2 - MATERIALS USED

2.1 - Armatures

Standard material : sheet steel of XE quality (AFNOR standard A 36 401)
Special outer rings can be produced using other materials for special applications.

2.2 - Springs

Standard : Stabilised XC 70 steel
On request : Z10 CN 18-09 stainless steel (AFNOR standard A 35 586).

NOTA : All the PAULSTRA range of fluorinated elastomer seals fluorocarbon (FKM) are equiped with stainless steel springs.

2.3 - Elastomers

	Mixes	Symbols	*Temperature range
STANDARD MIXES	**NITRILE (acrylo-nitrile butadiene)** This material is particularly resistant to the action of mineral oils and grease. Suitable in most other cases.	NBR	- 30°C to + 110°C
STANDARD MIXES	**FLUOROCARBON ELASTOMER** This elastomer has the best chemical and heat resistant characteristics. The new fluorocarbon formula offers very low abrasion and : - low shaft and lip wear. - resistance to ageing.	FKM	- 20°C to + 200°C

*** Temperatures on samples**

3 - THE SELECTION OF A SEAL FOR A ROTATING SHAFT*

3.1 - The type of fluid to be sealed

The fluids in contact with each face of the seal can be gases or liquids which are more or less viscous even pasty (in the case of greases). They must not have too aggressive actions on the materials which make up the seal (the outer ring, spring and elastomer).

3.1.1 - Armature and spring

The armature and spring of standard seals are steel, so they have a good resistance to all the chemical solvents which are currently used in industry with the exception of water and aqueous liquids which can cause rust and corrosion.
For any other kind of material, please consult our technical services.

3.1.2 - Elastomer

Chemical resistance
The standard seals made from a nitrile elastomer based mix have been designed to resist most current lubricating oils.
For more aggressive fluids, a formula based on fluorinated elastomer fluorocarbon (FKM) would be more appropriate.

FLUIDS	ELASTOMERS	
	Nitrile (NBR)	Fluoro-carbon elastomer (FKM)
Acetone	D	D
Acetic acid	A	D
10 % Hydrochloric acid	A	A
Concentrated Hydrochloric acid	D	A
20 % Nitric acid	D	A
10 % Sulphuric acid	A	A
Concentrated Sulphuric acid	D	A
Atmospheric air at 100 °C	C	A
Atmospheric air at 200 °C	D	A
Concentrated Ethyl alcohol	A	B
Methyl alcohol	A	B
Propyl alcohol	A	B
Ammonia	C	A
Benzene	D	B
Butter	A	A
Butane	A	A
Petrol	A	A
Super petrol	C	A
Chlorine	B	A
Cyclohexane	B	A
Water	A	A
Sewage	A	B
Concentrated Eau de Javel	C	A
Sea water	A	A
Freon	C	C
Freon 12	B	B
Carbonic gas	A	A
Smoke	C	A
Diesel oil	A	A
Diesel oil at 100 °C	C	A
Glycerine	A	A
Cereal oils	A	A
ASTM1 oil at 100 °C	A	A
ASTM1 oil at 150 °C	D	A
ASTM2 oil at 100 °C	A	A
ASTM2 oil at 150 °C	D	A

FLUIDS	ELASTOMERS	
	Nitrile (NBR)	Fluoro-carbon elastomer (FKM)
	A	A
ASTM3 oil at 100 °C	D	A
ASTM3 oil at 150 °C	A	A
Gear oil at 100 °C	D	A
Gear oil at 130 °C	A	A
EP hypoid oil at 100 °C	D	A
EP hypoid oil at 130 °C	A	A
ATF oil at 100 °C	D	A
ATF oil at 150 °C	A	A
Mineral motor oil at 100 °C	D	A
Mineral motor oil at 150 °C	A	A
Synthetic motor oil at 100 °C	D	A
Synthetic motor oil at 150 °C	A	A
Silicone oil		
	A	A
Isooctane fuel (Fuel A)	B	A
Isooctane-toluene (Fuel B)		
	A	A
Kerosene JP 1		
	A	A
Milk	B	B
Antifreeze (water + glycol)	D	C
Brake fluid (Lockheed)	D	D
Brake fluid (Lockheed) at 50 °C		
Ozone	D	A
Paraffin	A	A
Propane	A	A
Saline aluminium solutions	A	A
Magnesium salt solutions	A	A
Sodium chloride solutions	A	A
Soda	C	A
Toluene		
Trichlorethylene	C	A
	D	A

A: Good chemical resistance B: Average performance
C: Acceptable (depending on conditions of use) D: Unsuitable
* For rotating housing applications please consult us.

