
SKF

Lubrication

If rolling bearings are to operate reliably they must be adequately lubricated to prevent direct metal-to-metal contact between the rolling elements, raceways and cages. The lubricant also inhibits wear and protects the bearing surfaces against corrosion. The choice of a suitable lubricant and method of lubrication for each individual bearing application is therefore important, as is correct maintenance.

A wide selection of greases and oils is available for the lubrication of rolling bearings and there are also solid lubricants, e.g. for extreme temperature conditions. The actual choice of a lubricant depends primarily on the operating conditions, i.e. the temperature range and speeds as well as the influence of the surroundings.

The most favourable operating temperatures will be obtained when the minimum amount of lubricant needed for reliable bearing lubrication is provided. However, when the lubricant has additional functions, such as sealing or the removal of heat, additional amounts of lubricant may be required.

The lubricant in a bearing arrangement gradually loses its lubricating properties as a result of mechanical work, ageing and the build-up of contamination. It is therefore necessary for grease to be replenished or renewed and for oil to be filtered and changed at regular intervals.

The information and recommendations in this section relate to bearings without integral seals or shields. SKF bearings and bearing units with integral seals and shields on both sides are supplied greased. Information about the greases used by SKF as standard for these products can be found in the text preceding the relevant product tables together with a brief description of the performance data.

The service life of the grease in sealed bearings most often exceeds bearing life so that, with some exceptions, no provision is made for the relubrication of these bearings.

Note

Differences in the lubricating properties of seemingly identical lubricants – particularly grease – produced at different locations can exist. Therefore, SKF cannot accept liability for any lubricant or its performance. The user is therefore advised to specify lubricant properties in detail so as to obtain the most suitable lubricant for the application.

Grease lubrication

Grease can be used to lubricate rolling bearings under normal operating conditions in the majority of applications.

Grease has the advantage over oil that it is more easily retained in the bearing arrangement, particularly where shafts are inclined or vertical, and it also contributes to sealing the arrangement against contaminants, moisture or water.

Excessive amounts of grease will cause the operating temperature within the bearing to rise rapidly, particularly when running at high speeds. As a general rule, when starting up only the bearing should be completely filled, while the free space in the housing should be partly filled with grease. Before operating at full speed, the excess grease in the bearing must be enabled to settle or escape during a running-in period. At the end of the running-in period the operating temperature will drop considerably, indicating that the grease has been distributed in the bearing arrangement.

However, where bearings are to operate at very low speeds and good protection against contamination and corrosion is required, it is advisable to fill the housing completely with grease.

Lubricating greases

Lubricating greases consist of a mineral or synthetic oil combined with a thickener. The thickeners are usually metallic soaps. However, other thickeners, e.g. polyurea can be used for superior performance in certain areas, i.e. high temperature applications. Additives can also be included to enhance certain properties of the grease. The consistency of the grease depends largely on the type and concentration of the thickener used and on the operating temperature of the application. When selecting a grease, the consistency, operating temperature range, viscosity of the base oil, rust inhibiting properties and the load carrying ability are the most important factors to be considered. Detailed information on these properties follows.

Base oil viscosity

The importance of the oil viscosity for the formation of an oil film to separate the bearing surfaces and thus for the life of the bearing is dealt with in the section "Lubrication conditions – the viscosity ratio κ" on **page 59**; the information applies equally to the base oil viscosity of greases.

The base oil viscosity of the greases normally used for rolling bearings lies between 15 and 500 mm^2/s at 40 °C. Greases based on oils having higher viscosities than 1 000 mm^2/s at 40 °C bleed oil so slowly that the bearing will not be adequately lubricated. Therefore, if a calculated viscosity well above 1 000 mm^2/s at 40 °C is required because of low speeds, it is better to use a grease with a maximum viscosity of 1 000 mm^2/s and good oil bleeding properties or to apply oil lubrication.

The base oil viscosity also governs the maximum recommended speed at which a given grease can be used for bearing lubrication. The permissible rotational speed for grease is also influenced by the shear strength of the grease, which is determined by the thickener. To indicate the speed capability, grease manufacturers often quote a "speed factor"

$$A = n\,d_m$$

where
A = speed factor, mm/min
n = rotational speed, r/min
d_m = bearing mean diameter
= 0,5 (d + D), mm

For applications operating at very high speeds, e.g. at A > 700 000 for ball bearings, the most suitable greases are those incorporating base oils of low viscosity.

