2	0.25
	> 100 – 160	0.05	0.1	0.2
	> 160 – 250	–	0.05	0.1
	> 250 – 350	–	–	0.05
dynamic	≤ 30	0.2	0.25	0.3
	> 30 – 60	0.1	0.17	0.2
	> 60 – 80	–	0.1	0.15
	> 80 – 100	–	–	0.1

The gap dimensions given in the chart apply for all elastomer materials with the exception of silicone.

Back-up rings are to be used with bigger gap dimensions.

Layout guidelines

In order to achieve the best possible sealing effect, the chosen O-rings should have the biggest possible cross section.

The hardness of the material destined for the O-ring depends on the pressures, gap widths (tolerances), type of sealing application (static, dynamic), and surface quality of the items being sealed. For standard applications we recommend a material hardness of 70 Shore A. For applications with, for example, pulsating pressures, and especially those under high pressure, we recommend materials of up to 90 Shore A.

Deformation

The sealing effect of the O-ring is provided by radial or axial deformation in the installation housing.

In a static application, the average deformation should be 15 – 30%, in relation to the cross section, in a dynamic (hydraulic) application 10 – 18%, and in a dynamic (pneumatic) application 4 – 12%

Stretching and compression

O-rings can be stretched or compressed to certain limits while being installed without this affecting the sealing function. The installed O-ring should not be stretched by more than 6% (in relation to the inside diameter) as this could lead to an unacceptably large reduction of the cross-sectional area, and also level off the inner sleeve. According to the rules of Guldinus, a 1% expansion of the inside diameter leads to a 0.5% reduction in cross section.

The compression of the O-ring should not exceed 3%, as otherwise the O-ring could distort in the groove.

Calculating the stretching and compression of the O-ring is easy with the following formula:

$$\text{Stretching} = \frac{(d3\text{-}d1)}{d1} \times 100\%$$

$$\text{Compression} = \frac{(da\text{-}d6)}{da} \times 100\%$$

da = (d1 + 2 x d2)
d1 = O-ring inside diameter
d2 = O-ring cross section diameter
d3 = groove base diameter / inside
d6 = groove base diameter / outside

Groove filling

The rectangular cross section surface of the installation groove (except vacuum) should be about 25% bigger than the circular cross section of the O-ring. This means the O-ring has enough space for a possible increase in volume if it comes into contact with an aggressive medium. Also, the medium pressure may affect a large part of the O-ring surface in order to enhance the contact pressure required to achieve the sealing effect. The groove filling level should be 70% to 85%, and is easy to calculate with the following formula:

$$\text{Groove filling level} = \frac{A_{OR}}{A_{Nut}} \times 100\%$$

$$A_{OR} = d_2^2 \times \frac{\pi}{4}$$

$$A_{groove} = t \times b$$

Installation housings and design recommendations

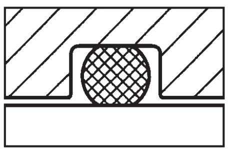
The installation housings (grooves) for O-rings should if possible be produced with right angles. The dimensions for the required depth and width depend on the particular application and cross-section. The dimensions are recommendations for the particular type of installation, and refer to the nominal sizes. They should be observed because the sealing function depends on the precise execution of the grooves.

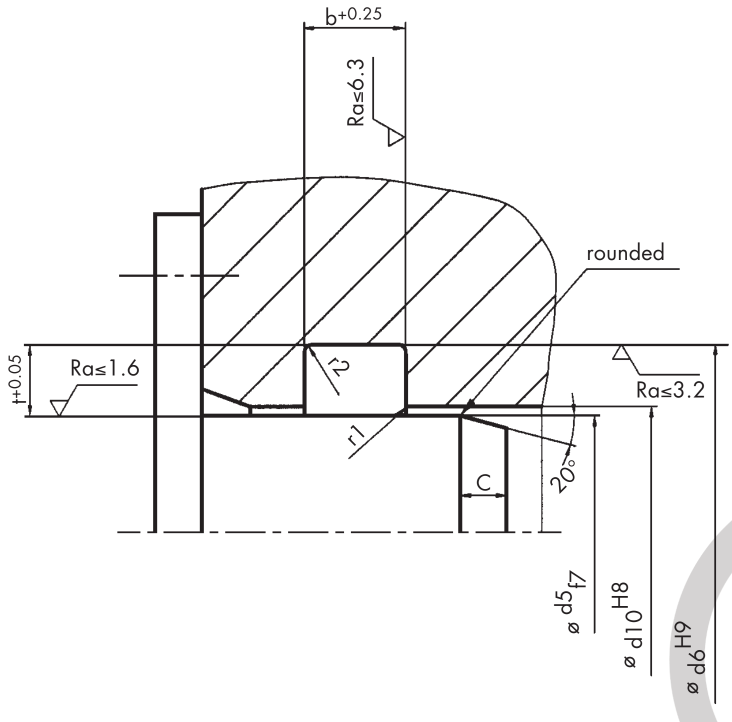
Static sealing

O-rings are ideal for sealing resting machine elements. We speak of a static or resting seal when the machine elements that are to be sealed do not move in relation to each other. If the groove is executed correctly, the items used as intended and the right material chosen, O-rings can seal pressures of up to 1000 bar.
(Back-rings may also be required.)