Mechanical resistance

The new brown colored fluorocarbon (FKM) formula presents a very low abrasivity and :
- low shaft and lip wear;
- resistance to ageing.

Heat resistance

For good performance an elastomeric seal must be used within its operating temperature range. The standard elastomeric mix is not only sensitive to high temperatures which harden it causing cracks and fissures, but also to intense cold which makes it hard and hardens it. The temperature which must be considered is that at the contact lip. It must be borne in mind that this gets much hotter than the ambient fluid, due to friction. For example, the temperature of the lip of a seal which seals the motor oil of a crankcase, where the shaft is rotating at high velocity (more than 8 m/s), can increase by about fifty degrees after a few minutes of service, whereas the oil, even next to the seal, will only warm up by a few degrees in the same period. The temperature displayed by a thermometer dipped into the crankcase oil is not therefore a determining factor.

In addition to the shaft speed, which is the most important factor, other parameters influence the heating of the lip such as the condition of the shaft surface, the tightness of the seal, the ventilation of the crankcase, and so on, so that it is very difficult to know the temperature of the lip in continuous operation.

The temperatures indicated in the table below are only valid if the fluid being sealed is not degraded at these temperatures.

Where high temperatures exceed the values shown in the table below, use seals in fluorinated elastomer.

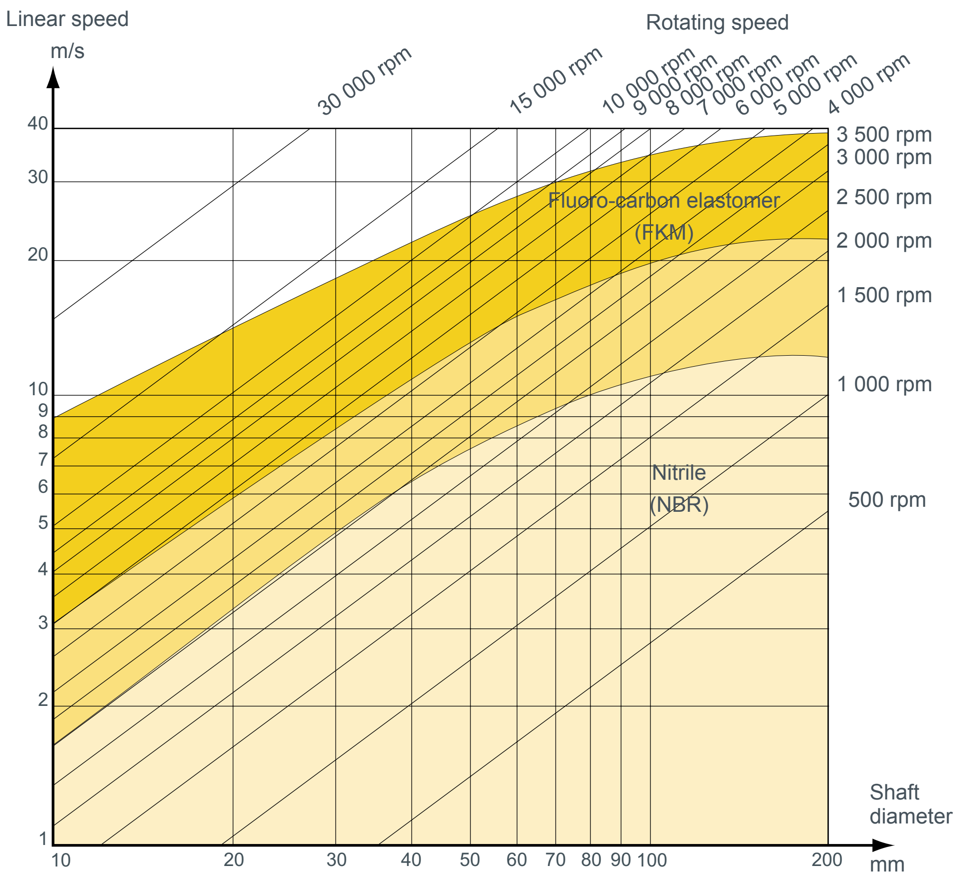
Our technical services are at your disposal to reply to your questions about the properties of various mixes.