Consistency

Greases are divided into various consistency classes according to the National Lubricating Grease Institute (NLGI) scale. The consistency of grease used for bearing lubrication should not change drastically when operated within its specified temperature range after mechanical working. Greases that soften at elevated temperatures may leak from the bearing arrangement. Those that stiffen at low temperatures may restrict rotation of the bearing or have insufficient oil bleeding.

Metallic soap thickened greases, with a consistency of 1, 2 or 3 are used for rolling bearings. The most common greases have a consistency of 2. Lower consistency greases are preferred for low temperature applications, or for improved pumpability. Consistency 3 greases are recommended for bearing arrangements with a vertical shaft, where a baffle plate is arranged beneath the bearing to prevent the grease from leaving the bearing.

In applications subjected to vibration, the grease is heavily worked as it is continuously thrown back into the bearing by vibration. Higher consistency greases may help here, but stiffness alone does not necessarily provide adequate lubrication. Therefore mechanically stable greases should be used instead.

Greases thickened with polyurea can soften or harden depending on the shear rate in the application. In applications with vertical shafts there is a danger that a polyurea grease will leak under certain conditions.

Temperature range – the SKF traffic light concept

The temperature range over which a grease can be used depends largely on the type of base oil and thickener used as well as the additives. The relevant temperatures are schematically illustrated in **diagram 1** in the form of a "double traffic light".

The extreme temperature limits, i.e. low temperature limit and the high temperature limit, are well defined.

- The low temperature limit (LTL), i.e. the lowest temperature at which the grease will enable the bearing to be started up without difficulty, is largely determined by the type of base oil and its viscosity.
- The high temperature limit (HTL) is determined by the type of thickener and for soap base greases is given by the dropping point. The dropping point indicates the temperature at which the grease loses its consistency and becomes a fluid.

It is evident that operation below the low temperature limit and above the high temperature limit is not advised as shown in **diagram 1** by the red zones. Although grease suppliers indicate the specific values for the low and high temperature limits in their product information, the really important temperatures for reliable operation are given by the SKF values for

- the low temperature performance limit (LTPL) and
- the high temperature performance limit (HTPL).

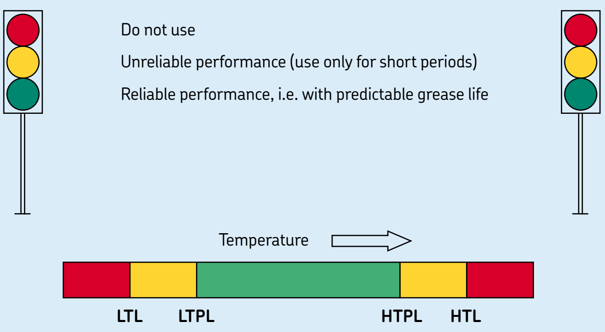
It is within these two limits, the green zone in **diagram 1**, where the grease will function reliably and grease life can be determined accurately, Since the definition of the high temperature performance limit is not standardized internationally, care must be taken when interpreting suppliers' data.

At temperatures above the high temperature performance limit (HTPL), grease will age and oxidize with increasing rapidity and the by-products of the oxidation will have a detrimental effect on lubrication. Therefore, temperatures in the amber zone, between the high temperature performance limit and the high temperature limit (HTL) should occur only for very short periods.

An amber zone also exists for low temperatures. With decreasing temperature, the tendency of grease to bleed decreases and the stiffness (consistency) of the grease increases. This will ultimately lead to an insufficient supply of lubricant to the contact surfaces of the rolling elements and raceways. In **diagram 1**, this temperature limit is indicated by the low temperature performance limit (LTPL). Values for the low temperature performance limit are different for roller and ball bearings. Since ball bearings are easier to lubricate than roller bearings, the low temperature performance limit is less important for ball bearings. For roller bearings, however, serious damage will result when the bearings are operated continuously below this limit. Short periods in this zone e.g. during a cold start, are not harmful since the heat caused by friction will bring the bearing temperature into the green zone.