Rectangular groove by radial deformation
This type of sealing is the preferred choice for sealing pins, bolts, tube connections or cylindrical tubes. The O-ring section is deformed radially on installation, i.e. in the direction of the centre of the bolt/pipe. The position of the groove, whether on the inside or the outside, does not play a functional part on solid components, but depends on the processing and installation possibilities. On thin walled parts where elastic deformation could occur such as with a cylindrical pipe, the groove should be on the fixed outer part (cylinder bottom) so that the groove on the side that is not subject to pressure does not increase as the item opens out.

Static sealing, internal sealing, rectangular groove by radial deformation

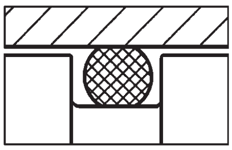


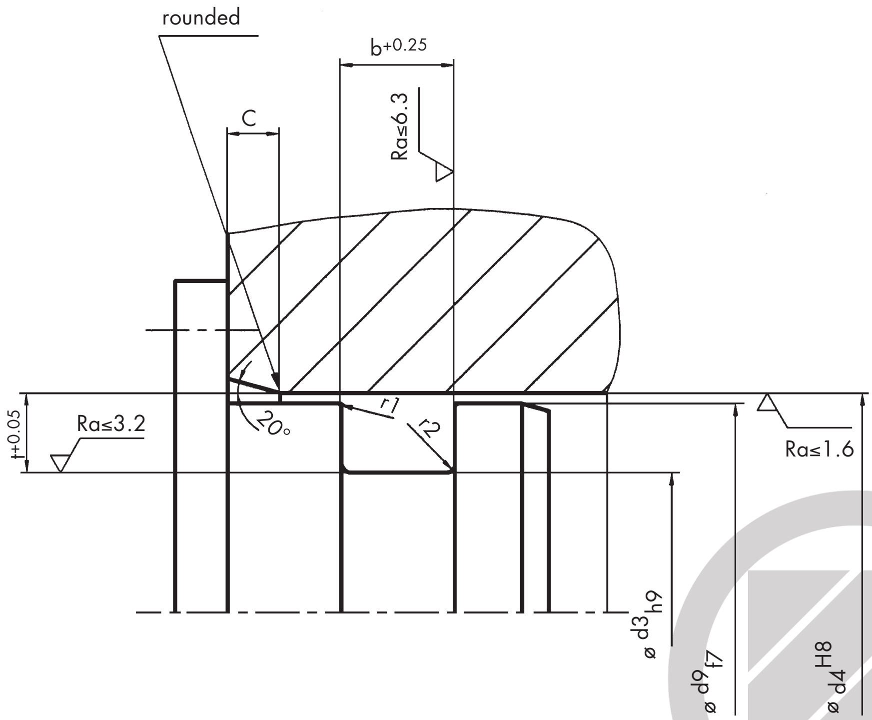


Groove dimensions

d2	Groove depth $t^{+0.05}$	Groove width $b^{+0.25}$	Lead-in chamfer C	d2	Groove depth $t^{+0.05}$	Groove width $b^{+0.25}$	Lead-in chamfer C
1	0.75	1.3	1.2	4	3.2	5.2	3
1.2	0.9	1.6	1.2	4.3	3.4	5.6	3
1.25	0.9	1.7	1.2	4.5	3.6	5.8	3
1.3	1	1.7	1.2	5	4	6.5	3
1.5	1.1	2	1.5	5.3	4.3	7	3
1.6	1.2	2.1	1.5	5.33	4.3	7.1	3.5
1.78	1.3	2.4	1.5	5.5	4.5	7.2	3.5
1.8	1.3	2.4	1.5	5.7	4.6	7.6	3.5
1.9	1.4	2.5	1.5	6	4.9	7.9	3.5
2	1.5	2.6	2	6.5	5.4	8.4	4
2.2	1.7	3	2	6.99	5.8	9.2	4
2.4	1.8	3.2	2	7	5.8	9.3	4
2.5	1.9	3.3	2	7.5	6.3	9.8	4
2.6	2	3.4	2	8	6.7	10.5	4
2.62	2	3.5	2	8.4	7.1	10.9	4.5
2.65	2	3.6	2	8.5	7.2	11	4.5
2.7	2.1	3.6	2	9	7.7	11.7	4.5
2.8	2.2	3.7	2	9.5	8.2	12.3	4.5
3	2.3	3.9	2.5	10	8.6	13	5
3.1	2.4	4	2.5	10.5	9	13.8	5
3.5	2.7	4.6	2.5	11	9.5	14.3	5
3.53	2.7	4.7	2.5	12	10.5	15.6	5
3.55	2.8	4.7	2.5	15	13.2	19.2	5
3.6	2.8	4.8	2.5				
3.7	2.9	4.9	2.5				

Static sealing, external sealing, rectangular groove by radial deformation





Rectangular groove by axial deformation

This type of installation is used primarily for flange and cover sealing. The O-ring cross section is deformed axially.