		Nitrile (NBR)		Fluoro-carbon elastomer (FKM)	
	Low temperature in °C (1)	- 40		- 30	
	Temperature in °C	Av. (2)	Max (3)	Av. (2)	Max (3)
Products to be sealed					
Mineral oil based	Motor oils	100	120	150	175
	Gear box oils	90	110	130	150
	Hypoid gear oils	90	110	130	150
	ATF oils	100	120	150	175
	Hydraulic oils	100	120	150	175
	EL and L diesel oils	90	100	+	
	Greases	100	120	150	175
Hydraulic liquids hard to ignite	HSB oil/water emulsion	80	100	-	
	HSC aqueous solution	80	100	-	
	HSD non-aqueous solution	--		130	150
Other products	Water	80	100	+	
	Detergents	80	100	+	
	Brake fluid	--		--	

(1) Temperature at which the seal continues to function.
(2) Average operating temperature.
(3) Maximum permissible temperature for not more than 10 hours over the life of the seal.
\+ Resistant. but normally not used.
\- Resistant. under certain conditions.
-- Does not resist.

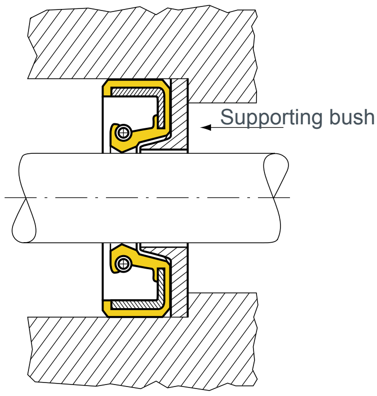
3.2 - Shaft speed

The graph below gives an indication of the rotary or linear velocity of the shaft in relation to various elastomers which are permissible under normal conditions of use.



3.3 - Pressure

The effective pressure to which a seal is submitted is the difference between the pressures of the fluids on each of its two sides (one of which is often the atmosphere). It is clear that the sealing lip should be found on the side which has the higher pressure. In theory, the lip seal for rotary shafts is not a pressure seal.
However, most PAULSTRA seals will resist pressures of the order of 0.5 bars without special precautions if the velocities do not exceed 3 m/s. At higher pressures, there is a risk that the lip may be turned back on itself or pressed onto the shaft with a force which gives rise to an unacceptable tightness and frictional torque. At low velocities most PAULSTRA seals will bear pressures of up to 3 or 4 bars with the addition of a supporting bush. This is not provided by PAULSTRA but it can be made up by the customer according to PAULSTRA's drawings.
The effective pressure is not necessarily constant. If the variations are slow and remain within the limits above. this is not a big problem. On the other hand, if they pulsate rapidly they can interfere with the performance of the seal.



You are advised to consult our technical services for any application which involves an effective pressure greater than 0.5 bars or a pulsating pressure.

4 - CONDITIONS FOR GOOD OPERATION

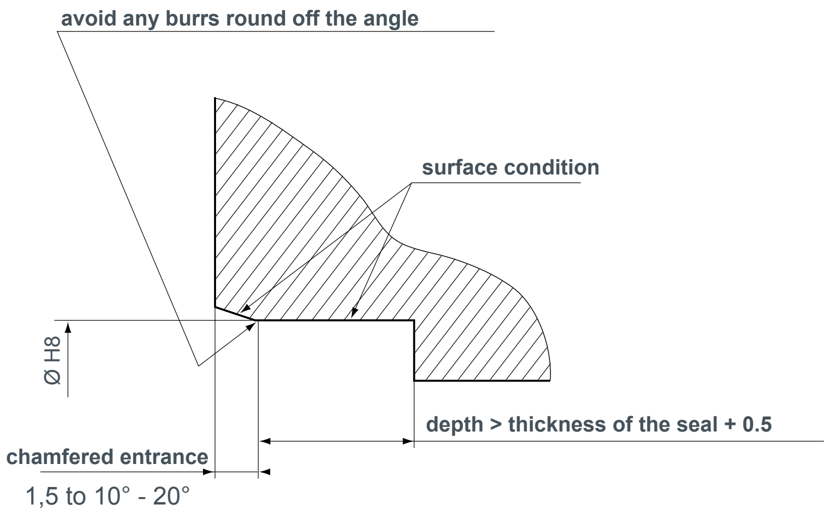
4.1 - The housing

It is extremely important that there be no sharp edges.

Our recommendations are shown on the figure below :

Recommended shape of the housing :

- for a covered seal :	R = 4 to 12,5 μ Ra = 1,6 to 4 μ
- for an external outer ring :	R = 3 to 8 μ Ra = 1,2 to 2,5 μ



Note : if the housing is made of a material with a high coefficient of expansion, this must be taken into consideration when defining the interference (tightness) with the seal.