Diagram 1

The SKF traffic light concept



LTL Low temperature limit
LTPL Low temperature performance limit
HTPL High temperature performance limit
HTL High temperature limit

Note

The SKF traffic light concept is applicable for any grease; however, the temperature zones differ from grease to grease and can only be determined by functional bearing testing. The traffic light limits for

- grease types normally used for rolling bearings are shown in **diagram 2** and for
- SKF greases are shown in **diagram 3**.

The temperature zones shown in these diagrams are based on extensive tests conducted in SKF laboratories and may differ from those quoted by lubricant manufacturers. The zones shown in **diagram 2** are valid for commonly available NLGI 2 greases without EP additives. The temperatures in the diagrams relate to the observed self-induced bearing temperature (usually measured on the non-rotating ring). Since the data for each grease type is a summary of many greases of more or less similar composition, the transitions for each group are not sharp but fall within a small range.

Protection against corrosion, behaviour in the presence of water

Grease should protect the bearing against corrosion and should not be washed out of the bearing arrangement in cases of water penetration. The thickener type solely determines the resistance to water: lithium complex, calcium complex and polyurea greases offer usually very good resistance. The type of rust inhibitor additive mainly determines the rust inhibiting properties of greases.

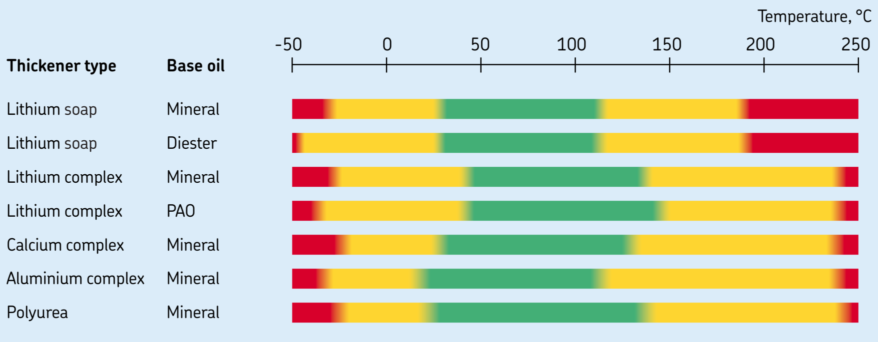
At very low speeds, a full grease pack is beneficial for corrosion protection and for the prevention of water ingress.

Load carrying ability: EP and AW additives

Bearing life is shortened if the lubricant film thickness is not sufficient to prevent metal-to-metal contact of the asperities on the contact surfaces. One option to overcome this is to use so-called EP (Extreme Pressure) additives. High temperatures induced by local asperity contact, activate these additives promoting mild wear at the points of contact. The result is a smoother surface, lower contact stresses and an increase in service life.

Diagram 2

The SKF traffic light concept – standard greases



Many modern EP additives are of the sulphur/phosphorus type. Unfortunately these additives may have a negative effect on the strength of the bearing steel matrix. If such additives are used then the chemical activity may not be restricted to the asperity contacts. If the operating temperature and contact stresses are too high, the additives may become chemically reactive even without asperity contact. This can promote corrosion/diffusion mechanisms in the contacts and may lead to accelerated bearing failure, usually initiated by micro pitting. Therefore, SKF recommends the use of less reactive EP additives for operating temperatures above 80 °C. Lubricants with EP additives should not be used for bearings operating at temperatures higher than 100 °C. For very low speeds, solid lubricant additives such as graphite and molybdenum disulphide (MoS_2) are sometimes included in the additive package to enhance the EP effect. These additives should have a high purity level and a very small particle size; otherwise dents due to overrolling of the particles might reduce bearing fatigue life.

AW (Anti-Wear) additives have a function similar to that of EP additives, i.e. to prevent severe metal-to-metal contact. Therefore EP and AW additives are very often not differentiated between. However, the way they work is different. The main difference is that an AW additive builds a protective layer that adheres to the surface. The asperities are then sliding over each other whitout metallic contact. The roughness is therefore not reduced by mild wear as in the case of EP additives. Here too special care has to be taken; AW additives may contain elements that, in the same way as the EP additives, can migrate into the bearing steel and weaken the structure.

Certain thickeners (e.g. calcium sulphonate complex) also provide an EP/AW effect without chemical activity and the resulting effect on bearing fatigue life. Therefore, the operating temperature limits for EP additives do not apply for these greases.