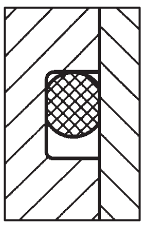
Note that the O-ring should be placed against the non-pressure side of the groove on installation in order to prevent it from moving in the groove when pressure is applied or increases.

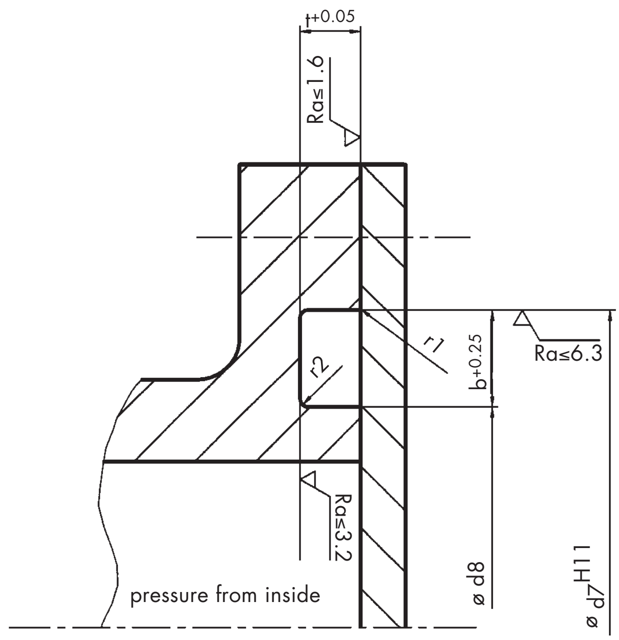
If the O-ring moves in the groove, it will be stretched and compressed, which causes material fatigue and premature wear. Observing the pressure direction will prevent the surface of the O-ring from possibly rolling, and thus being destroyed.

- If pressure is applied from the inside, the outer diameter of the O-ring should be placed against the outer diameter of the groove, or else be up to max. 3% bigger (the O-ring will be compressed).
- If pressure is applied from the outside, the inner diameter of the O-ring should be placed against the inner diameter of the groove or else be up to max. 6% smaller (the O-ring will be stretched).

When the item is intended for axial installation, the cover screwing should be very strongly designed to ensure that the gap between the sealed surfaces never exceeds the permitted size. The pressure could otherwise squeeze out the O-ring.