The lack of a chamfer or too small a chamfer can cause :

- a deterioration of the exterior of the seals (cutting of the elastomer or stripping of the sealing lacquer);
- a big increase in the force of insertion which could cause deformation of the outer ring;
- a defective axial positioning.

A surface with a very rough finish can cause the same problems and can therefore also be the reason for a leak. On the other hand, if the finish is too smooth the extraction force may be too low.

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4.2 - The shaft

The PAULSTRA recommendations are as follows :

- **Tolerance on the diameter :** h 11.

- **Surface state :** R = 0.4 to 1.2 ED (so Ra ≃0.2 to 0.5).

- **Hardness** : if V ≤ 4 m/s : 45 HRC minimum (say 455 HV or 155 kg/mm2).
if V > 4 m/s : 55 HRC minimum (say 625 HV or 195 kg/mm2).

- **Thickness of the treated zone** : 0.3 mm minimum.

- **Circularity** : 5 microns.

- **Neutrality** : All machined surfaces have grooves from the machining process. If these grooves are inclined in relation to the axis of the shaft, they form a helix which will produce a hydrodynamic action.

The bearing surfaces of a seal must be neutral (i.e. there must be no orientation of the machining grooves).

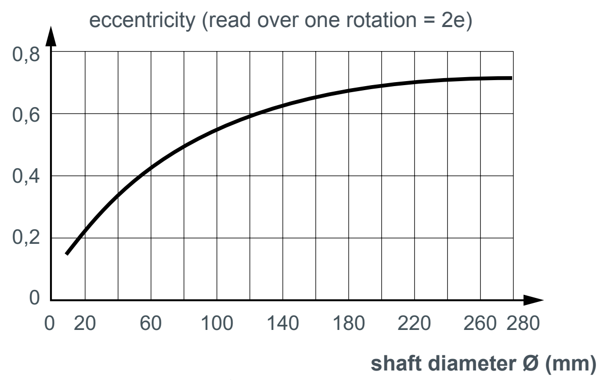
It is possible to orient the machine grooves deliberately to produce pumping from the exterior to the interior of the mechanism. However, **we advise against this as there will be increased wear of the seal.**

Hard chroming is also not to be recommended, unless it is of sufficient thickness and quality.

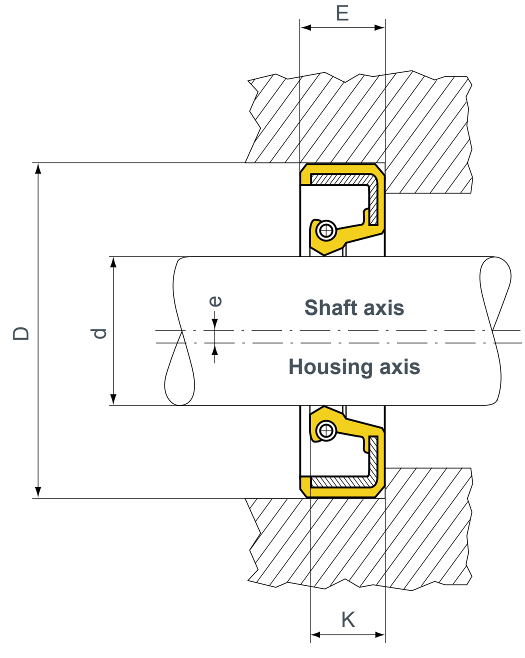
4.3 - Eccentricity between the housing and the shaft

The housing and the shaft should be centred on one another as precisely as possible. If there is a radial displacement between the axis of the seal and the axis of the shaft, the suppleness of the rubber lip enables assembly without "yawning" within certain limits.
The eccentricity is the distance between the axis of the seal housing and the axis of the shaft, the two axes being parallel to each other.

The curve below shows the maximum permitted eccentricities as a function of the shaft diameter.