Diagram 3

The SKF traffic light concept – SKF greases

For operating temperatures above 150 °C, SKF LGET 2 is recommended

If the lubricant film thickness is sufficient, SKF does not generally recommend the use of EP and AW additives. However there are circumstances where EP/AW additives may be useful. If excessive sliding between the rollers and raceways is expected they may be beneficial. Contact the SKF application engineering service for further information.

Miscibility

If it becomes necessary to change from one grease to another, the miscibility or the ability to mix greases without adverse effects should be considered. If incompatible greases are mixed, the resulting consistency can change dramatically so that bearing damage e.g. due to severe leakage, could result.

Greases having the same thickener and similar base oils can generally be mixed without any detrimental consequences, e.g. a lithium thickener/mineral oil grease can generally be mixed with another lithium thickener/mineral oil grease. Also, some greases with different thickeners e.g. calcium complex and lithium complex greases, are miscible with each other.

In bearing arrangements where a low grease consistency might lead to grease escaping from the arrangement, the next relubrication should involve purging all the old grease from the arrangement and the lubrication ducts, rather than replenishing it (→ section "Relubrication", starting on **page 237**).

The preservative with which SKF bearings are treated is compatible with the majority of rolling bearing greases with the possible exception of polyurea greases (→ section "Preparations for mounting and dismounting" on **page 258**). Note that synthetic fluorinated oil based greases using a PTFE thickener, e.g. SKF LGET 2 grease, are not compatible with standard preservatives and the preservatives must be removed before applying grease. Contact the SKF application engineering service for further information.

SKF greases

The SKF range of lubricating greases for rolling bearings comprises many types of grease and covers virtually all application requirements. These greases have been developed based on the latest information about rolling bearing lubrication and have been thoroughly tested both in the laboratory and in the field. Their quality is continuously monitored by SKF.

The most important technical specifications on SKF greases are provided in **table 2** on **pages 246** and **247,** together with a quick selection guide. The temperature ranges where the SKF greases can be used are schematically illustrated in **diagram 3**, **page 235**, according to the SKF traffic light concept.

Further information on SKF greases can be found in the catalogue "SKF Maintenance and Lubrication Products" or online at www.mapro.skf.com.

For a more detailed selection of the appropriate grease for a specific bearing type and application, use the Internet based SKF grease selection program LubeSelect. This program can be found online at www.aptitudexchange.com.

Relubrication

Rolling bearings have to be relubricated if the service life of the grease is shorter than the expected service life of the bearing. Relubrication should always be undertaken at a time when the condition of the existing lubricant is still satisfactory.

The time at which relubrication should be undertaken depends on many related factors. These include bearing type and size, speed, operating temperature, grease type, space around the bearing and the bearing environment. It is only possible to base recommendations on statistical rules; the SKF relubrication intervals are defined as the time period, at the end of which 99 % of the bearings are still reliably lubricated. This represents the L_1 grease life.

SKF recommends using experience based on data from actual applications and tests, together with the estimated relubrication intervals provided hereafter.

Relubrication intervals

The relubrication intervals t_f for bearings with rotating inner ring on horizontal shafts under normal and clean conditions can be obtained from **diagram 4** as a function of

- the speed factor A multiplied by the relevant bearing factor b_f where
  A = n d_m
  n = rotational speed, r/min
  d_m = bearing mean diameter = 0,5 (d + D), mm
  b_f = bearing factor depending on bearing type and load conditions (→ **table 1**, **page 239**)
- the load ratio C/P

The relubrication interval t_f is an estimated value, valid for an operating temperature of 70 °C, using good quality lithium thickener/ mineral oil greases. When bearing operating conditions differ, adjust the relubrication intervals obtained from **diagram 4** according to the information given under "Adjustments of relubrication intervals due to operating conditions and bearing types", starting on **page 240**.

If the speed factor A exceeds a value of 70 % of the recommended limit according to **table 1**, or if ambient temperatures are high, then the use of the calculations presented in the section "Speeds and vibration", starting on **page 107**, is recommended to check the operating temperature and the proper lubrication method.

When using high performance greases, a longer relubrication interval and grease life may be possible. Contact the SKF application engineering service for additional information.

