Sealing arrangements

Whatever the bearing arrangement, it consists not only of the bearings but includes associated components. Besides shafts and housings these associated components include the sealing, the performance of which is vital to the cleanliness of the lubricant and the overall service life of the bearing arrangement. For the designer, this means that bearing and sealing arrangement should be viewed as an integrated system and should be treated as such.

Where seals for rolling bearings are concerned, a distinction is made between seals that are integral with the bearing and those that are positioned outside the bearing and are separate from it. Sealed bearings are generally used for arrangements where a sufficiently effective external seal cannot be provided because there is inadequate space or for cost reasons.

Types of seals

The purpose of a seal is to prevent any contaminants from entering into a controlled environment. External seals must be able to prevent media from passing between a stationary and rotating surface, e.g. a housing and shaft. Integral bearing seals must be able to keep contaminants out and lubricant in the bearing cavity.

To be effective, the seal should be sufficiently capable of deformation to be able to compensate for any surface irregularities but also be strong enough to withstand operating pressures. The materials from which the seal is made should also be able to withstand a wide range of operating temperatures, and have appropriate chemical resistance.

There are several seal types; for example, DIN 3750 distinguishes between the following basic types:

- seals in contact with stationary surfaces,
- seals in contact with sliding surfaces,
- non-contact seals,
- bellows and membranes.

The seals in contact with stationary surfaces are known as static seals and their effectiveness depends on the radial or axial deforma-

Fig 42

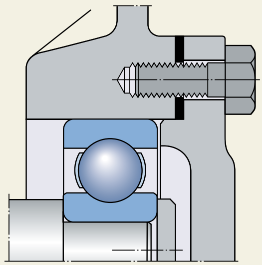


Fig 43

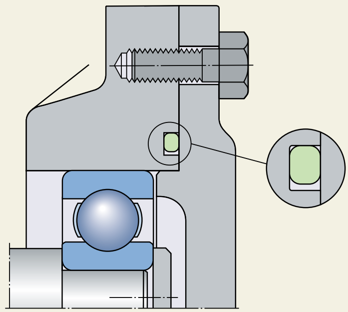
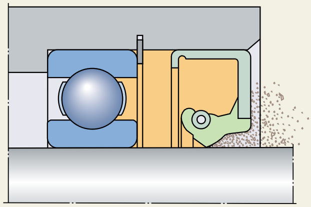


Fig 44



tion of their cross section when installed. Gaskets (➔ **fig** 42) and O-rings (➔ **fig** 43) are typical examples of static seals.

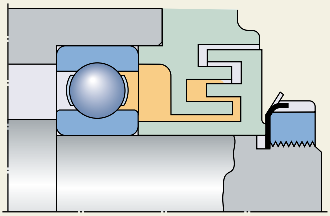
Seals in contact with sliding surfaces are called dynamic seals and are used to seal passages between machine components that move relative to each other either linearly or in the circumferential direction. These dynamic seals have to retain lubricant, exclude contaminants, separate different media and withstand differential pressures. There are various types of dynamic seals, including packing and piston seal rings, which are used for linear or oscillating movements. However, the most common seal is the radial shaft seal (➔ **fig** 44), which is used in a wide variety of applications in all branches of industry.

Non-contact radial shaft seals function by virtue of the sealing effect of a narrow, relatively long gap, which can be arranged axially, radially or in combination. Non-contact seals, which range from simple gap-type seals to multi-stage labyrinths (➔ **fig** 45) are practically without friction and do not wear.

Bellows and membranes are used to seal components that have limited movement relative to each other.

Because of the importance of dynamic radial seals for the efficient sealing of bearing arrangements, the following information deals almost exclusively with radial seals, their various designs and executions.

Fig 45



Selection of seal type

Seals for bearing arrangements should provide a minimum amount of friction and wear while providing maximum protection even under the most arduous conditions. Because bearing performance and service life are so closely tied to the effectiveness of the seal, the influence of contaminants on bearing life is a key design factor. For more information on the influence of contamination on bearing performance, please refer to the section "Selection of bearing size", starting on **page 49**.

Many factors have to be considered when selecting the most suitable seal type for a particular bearing arrangement:

- the lubricant type: oil or grease,
- the peripheral (circumferential) speed at the sealing surface,
- the shaft arrangement: horizontal or vertical,
- possible shaft misalignment,
- available space,
- seal friction and the resulting temperature increase,
- environmental influences, and
- justifiable cost

Selecting the correct seal is of vital importance to the performance of a bearing. It is therefore necessary to accurately specify the sealing requirements and to accurately define the external conditions.