Static sealing, pressure from inside, rectangular groove by axial deformation

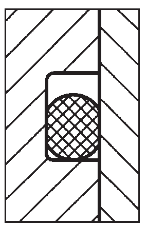


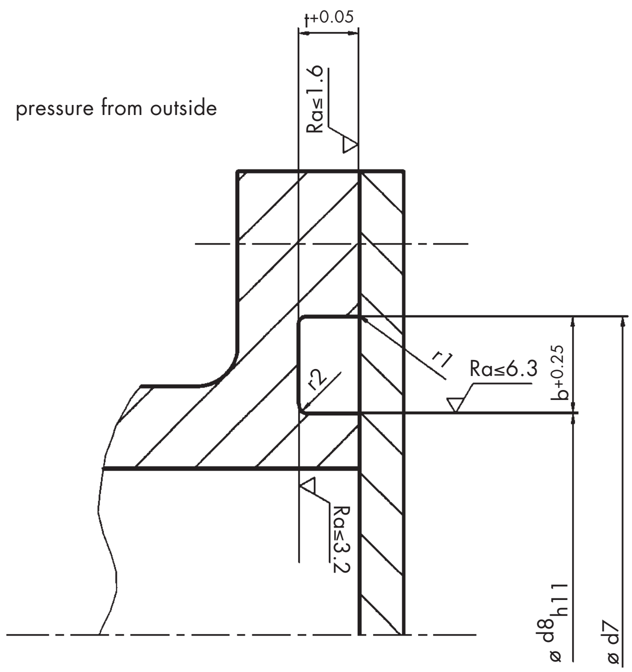


Groove dimensions

d2	Groove depth t+0.05	Groove width b+0.25	d2	Groove depth t+0.05	Groove width b+0.25
1	0.7	1.4	4	3.1	5.5
1.2	0.9	1.6	4.3	3.3	5.9
1.25	0.9	1.7	4.5	3.5	6.1
1.3	1	1.7	5	4	6.7
1.5	1.1	2.1	5.3	4.2	7.2
1.6	1.2	2.2	5.33	4.2	7.3
1.78	1.3	2.5	5.5	4.5	7.4
1.8	1.3	2.6	5.7	4.6	7.6
1.9	1.4	2.7	6	4.8	8.1
2	1.5	2.8	6.5	5.3	8.6
2.2	1.6	3.1	6.99	5.7	9.7
2.4	1.8	3.3	7	5.7	9.7
2.5	1.9	3.5	7.5	6.2	10.1
2.6	2	3.6	8	6.6	10.7
2.62	2	3.7	8.4	7.1	11.1
2.65	2	3.8	8.5	7.2	11.3
2.7	2.1	3.8	9	7.6	12
2.8	2.1	4	9.5	8.1	12.5
3	2.3	4.1	10	8.5	13.6
3.1	2.4	4.2	10.5	8.9	14
3.5	2.7	4.8	11	9.4	14.7
3.53	2.7	4.9	12	10.4	15.7
3.55	2.7	5	15	13.2	19.4
3.6	2.8	5.1			
3.7	2.9	5.2			

Static sealing, pressure from outside, rectangular groove by axial deformation

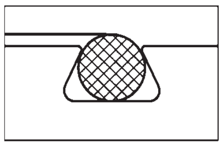


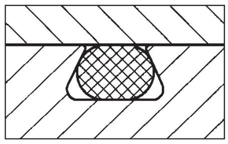


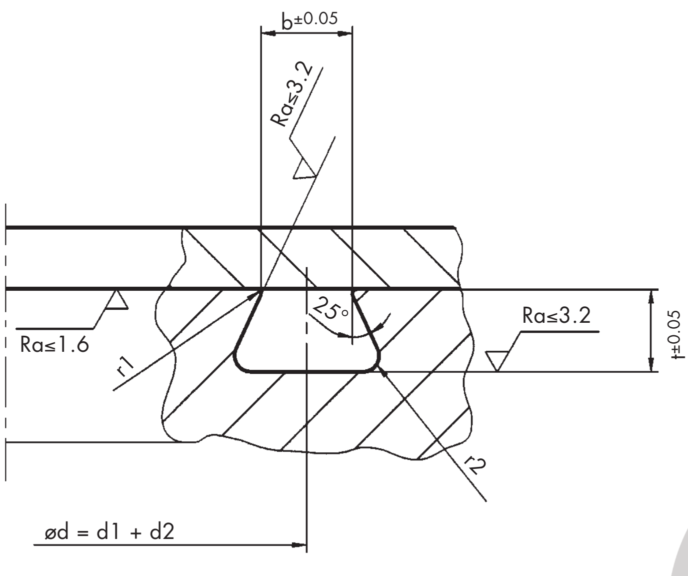
Trapezoidal groove
Trapezoidal grooves are difficult and expensive to manufacture. This groove geometry is only worthwhile if the O-ring needs to be held in the groove during assembly, for the application and removal of compression moulding tools, or for overhead installations.

A trapezoidal groove is really only advisable for cross sections of 2 mm and more. The average groove diameter equates to the inner diameter plus the cord thickness of the O-ring.