Diagram 4

Relubrication intervals at operating temperatures of 70 °C

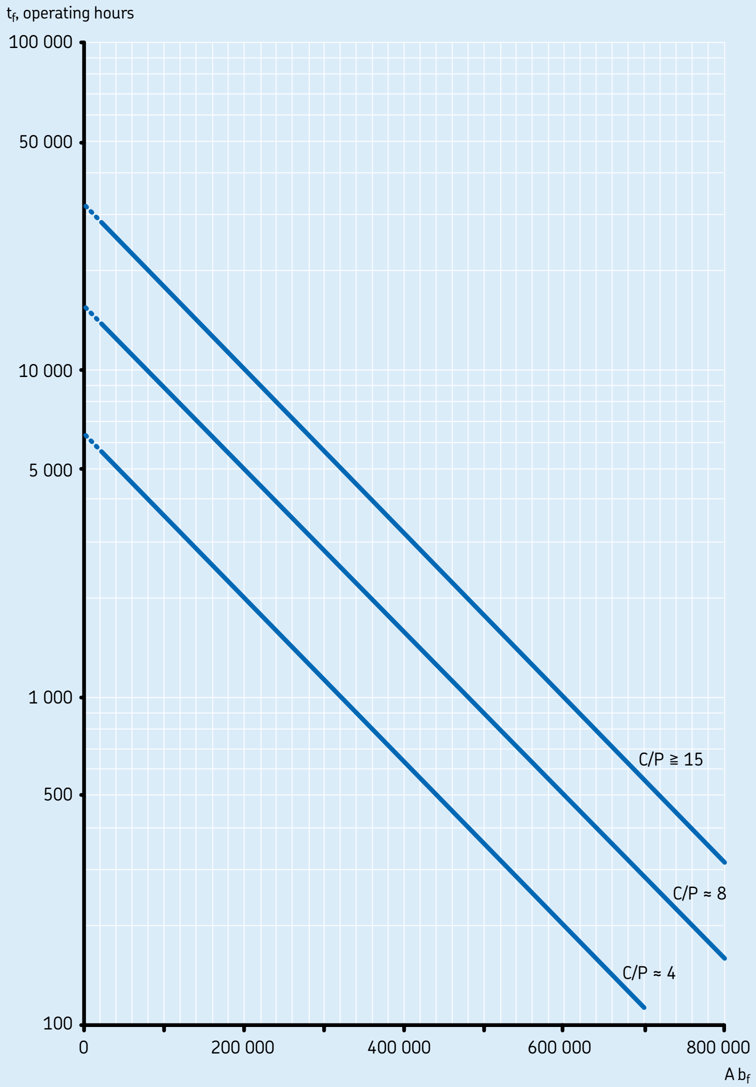


Table 1

Bearing factors and recommended limits for speed factor A

Bearing type[1]	**Bearing factor** b_f	**Recommended limits for speed factor A for load ratio** C/P ≥ 15	C/P ≈ 8	C/P ≈ 4
–	–	mm/min		
Deep groove ball bearings	1	500 000	400 000	300 000
Angular contact ball bearings	1	500 000	400 000	300 000
Self-aligning ball bearings	1	500 000	400 000	300 000
Cylindrical roller bearings				
– non-locating bearing	1,5	450 000	300 000	150 000
– locating bearing, without external axial loads or with light but alternating axial loads	2	300 000	200 000	100 000
– locating bearing, with constantly acting light axial load	4	200 000	120 000	60 000
– whithout cage, full complement[2]	4	NA[3]	NA[3]	20 000
Taper roller bearings	2	350 000	300 000	200 000
Spherical roller bearings				
– when load ratio $F_a/F_r < e$ and $d_m \leq 800$ mm				
series 213, 222, 238, 239	2	350 000	200 000	100 000
series 223, 230, 231, 232, 240, 248, 249	2	250 000	150 000	80 000
series 241	2	150 000	80 000[4]	50 000[4]
– when load ratio $F_a/F_r < e$ and $d_m > 800$ mm				
series 238, 239	2	230 000	130 000	65 000
series 230, 231, 232, 240, 248, 249	2	170 000	100 000	50 000
series 241	2	100 000	50 000[4]	30 000[4]
– when load ratio $F_a/F_r > e$				
all series	6	150 000	50 000[4]	30 000[4]
CARB toroidal roller bearings				
– with cage	2	350 000	200 000	100 000
– without cage, full complement[2]	4	NA[3]	NA[3]	20 000
Thrust ball bearings	2	200 000	150 000	100 000
Cylindrical roller thrust bearings	10	100 000	60 000	30 000
Spherical roller thrust bearings				
– rotating shaft washer	4	200 000	170 000	150 000