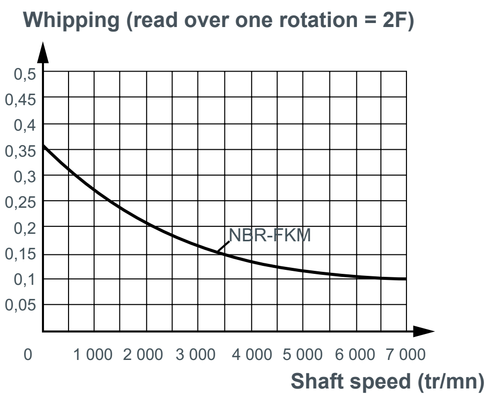


eccentricity = f (Ø)

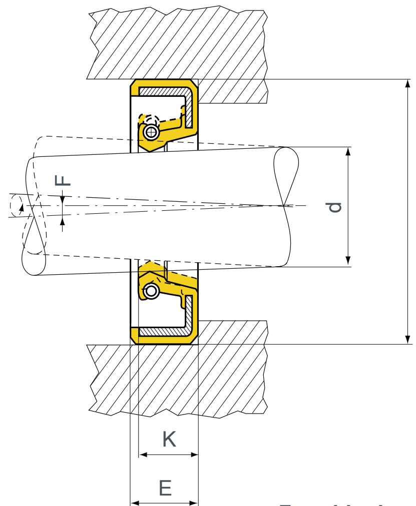


4.4 - Whipping and out of true

This phenomenon occurs when the geometric axis of the shaft does not coincide exactly with the rotational axis. This can be the result, for example, of a worn bearing or the bending of the shaft. The amplitude of whipping increases with distance from a bearing. so the seal should be placed as near as possible to the bearings. Whipping is measured in mm by the radius of the circle described by a point on the axis of the shaft which is in the same plane as the lip.
The curve below shows the maximum whipping permissible as a function of the rotational velocity of the shaft.



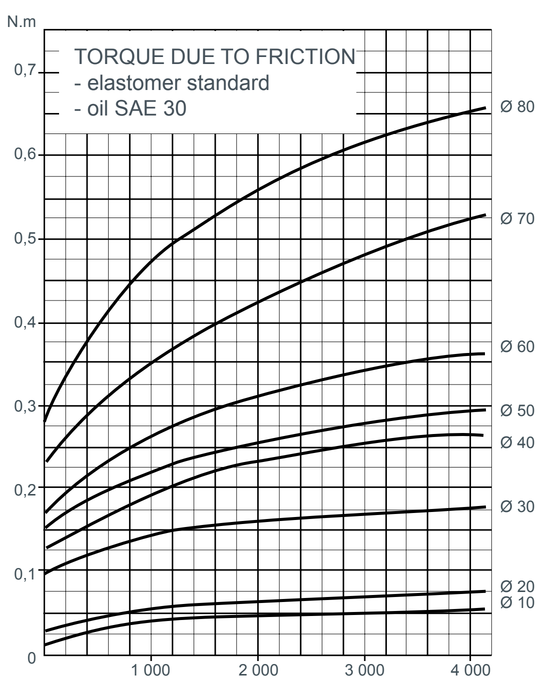
Whipping = f (V)

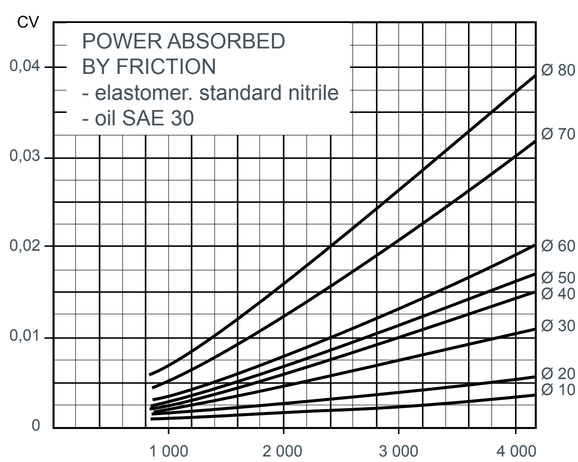


F = whipping

4.5 - Power absorbed due friction

Due to it's design, a lip seal produces friction which will provide some resistance to the rotation of the shaft. For a chosen speed, the resisting torque is function of : the shape of the seal, the friction coefficient and other environment factors such as (materials. tightness of the seal on the shaft, roughness of the shaft, wear, lubrication, temperature ...).





The curves above gives a first indication for the standard Nitrile elastomer. They were plotted under average working conditions using a standard seal with little wear and a lubricated shaft with good surface finish and running temperature of less than 100 °C.