Static sealing, trapezoidal groove







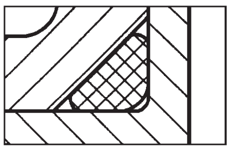
Groove dimensions

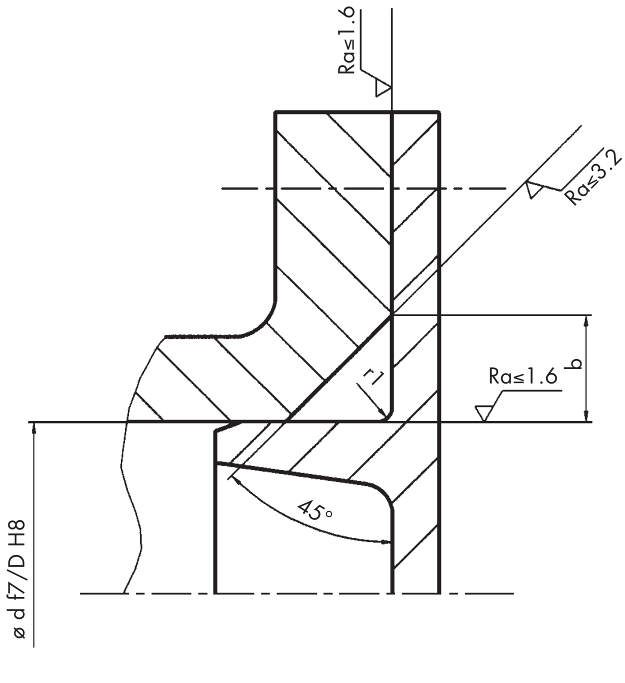
d2	Groove depth t ±0.05	Groove width b ±0.05	r2	r1
2	1.5	1.6	0.4	0.25
2.2	1.6	1.7	0.4	0.25
2.4	1.8	1.9	0.4	0.25
2.5	2	2	0.4	0.25
2.6	2.1	2.1	0.4	0.25
2.62	2.1	2.1	0.4	0.25
2.65	2.1	2.1	0.4	0.25
2.7	2.2	2.1	0.4	0.25
2.8	2.3	2.2	0.4	0.25
3	2.4	2.4	0.4	0.25
3.1	2.5	2.5	0.4	0.25
3.5	2.8	2.9	0.8	0.25
3.53	2.8	2.9	0.8	0.25
3.55	2.8	2.9	0.8	0.25
3.6	2.9	3	0.8	0.25
3.7	3	3.1	0.8	0.25
4	3.2	3.3	0.8	0.25
4.3	3.3	3.6	0.8	0.25
4.5	3.7	3.7	0.8	0.25
5	4.2	4	0.8	0.25
5.3	4.6	4.2	0.8	0.4
5.33	4.6	4.2	0.8	0.4
5.5	4.7	4.4	0.8	0.4
5.7	4.9	4.5	0.8	0.4
6	5.1	4.7	0.8	0.4
6.5	5.6	5.1	0.8	0.4
6.99	6	5.6	1.6	0.4
7	6	5.6	1.6	0.4
7.5	6.4	6.1	1.6	0.4
8	6.9	6.3	1.6	0.4
8.4	7.3	6.7	1.6	0.5
8.5	7.4	6.8	1.6	0.5
9	7.8	7.2	1.6	0.5
9.5	8.2	7.7	1.6	0.5
10	8.7	8	1.6	0.5

Conical groove

In individual cases involving screwed flange and cover sealing design, requirements may call for a conical groove. However, with this particular groove geometry it can be difficult to ensure a defined deformation of the O-ring. Furthermore, the restricted space of a conical groove can be disadvantageous if the surrounding media then cause the O-ring to swell.

Static sealing, conical groove





Groove dimensions

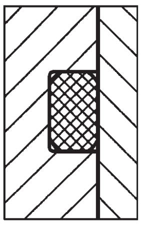
d2	Side length b	Tolerance (+)	r1
1	1.45	0.1	0.25
1.2	1.7	0.1	0.25
1.25	1.75	0.1	0.25
1.3	1.8	0.1	0.3
1.5	2.1	0.1	0.3
1.6	2.15	0.1	0.3
1.78	2.4	0.1	0.3
1.8	2.45	0.1	0.3
1.9	2.6	0.1	0.4
2	2.75	0.1	0.4
2.2	3	0.1	0.4
2.4	3.25	0.15	0.4
2.5	3.4	0.15	0.5
2.6	3.55	0.15	0.5
2.62	3.6	0.15	0.5
2.65	3.6	0.15	0.5
2.7	3.7	0.15	0.6
2.8	3.8	0.15	0.6
3	4.1	0.2	0.6
3.1	4.25	0.2	0.6
3.5	4.8	0.2	0.8
3.53	4.8	0.2	0.8
3.55	4.85	0.2	0.8
3.6	4.9	0.2	0.9
3.7	5.05	0.2	0.9
4	5.5	0.2	1.2
4.3	5.9	0.2	1.2
4.5	6.15	0.2	1.2
5	6.85	0.25	1.2
5.3	7.25	0.25	1.4
5.33	7.3	0.25	1.4
5.5	7.55	0.25	1.5
5.7	7.8	0.25	1.5
6	8.2	0.3	1.5
6.5	8.9	0.3	1.7
6.99	9.6	0.3	2
7	9.6	0.3	2
7.5	10.3	0.3	2
8	11	0.4	2
8.4	11.55	0.4	2
8.5	11.7	0.4	2
9	12.4	0.4	2.5
9.5	13.05	0.4	2.5
10	13.7	0.4	2.5
10.5	14.4	0.4	2.5
10	15.1	0.4	2.5
12	16.5	0.5	3
15	20.6	0.5	3