1) The bearing factors and recommended practical speed factor "A" limits apply to bearings with standard internal geometry and standard cage execution. For alternative internal bearing design and special cage execution, please contact the SKF application engineering service

2) The t_f value obtained from **diagram 4** needs to be divided by a factor of 10

3) Not applicable, for these C/P values a caged bearing is recommended instead

4) For higher speeds oil lubrication is recommended

Adjustments of relubrication intervals due to operating conditions and bearing types

Operating temperature

To account for the accelerated ageing of grease with increasing temperature, it is recommended halving the intervals obtained from the **diagram 4** for every 15 °C increase in operating temperature above 70 °C, remembering that the high temperature performance limit for the grease (→ **diagram 1**, HTPL, on **page 233**) should not be exceeded.

The relubrication interval t_f may be extended at temperatures below 70 °C if the temperature is not close to the lower temperature performance limit (→ **diagram 1**, LTPL, on **page 233**). A total extension of the relubrication interval t_f by more than a factor of two never is recommended. In case of full complement bearings and thrust roller bearings, t_f values obtained from **diagram 4** should not be extended.

Moreover, it is not advisable to use relubrication intervals in excess of 30 000 hours.

For many applications, there is a practical grease lubrication limit, when the bearing ring with the highest temperature exceeds an operating temperature of 100 °C. Above this temperature special greases should be used. In addition, the temperature stability of the bearing and premature seal failure should be taken into consideration.

For high temperature applications please consult the SKF application engineering service.

Vertical shaft

For bearings on vertical shafts, the intervals obtained from **diagram 4** should be halved. The use of a good sealing or retaining shield is a prerequisite to prevent grease leaking from the bearing arrangement.

Vibration

Moderate vibration will not have a negative effect on grease life, but high vibration and shock levels, such as those in vibrating screen applications, will cause the grease to churn. In these cases the relubrication interval should be reduced. If the grease becomes too soft, grease with a better mechanical stability, e.g. SKF grease LGHB 2 or grease with higher stiffness up to NLGI 3 should be used.

Outer ring rotation

In applications where the outer ring rotates, the speed factor A is calculated differently: in this case use the bearing outside diameter D instead of d_m. The use of a good sealing mechanism is a prerequisite in order to avoid grease loss.

Under conditions of high outer ring speeds (i.e. > 40 % of the reference speed listed in the product tables), greases with a reduced bleeding tendency should be selected.

For spherical roller thrust bearings with a rotating housing washer oil lubrication is recommended.

Contamination

In case of ingress of contamination, more frequent relubrication than indicated by the relubrication interval will reduce the negative effects of foreign particles on the grease while reducing the damaging effects caused by overrolling the particles. Fluid contaminants (water, process fluids) also call for a reduced interval. In case of severe contamination, continuous relubrication should be considered.

Very low speeds

Bearings that operate at very low speeds under light loads call for a grease with low consistency while bearings that operate at low speeds and heavy loads need to be lubricated by high viscosity greases, and if possible, with very good EP characteristics.

Solid additives such as graphite and molybdenum disulphide (MoS_2) can be considered for a speed factor A < 20 000. Selecting the proper grease and grease fill is very important in low speed applications.

High speeds

Relubrication intervals for bearings used at high speeds i.e. above the recommended speed factor A provided in **table 1**, **page 239**, only apply when using special greases or modified bearing executions, e.g. hybrid bearings. In these cases continuous relubrication techniques such as circulating oil, oil-spot etc, are more suitable than grease lubrication.

Very heavy loads

For bearings operating at a speed factor A > 20 000 and subjected to a load ratio C/P < 4 the relubrication interval is further reduced. Under these very heavy load conditions, continuous grease relubrication or oil bath lubrication is recommended.

In applications where the speed factor A < 20 000 and the load ratio C/P = 1–2, reference should be made to the information under “Very low speeds” on **page 240**. For heavy loads and high speeds circulating oil lubrication with cooling is generally recommended.