5 - THE ASSEMBLY OF SEALS

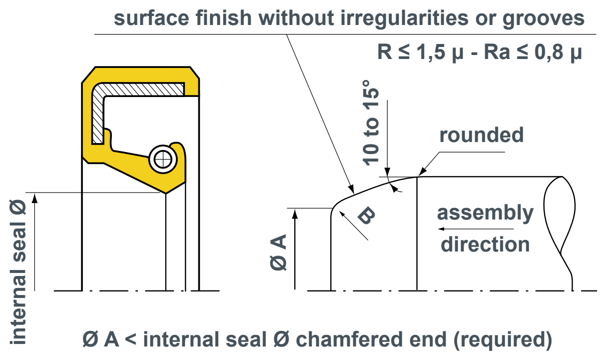
The assembly of seals is a very delicate operation which can ruin the efficiency of a very good product if it is not done properly.
The assembly of a seal must be done in accordance with the following rules :

- avoid damage to the lip;
- avoid damage to the cover of the external diameter;
- lubricate the sealing ridge to avoid damage at the first start-up;
- position the seal correctly :
  - misalignment (the seal must be perpendicular in relation to the axis);
  - axial position.

The information given below should help constructors to put these rules into practice.

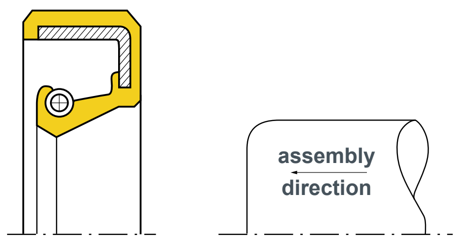
5.1 - Assembly on a shaft without splines

fitting against the lip



Ø A < internal seal Ø chamfered end (required)

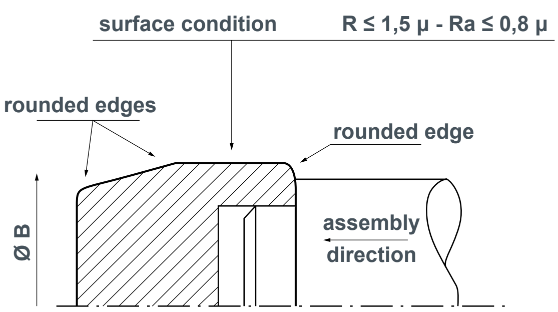
fitting with the lip



rounded or chamfered end
(sharp edges removed)

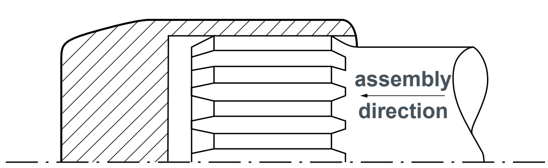
5.2 - Assembly on a shaft with splines or a shoulder

assembly tool for shouldered shaft



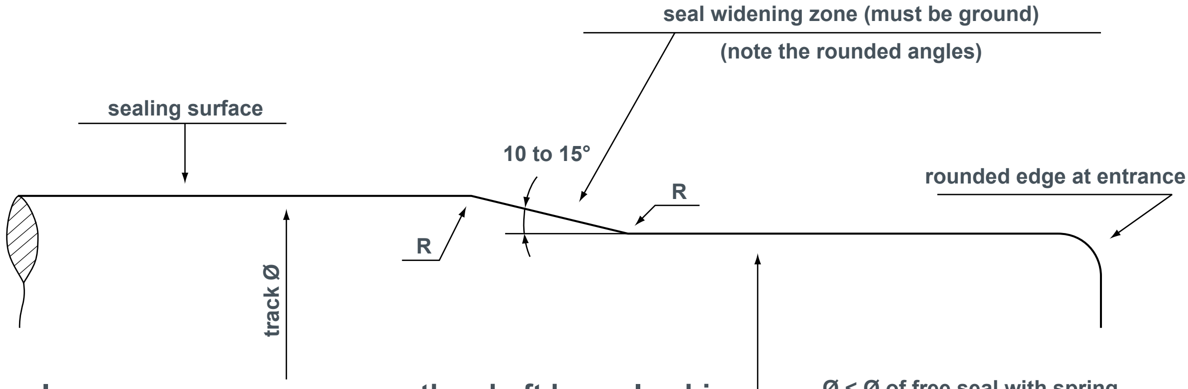
Ø B = Ø nominal shaft + 0,2

assembly tool for splined shaft



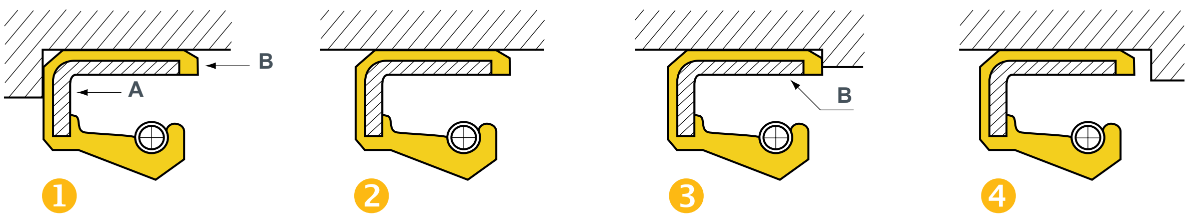
The use of these assembly tools is helpful. However, we recommend the use of a lead-in on the shaft whenever possible.