Where full application details are available, reference can be made to the SKF publications:

- Catalogue "CR seals",
- Handbook "Sealing arrangement design guide" or
- "SKF Interactive Engineering Catalogue" on CD-ROM or online at www.skf.com.

If little or no experience is available for a given application, SKF, also one of the largest seal manufacturers in the world, can assist in the selection process or make proposals for suitable seals.

Two types of external sealing devices are normally used with rolling bearings: contact and non-contact seals. The type chosen depends on the needs of the application.

Non-contact seals

The effectiveness of an external non-contact seal depends in principle on the sealing action of the narrow gap between the rotating and stationary components. The gap may be arranged radially, axially or in combination (➔ **fig** 46). These seals can be as simple as a gap-type seal or more complex like a labyrinth seal. In either case, because there is no contact, these seals generate virtually no friction and do not wear. They are generally not easily damaged by solid contaminants and are particularly suitable for high speeds and high temperatures. To enhance their sealing efficiency grease can be pressed into the gap(s) formed by the labyrinth.

Contact seals

The effectiveness of a contact seal depends on the seal's ability to exert a minimum pressure on its counterface by a relatively narrow sealing lip or surface. This pressure (➔ **fig** 47) may be produced either by

- the resilience of the seal, resulting from the elastic properties of the seal material. (**a**)
- the designed interference between the seal and its counterface (**b**) or
- a tangential force exerted by a garter spring incorporated in the seal (**c**).

Contact seals are generally very reliable, particularly when wear is kept to a minimum by producing an appropriate surface finish for the counterface and by lubricating the seal lip/counterface contact area. The friction of the seal on its counterface and the rise in temperature that this generates are a disadvantage and contact seals are therefore only useful for operation up to certain peripheral speeds depending mainly on the seal type and counterface roughness. They are also susceptible to mechanical damage, e.g. as a result of improper mounting, or by solid contaminants. To prevent damage by solid contaminants it is customary to place a non-contact seal in front of a contact seal in order to protect it.

Fig 46

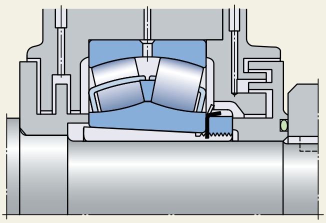
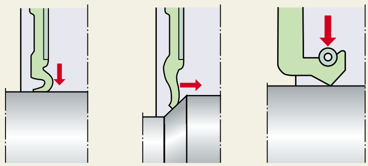


Fig 47



a b c

Integral bearing seals

SKF supplies several bearing types fitted with shields or contact seals on one or both sides. These provide an economic and space-saving solution to many sealing problems. Bearings with shields or seals on both sides are supplied already greased and are generally maintenance-free. Actual seal designs are described in detail in the introductory text to the relevant bearing table sections.

Bearings with shields

Bearings fitted with shields (➔ **fig** 48), are used for arrangements where contamination is not heavy and where there is no danger of water, steam etc. coming into contact with the bearing. Shields are also used in applications where reduced friction is important due to speed or operating temperature considerations.

Shields are made from sheet steel and form

- a long sealing gap with the land of the inner ring shoulder (**a**) or
- an efficient labyrinth seal with a recess in the inner ring shoulder (**b**).

Bearings with contact seals

Bearings with contact seals, referred to simply as seals are preferred for arrangements were contamination is moderate and where the presence of moisture or water spray etc. cannot be ruled out, or where a long service life without maintenance is required.

SKF has developed a series of seals (➔ **fig** 49). Depending on the bearing type and/or size the bearings may be equipped with standard seals which seal against

- the inner ring shoulder (**a**) and/or against a recess in the inner ring shoulder (**b**, **c**), or
- the lead-in at the sides of the inner ring raceway (**d**, **e**) or the outer ring (**f**).