Very light loads

In many cases the relubrication interval may be extended if the loads are light (C/P = 30 to 50). To obtain satisfactory operation the bearings should be subjected at least to the minimum load as stated in the text preceding the relevant product tables.

Misalignment

A constant misalignment within the permissible limits does not adversely affect the grease life in spherical roller bearings, self-aligning ball bearings or toroidal roller bearings.

Large bearings

To establish a proper relubrication interval for line contact bearings, in particular large bearings (d > 300 mm) used in critical bearing arrangements in process industries, an interactive procedure is recommended. In these cases it is advisable to initially relubricate more frequently and adhere strictly to the recommended regreasing quantities (→ section “Relubrication procedures” on **page 242**).

Before regreasing, the appearance of the used grease and the degree of contamination due to particles and water should be checked. Also the seal should be checked completely, looking for wear, damage and leaks. When the condition of the grease and associated components is found to be satisfactory, the relubrication interval can be gradually increased.

A similar procedure is recommended for spherical roller thrust bearings, prototype machines and upgrades of high-density power equipment or wherever application experience is limited.

Cylindrical roller bearings

The relubrication intervals from **diagram 4**, **page 238**, are valid for cylindrical roller bearings fitted with

- an injection moulded cage of glass fibre reinforced polyamide 6,6, roller centred, designation suffix P
- a two-piece machined brass cage, roller centred, designation suffix M.

For cylindrical roller bearings with

- a pressed steel cage, roller centred, no designation suffix or suffix J, or
- a machined brass cage, inner or outer ring centred, designation suffixes MA, MB, ML or MP,

the value for the relubrication interval from **diagram 4** should be halved and a grease with good oil bleeding properties should be applied. Moreover, grease lubricated bearings with a MA, MB, ML or MP cage should not be operated at speeds exceeding the speed factor $A = n \times d_m$ = 250 000. For applications exceeding this value, please consult the SKF application engineering service. SKF generally recommends to lubricate these bearings with oil.

Observations

If the determined value for the relubrication interval t_f is too short for a particular application, it is recommended to

- check the bearing operating temperature
- check whether the grease is contaminated by solid particles or fluids
- check the bearing application conditions, such as load or misalignment

and, last but not least, a more suitable grease should be considered.

Relubrication procedures

The choice of the relubrication procedure generally depends on the application and on the relubrication interval t_f obtained:

- Replenishment is a convenient and preferred procedure if the relubrication interval is shorter than six months. It enables uninterrupted operation and provides, when compared with continuous relubrication, a lower steady state temperature.
- Renewing the grease fill is generally recommended when the relubrication intervals are longer than six months. This procedure is often applied as part of a bearing maintenance schedule e.g. in railway applications.
- Continuous relubrication is used when the estimated relubrication intervals are short, e.g. due to the adverse effects of contamination, or when other procedures of relubrication are inconvenient because access to the bearing is difficult. Continuous relubrication is not recommended for applications with high rotational speeds since the intensive churning of the grease can lead to very high operating temperatures and destruction of the grease thickener structure.

When using different bearings in a bearing arrangement it is common practice to apply the lowest estimated relubrication interval for both bearings. The guidelines and grease quantities for the three alternative procedures are provided below.

Replenishment

As mentioned in the introduction of the grease lubrication section, the bearing should initially be completely filled, while the free space in the housing should be partly filled. Depending on the intended method of replenishment, the following grease fill percentages for this free space in the housing are recommended:

- 40 % when replenishing is made from the side of the bearing (→ **fig. 1**).
- 20 % when replenishing is made through the annular groove and lubrication holes in the bearing outer or inner ring (→ **fig. 2**).