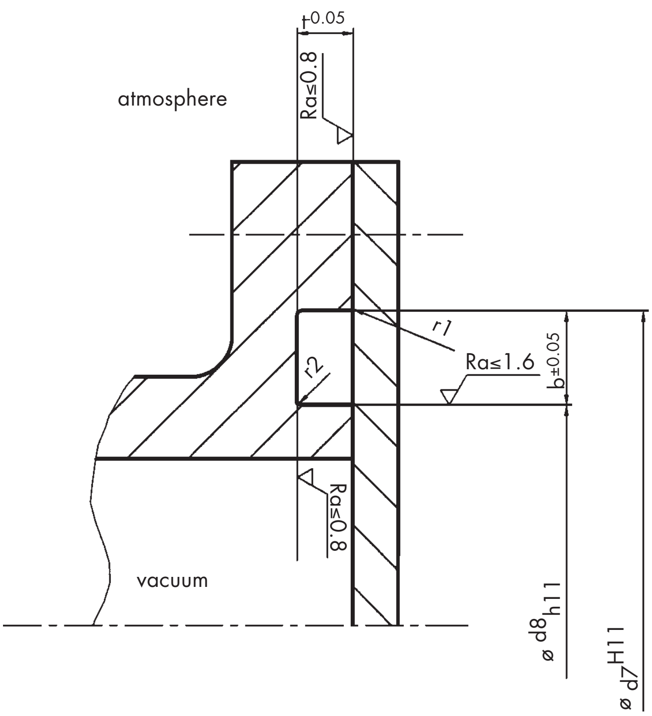
Vacuum sealing
Vacuum sealing is a special kind of static O-ring sealing. In this type, the system pressure that is to be sealed is less than the atmospheric pressure (p_{atm}= 1.01325 bar).

Contrary to the general installation guidelines for static O-ring sealing, the following recommendations apply for vacuum sealing:

- The groove should be almost 100% filled by the deformed O-ring. This creates greater contact surfaces and increases the diffusion time through the elastomer material.
- The deformation of the O-ring section should be about 30%.
- A vacuum grease should be used (reduces leakage).
- The surface quality (roughness depth) of the groove and sealed surfaces should be considerably better than of standard static sealing, and the percentage contact area should be t_p > 50%.
- The chosen elastomer should be gas compatible, have low permeability and a low compression set. We recommend fluoro rubber for standard applications.

Static sealing, vacuum sealing





Groove dimensions

d2	Groove depth $t^{-0.05}$	Groove width $b^{\pm 0.05}$	r1	r2
1.5	1.05	1.8	0.1	0.2
1.78	1.25	2.1	0.1	0.2
1.8	1.25	2.1	0.1	0.2
2	1.4	2.3	0.1	0.3
2.5	1.75	2.9	0.1	0.3
2.6	1.8	3	0.1	0.4
2.62	1.85	3.1	0.1	0.4
2.65	1.85	3.1	0.1	0.4
2.7	1.9	3.15	0.1	0.4
2.8	1.95	3.2	0.1	0.4
3	2.1	3.5	0.1	0.6
3.1	2.2	3.6	0.1	0.6
3.5	2.45	4.1	0.2	0.6
3.53	2.5	4.1	0.2	0.6
3.55	2.5	4.15	0.2	0.6
3.6	2.5	4.2	0.2	0.6
3.7	2.6	4.3	0.2	0.6
4	2.8	4.7	0.2	0.6
4.5	3.15	5.3	0.2	0.8
5	3.5	5.9	0.2	0.8
5.3	3.7	6.3	0.2	1
5.33	3.7	6.3	0.2	1
5.5	3.8	6.6	0.2	1
5.7	4	6.7	0.2	1
6	4.2	7.1	0.2	1
6.5	4.6	7.6	0.2	1
6.99	4.9	8.2	0.3	1
7	4.9	8.2	0.3	1
7.5	5.3	8.7	0.3	1
8	5.6	9.4	0.3	1
8.4	5.9	9.9	0.3	1
8.5	6	10	0.3	1
9	6.4	10.5	0.3	1
9.5	6.7	11.2	0.3	1
10	7.1	11.7	0.3	1

Dynamic sealing

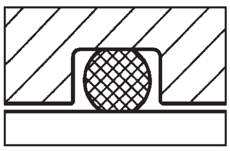
O-rings are used successfully as sealing elements in dynamic applications. However, their use is limited to lower pressures and speeds, or to use in small installation housings.

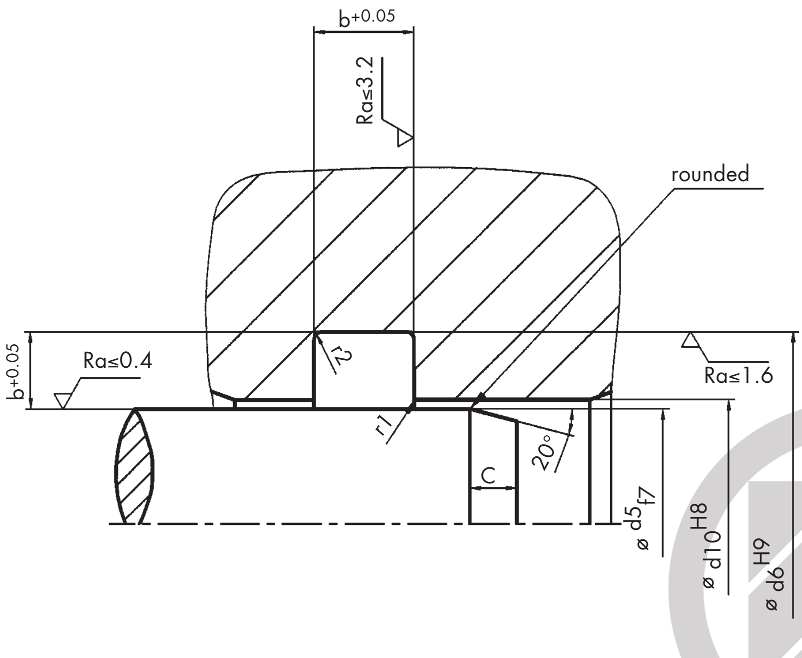
Because of the friction resistance in movement, e.g. in hydraulic or pneumatic components, a smaller O-ring deformation is chosen than for static sealing. The item should always be well lubricated in order to prevent a loss of power due to friction and premature wear of the O-ring if it runs dry.