Fig 48

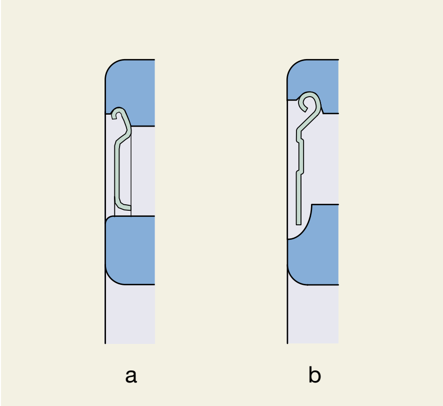
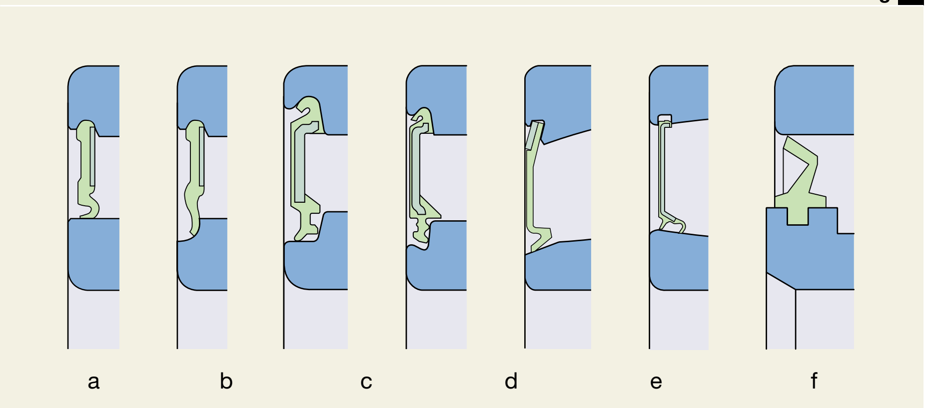


Fig 49



For deep groove ball bearings SKF has developed two additional seal types (➔ **fig 50**), referred to as

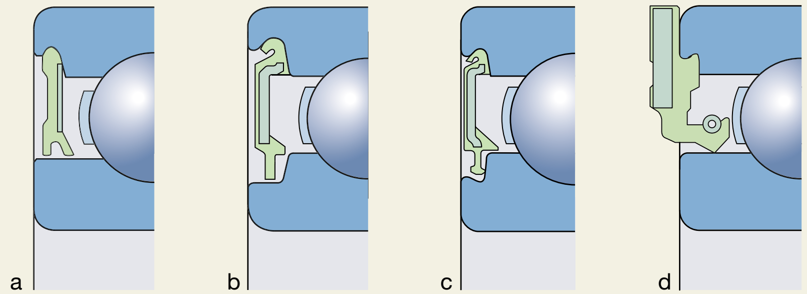
- the low-friction seal (**a**, **b**, **c**), which is practically without contact and fulfils high demands on sealing and the low-friction operation of the bearing.
- the spring-loaded radial shaft Waveseal® (**d**), which is incorporated on one side and together with the bearing, form the ICOS™ oil sealed bearing unit.

Seals integrated in SKF bearings are generally made of elastomer materials and reinforced by sheet steel. Depending on the series, size and the application requirements, the seals are generally produced from

- acrylonitrile butadiene rubber (NBR)
- hydrogenated acrylonitrile butadiene rubber (HNBR)
- fluoro rubber (FPM)

The selection of the appropriate seal material depends on the expected operating temperature and the applied lubricant. Concerning the permissible operating temperatures, please refer to section “Seal materials”, starting on **page 142**.

Fig **50**



External seals

For bearing arrangements where the efficiency of the seal under the given operating conditions is more important than space considerations or cost, there are several possible seal types to choose from.

The seals offered by SKF are given special attention in the following section. Many ready-to-mount external seals are available commercially. For seals that are not part of the SKF range, the information provided in the following section is to be used as a guideline only. SKF takes no responsibility for the performance of these non-SKF products. Be sure to check with the seal manufacturer before designing any seal into an application.

Non-contact seals

The simplest seal used outside the bearing is the gap-type seal, which creates a small gap between the shaft and housing (➔ **fig** 51). This type of seal is adequate for grease lubricated applications that operate in dry, dust-free environments. To enhance the efficiency of this seal, one or more concentric grooves can be machined in the housing bore at the shaft exit (➔ **fig** 52). The grease emerging through the gap fills the grooves and helps to prevent the entry of contaminants.

With oil lubrication and horizontal shafts, helical grooves – right-hand or left-hand depending on the direction of rotation of the shaft – can be provided in the shaft or housing bore (➔ **fig** 53). These serve to return emerging oil to the bearing position. It is essential here that the direction of shaft rotation does not change.