5.3 - Paulstra recommendations for the shape of the shaft



Mounting sleeves are unnecessary as the shaft has a lead-in

5.4 - Axial positionning and alignement



1. The seal is mounted against a stop on the rear side. This presents no particular problem provided that pressure is applied at "A" to insert it and not "B".

2. Here there is no axial stop. The mounting tool positions the seal both axially and perpendicularly.

3. The seal is mounted against a stop on the front side. This should be avoided as the elastomer at B could be compressed and the seal will tend to move out of position.

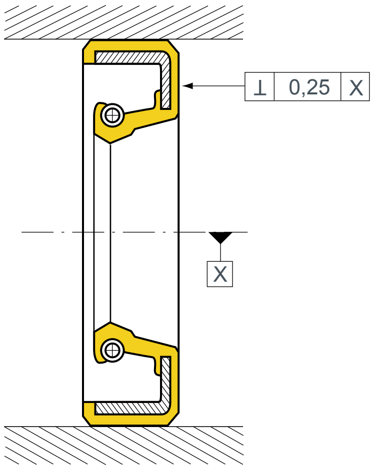
4. The housing has a shoulder as in 3, but the seal is positioned by the mounting tool. This case joint is preferable to case 3.

   The mounting tool should be designed to position the seal correctly both axially and perpendicularly but its shape should be such as to allow deformation of the elastomer covering the outer ring towards the rear, thus avoiding cutting the covering at the time of insertion. In some cases, the bead "C" does not get cut off and sticks between the housing and the assembly mandrel in which case it is impossible to locate the seal. When the seals have an anti-dust lip, care should be taken that the mounting tools do not turn it back on itself.

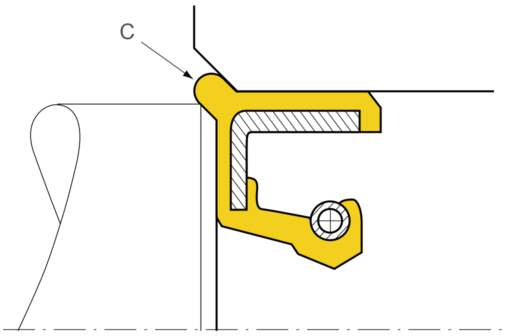
While it is true that modern seal design (corrugations on the outside, pre-centred shape chamfers without burrs, etc.) tends to reduce problems during assembly, the comments made are still worth noting.
Also, the elastomer part of a semi-covered seal behaves in the same way as a fully covered seal.

- Time should be allowed during assembly to allow in order to allow the elastomer time to settle.
- The seal must be held in position for a few seconds once mounted to avoid too large a return movement.

We recommend the following :
- V = 1200 mm/mn (maximum : 1500 mm/mn).
- time held in position: 5 seconds (minimum 2 seconds).

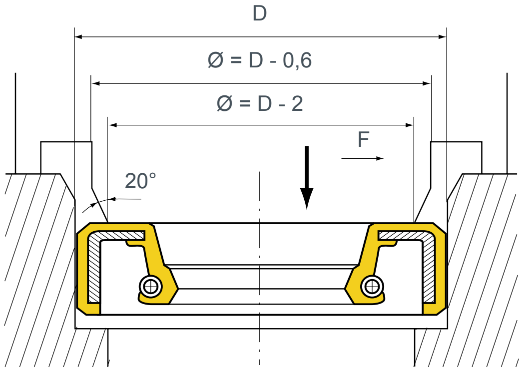


Perpendicular tolerance

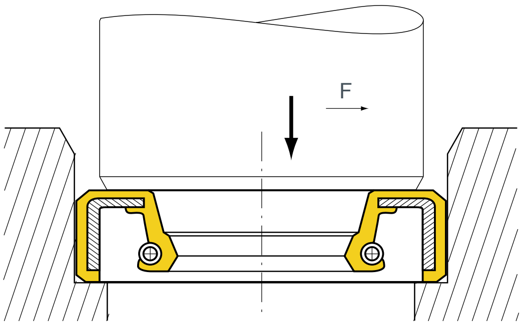


Formation of the bead

5.5 - Recommendations for the assembly tool



GOOD



TO BE AVOIDED

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5.6 - Lubrication during assembly

While the first means of avoiding damage to the outside of the seal is to pay attention to the housing characteristics, the second means, which is just as important, is lubrication :
- be it of the housing;
- or the outside of the seals;
- or both at the same time.