The installation housings are the same for the reciprocating movement, and for the movement with simultaneous rotating (helical) movement. There are differences between the housings of hydraulic and pneumatic applications, because of the differences in pressure and lubrication.

Hydraulics
O-rings should only be used to seal hydraulic pistons and rods if there is little space for the installation, or if the rod stroke is relatively short with a low frequency, and the seal does not have to be completely leak-proof. In fact, a tiny amount of leakage is desirable as it provides a lubricant film that reduces friction and wear.

Dynamic sealing, internal sealing, rectangular groove by radial deformation



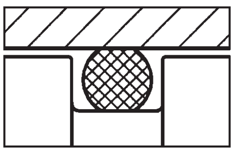


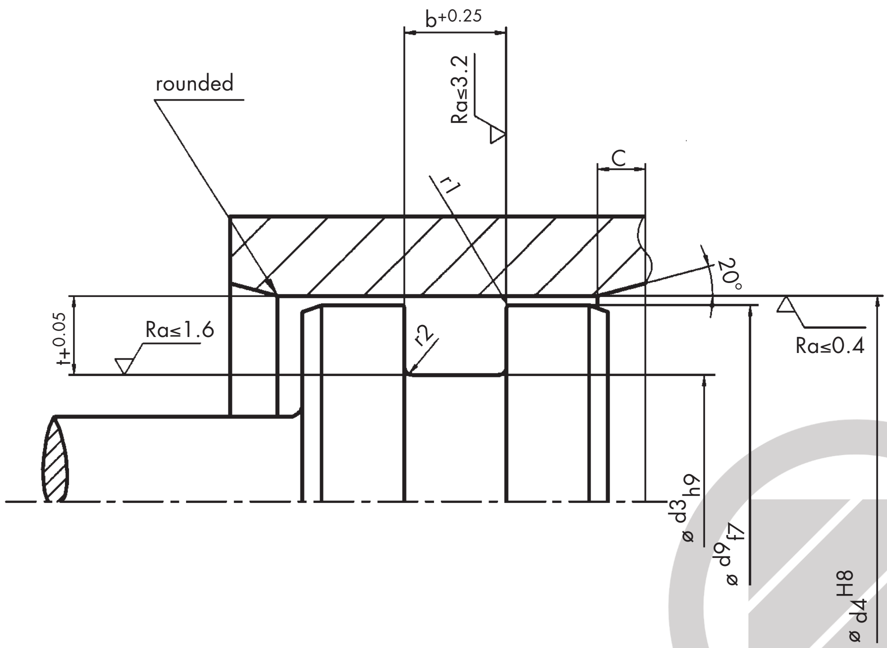
Groove dimensions

d2	Groove depth $t^{+0.05}$	Groove width $b^{+0.25}$	Lead-in chamfer C
1	0.9	1.3	1
1.2	1	1.6	1
1.25	1.1	1.6	1
1.3	1.1	1.7	1.2
1.5	1.3	1.9	1.2
1.6	1.4	2	1.2
1.78	1.5	2.3	1.3
1.8	1.5	2.4	1.3
1.9	1.6	2.5	1.3
2	1.7	2.6	1.3
2.2	1.9	2.8	1.3
2.4	2.1	3	1.4
2.5	2.2	3.1	1.4
2.6	2.2	3.3	1.5
2.62	2.2	3.4	1.5
2.65	2.3	3.4	1.5
2.7	2.4	3.4	1.5
2.8	2.4	3.6	1.6
3	2.6	3.8	1.8
3.1	2.7	3.9	1.8
3.5	3.1	4.4	2
3.53	3.1	4.5	2
3.55	3.1	4.5	2
3.6	3.1	4.6	2

d2	Groove depth $t^{+0.05}$	Groove width $b^{+0.25}$	Lead-in chamfer C
3.7	3.2	4.8	2
4	3.5	5.1	2
4.3	3.8	5.5	2.5
4.5	4	5.7	2.5
5	4.4	6.4	2.7
5.3	4.7	6.8	2.9
5.33	4.7	6.9	2.9
5.5	4.9	7.1	3
5.7	5.1	7.2	3
6	5.4	7.5	3.6
6.5	5.8	8.1	3.6
6.99	6.2	8.8	3.6
7	6.2	8.9	3.6
7.5	6.7	9.4	3.8
8	7.1	10.2	4
8.4	7.5	10.6	4.2
8.5	7.6	10.8	4.2
9	8.1	11.4	4.5
9.5	8.5	12	4.5
10	9	12.6	4.5
10.5	9.5	13.2	5
11	9.9	13.9	5
12	10.9	15.1	5
15	13.7	18.8	5