Fig 51

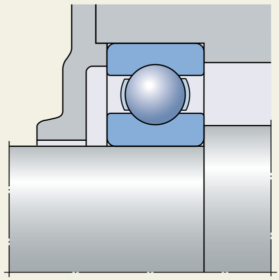


Fig 52

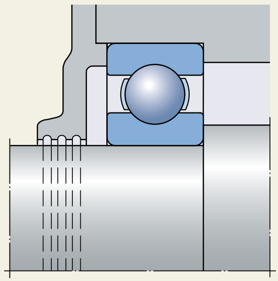


Fig 53

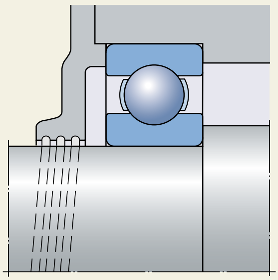


Fig 54

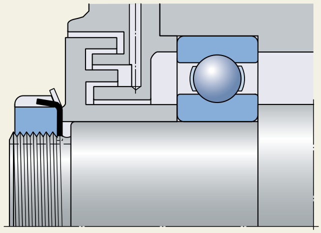
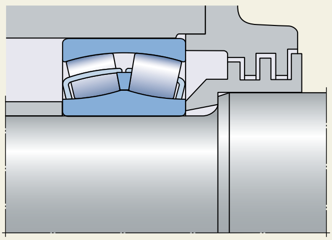


Fig 55



Single or multi-stage labyrinth seals are considerably more effective than simple gap-type seals, but are more expensive to produce. They are chiefly used with grease lubrication. Their efficiency can be further improved by periodically applying a water-insoluble grease, e.g. a grease with a lithium-calcium thickener, via a duct to the labyrinth passages. The tongues of the labyrinth seal are arranged axially (➔ **fig** 54) for one-piece housings and radially (➔ **fig** 55) for split housings. The width of the axial passages of the labyrinth remains unchanged when axial displacement of the shaft occurs in operation and can thus be very narrow. If angular misalignment of the shaft with respect to the housing can occur, labyrinths with inclined passages are used (➔ **fig** 56).

Effective and inexpensive labyrinth seals can be made using commercially available products, e.g. using SKF sealing washers (➔ **fig** 57). Sealing efficiency increases with the number of washer sets used, or can be further enhanced by incorporating flocked washers. Additional information on these sealing washers can be found in the section “Seals” in the “SKF Interactive Engineering Catalogue”, available on CD-ROM or online at www.skf.com.

Fig 56

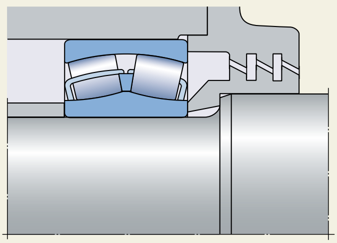
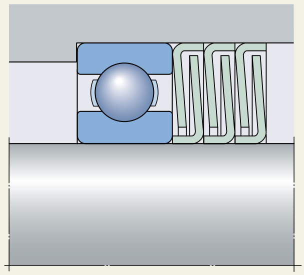


Fig 57



Rotating discs (➔ **fig** 58) are often fitted to the shaft to improve the sealing action of shields, and flinger rings, grooves or discs are used for the same purpose with oil lubrication. The oil from the flinger is collected in a channel in the housing and returned to the inside of the housing through suitable ducts (➔ **fig** 59).

Contact seals

Radial shaft seals are contact seals that are used, above all, for sealing oil-lubricated bearings. These ready-to-mount elastomer sealing components normally have a metal reinforcement or casing. The sealing lip is usually a synthetic rubber and is normally pressed against a counterface on the shaft by a garter spring. Depending on the seal material and medium to be retained and/or excluded, radial shaft seals can be used at temperatures between –60 and +190 °C.

The contact area between the sealing lip and counterface is of vital importance to sealing efficiency. The surface hardness of the counterface should normally be at least 55 HRC and the hardened depth should be at least 0,3 mm, the surface roughness to ISO 4288:1996 should be within the guidelines of R_a = 0,2 to 0,8 μm. In applications, where speeds are low, lubrication is good and contamination is minimal, a lower hardness can be acceptable. To avoid the pumping action produced by helical grinding marks, plunge grinding is recommended. If the main purpose of the radial shaft seal is to prevent lubricant from leaving the housing, the seal should be mounted with the lip facing inwards (➔ **fig** 60). If the main purpose is to exclude contaminants, the lip should face outwards, away from the bearing (➔ **fig** 61, **page 226**).