This not only avoids damage to the seal but also ensures a better axial positioning.
A seal whose outside diameter is not lubricated will certainly be damaged on the outside when it is mounted in a dry housing (elastomer cover cut or ripped sealing lacquer removed).
Also, when the unit is started up, the oil will always take some time before it reaches the lip of the seal (from a few seconds to a few tenths of seconds depending to the application).
If it is the first start, and if the lip has not been lubricated at assembly, it will function “dry” dynamically which will lead to great wear and the risk of total deterioration.
It is therefore essential to lubricate the sealing ridge.
For later starts, the problem is different because a film of oil will be retained under the lip by capillarity action.

5.7 - Reminder of the main principles of assembly

- **Protect the lip and the outside of the seal by paying attention to the recommendations for the Shaft and the housing.**
- **Apply the insertion force to the rigid part of the outer ring.**
- **Centre the seal correctly in relation to the housing and/or the shaft.**
- **Lubricate the outside diameter and/or the housing.**
- **Lubricate the sealing ridge.**

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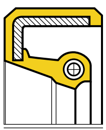
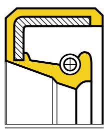
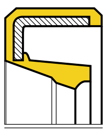
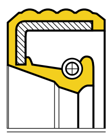
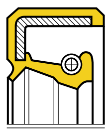
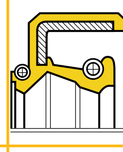
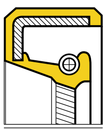
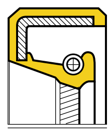
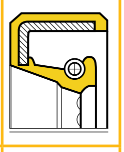
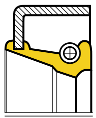
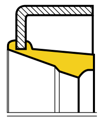
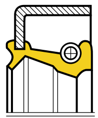
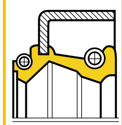
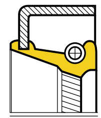
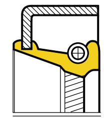
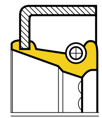
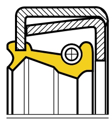
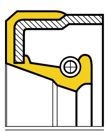
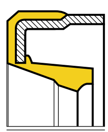
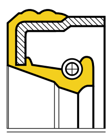
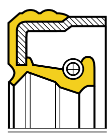
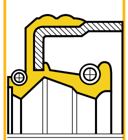
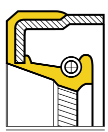
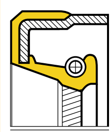
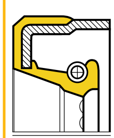
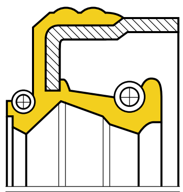
6 - CLASSIFICATION OF THE MAIN PROFILES OF LIP SEALS

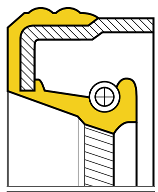
	SPRING			CORRUGATED COVER (W)	ANTI-DUST LIP		RIDGES		
	embedded (I)	visible (E)	none (O)		WITHOUT SPRING (L)	WITH SPRING (R)	on the left (G)	to the right (D)	bi-direct. (V)
I Covered outer ring	II 	**IE** 	IO 	IEW 	**IEL** 	IELR 	IEG 	IED 	IEV 
E Bare outer ring	-	EE 	EO 	-	EEL 	EELR 	EEG 	EED 	EEV 
CS Bare outer ring reinforced	-	-	-	-	CSEL 	-	-	-	-
M Semico-vered outer ring	-	ME 	MO 	MEW 	MEWL 	MEWLR 	MEG 	MED 	MEV 

Note : other cases are available
X = exterior lip
S = special cross-section
P = protector

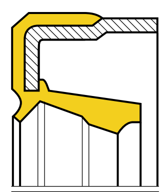
CLASSIFICATION EXAMPLE



MEWLR



MEWG



MOWL

M	Semi-covered	**M**	Semi-covered	**M**	Semi-covered
E	Spring visible	**E**	Spring visible	**O**	No spring
W	With corrugations	**W**	With corrugations	**W**	With corrugations
LR	Anti-dust lip with spring	**G**	Ridges to the left	**L**	Anti-dust lip