Dynamic sealing, external sealing, rectangular groove by radial deformation

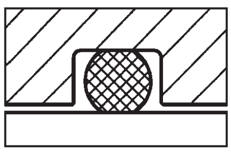


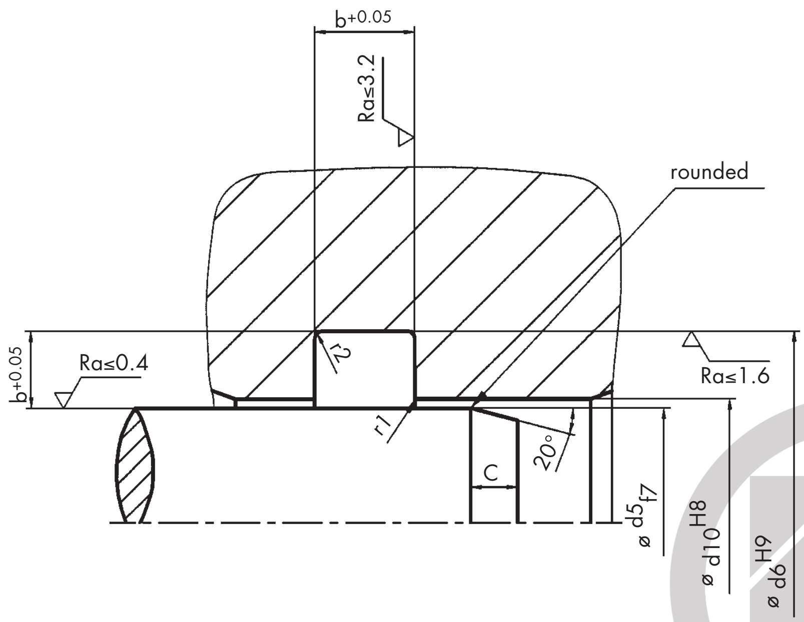


Pneumatics

In pneumatics, O-rings are used primarily to seal reciprocating movements. The deformation of the O-ring should be less than in hydraulic applications in order to keep the loss of power due to friction down, even with inadequate lubrication, in order to achieve the maximum possible lifetimes.

Dynamic sealing, internal sealing, rectangular groove by radial deformation





Groove dimensions

d2	Groove depth $t^{+0.05}$	Groove width $b^{+0.25}$	Lead-in chamfer C	d2	Groove depth $t^{+0.05}$	Groove width $b^{+0.25}$	Lead-in chamfer C
1	0.95	1.2	0.9	4	3.7	4.8	2
1.2	1.05	1.5	1	4.3	4	5.1	2
1.25	1.15	1.5	1	4.5	4.2	5.4	2.3
1.3	1.15	1.6	1.1	5	4.65	5.9	2.3
1.5	1.35	1.8	1.1	5.3	4.95	6.4	2.7
1.6	1.45	1.9	1.2	5.33	4.95	6.4	2.7
1.78	1.55	2.2	1.2	5.5	5.15	6.5	2.8
1.8	1.55	2.3	1.2	5.7	5.35	6.8	3
1.9	1.7	2.3	1.2	6	5.6	7.2	3.1
2	1.8	2.4	1.2	6.5	6.1	7.8	3.3
2.2	2	2.6	1.4	6.99	6.55	8.4	3.6
2.4	2.15	2.9	1.4	7	6.6	8.4	3.6
2.5	2.25	3	1.4	7.5	7.1	8.9	3.8
2.6	2.35	3.1	1.4	8	7.6	9.5	4
2.62	2.35	3.1	1.5	8.4	7.9	10.1	4.2
2.65	2.35	3.2	1.5	8.5	8	10.2	4.2
2.7	2.45	3.3	1.5	9	8.5	10.8	4.3
2.8	2.55	3.4	1.5	9.5	9	11.4	4.3
3	2.7	3.6	1.5	10	9.5	12	4.5
3.1	2.8	3.7	1.5				
3.5	3.15	4.2	1.8				
3.53	3.2	4.3	1.8				
3.55	3.2	4.3	1.8				
3.6	3.3	4.3	1.8				
3.7	3.4	4.4	1.8				

Dynamic sealing, external sealing, rectangular groove by radial deformation