Fig 58

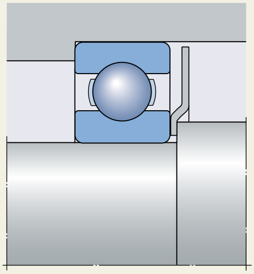


Fig 59

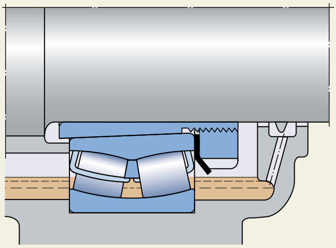


Fig 60

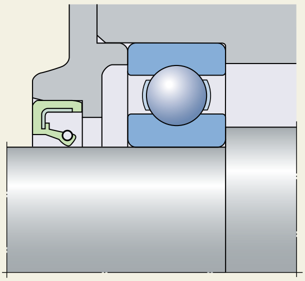


Fig 61

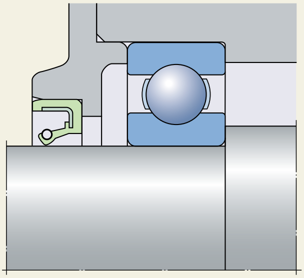


Fig 62

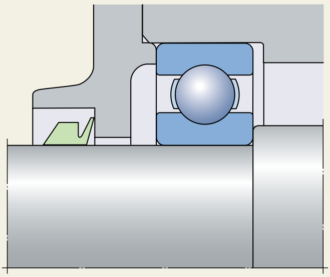
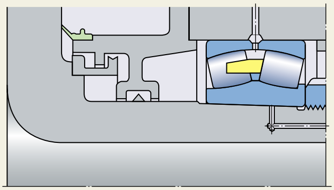


Fig 63



V-ring seals (➔ **fig** 62) can be used both with oil and with grease lubrication. The elastic rubber ring (body) of the seal firmly grips the shaft and rotates with it, while the sealing lip exerts a light axial pressure on the stationary component, e.g. the housing. Depending on the material, V-rings can be used at operating temperatures between –40 and +150 °C. They are simple to install and at low speeds permit relatively large angular misalignments of the shaft. A surface roughness R_a of between 2 and 3 μm is sufficient for the counterface. At peripheral speeds above 8 m/s the V-ring must be axially located on the shaft. At speeds above 12 m/s the ring must be prevented from “lifting” from the shaft by, for example, a sheet metal support ring. When the peripheral speed exceeds 15 m/s the sealing lip will lift from the counterface so that the V-ring becomes a gap-type seal. The good sealing action of the V-ring depends mainly on the fact that the ring body acts as a flinger, repelling dirt and fluids. Therefore, with grease lubrication the seal is generally arranged outside the housing, whereas for oil lubrication it is normally arranged inside the housing with the lip pointing away from the bearing position. Used as a secondary seal, V-rings protect the primary seal from excessive contaminants and moisture.

Axial clamp seals (➔ **fig** 63) are used as secondary seals for large diameter shafts in applications where protection is required for the primary seal. They are clamped in position on a non-rotating component and seal axially against a rotating counterface. For this type of seal, it is sufficient if the counterface is fine turned and has a surface roughness R_a of 2,5 μm.

Mechanical seals (➔ **fig** 64) are used to seal grease or oil lubricated bearing positions where speeds are relatively low and operating conditions difficult and arduous. They consist of two sliding steel rings with finely finished sealing surfaces and two plastic cup springs (Belleville washers), which position the sliding rings in the housing bore and provide the necessary preload force to the sealing surfaces. There are no special demands on the mating surfaces in the housing bore.

Felt seals (➔ **fig** 65) are generally used with grease lubrication. They are simple and inexpensive and can be used at peripheral speeds of up to 4 m/s and at operating temperatures up to +100 °C. The counterface should be ground to a surface roughness $R_a \leq 3,2$ µm. The efficiency of a felt seal can be much improved by mounting a simple labyrinth seal as a secondary seal. Before being inserted in the housing groove, the felt rings or strips should be soaked in oil at about 80 °C.

Spring washers (➔ **fig** 66) provide simple, inexpensive and space-saving seals for grease lubricated rigid bearings, particularly deep groove ball bearings. The washers are clamped against either the outer ring or the inner ring and exert a resilient pressure axially against the other ring. After a certain running-in period these seals become non-contact seals by forming a very narrow gap-type seal.

More detailed information on seals supplied by SKF will be found in the SKF catalogue “CR seals” and seals incorporated in SKF products are also described in detail in literature dealing with these products.

Fig 64

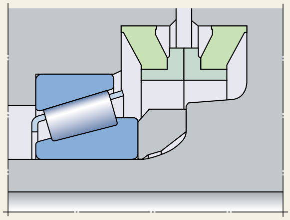


Fig 65

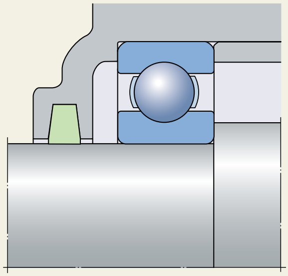


Fig 66