Suitable quantities for replenishment from the side of a bearing can be obtained from

$$G_p = 0{,}005\, D\, B$$

and for replenishment through the bearing outer or inner ring from

$$G_p = 0{,}002\, D\, B$$

where

G_p = grease quantity to be added when replenishing, g
D = bearing outside diameter, mm
B = total bearing width (for thrust bearings use height H), mm

Fig. 1

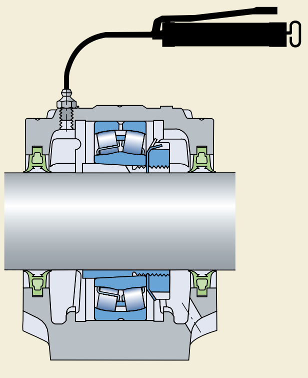
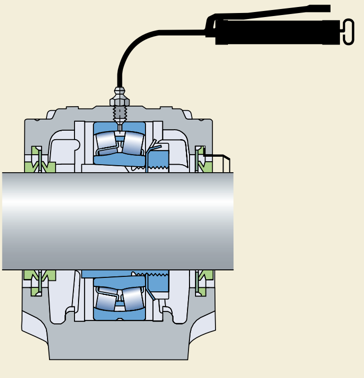


Fig. 2



To facilitate the supply of grease using a grease gun, a grease nipple must be provided on the housing. If contact seals are used, an exit hole in the housing should also be provided so that excessive amounts of grease will not build up in the space surrounding the bearing (→ **fig. 1**) as this might cause a permanent increase in bearing temperature. The exit hole should be plugged when high-pressure water is used for cleaning.

The danger of excess grease collecting in the space surrounding the bearing and causing temperature peaks, with its detrimental effect on the grease as well as the bearing, is more pronounced when bearings operate at high speeds. In these cases it is advisable to use a grease escape valve rather than an exit hole. This prevents over-lubrication and enables relubrication to be performed while the machine is in operation. A grease escape valve consists basically of a disc that rotates with the shaft and which forms a narrow gap together with the housing end cover (→ **fig. 3**). Excess and used grease are thrown out by the disc into an annular cavity and leaves the housing through an opening on the underside of the end cover. Additional information about the design and dimensioning of grease escape valves can be supplied on request.

To be sure that fresh grease actually reaches the bearing and replaces the old grease, the lubrication duct in the housing should either feed the grease adjacent to the outer ring side face (→ **figs. 1** and **4**) or, better still, into the bearing. To facilitate efficient lubrication some bearing types, e.g. spherical roller bearings, are provided with an annular groove and/or lubrication holes in the outer or inner ring (→ **figs. 2** and **5**).

Fig. 3

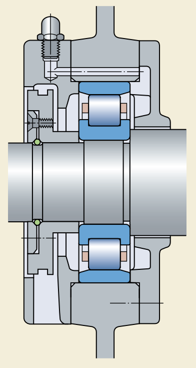


Fig. 4

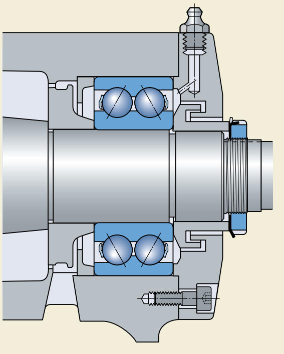
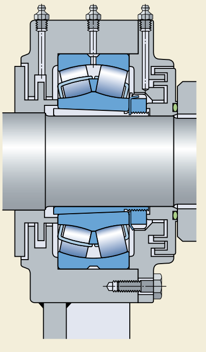


Fig. 5



To be effective in replacing old grease, it is important that grease is replenished while the machine is operating. In cases where the machine is not in operation, the bearing should be rotated during replenishment. When lubricating the bearing directly through the inner or outer ring, the fresh grease is most effective in replenishment; therefore, the amount of grease needed is reduced when compared with relubricating from the side. It is assumed that the lubrication ducts were already filled with grease during the mounting process. If not, a greater relubrication quantity during the first replenishment is needed to compensate for the empty ducts.

Where long lubrication ducts are used, check whether the grease can be adequately pumped at the prevailing ambient temperature.

The complete grease fill should be replaced when the free space in the housing can no longer accommodate additional grease, e.g. approximately above 75 % of the housing free volume. When relubricating from the side and starting with 40 % initial fill of the housing, the complete grease fill should be replaced after approximately five replenishments. Due to the lower initial fill of the housing and the reduced topping-up quantity during replenishment in the case of relubricating the bearing directly through inner or outer ring, renewal will only be required in exceptional cases.

Renewing the grease fill

When renewal of the grease fill is made at the estimated relubrication interval or after a certain number of replenishments, the used grease in the bearing arrangement should be completely removed and replaced by fresh grease.

Filling the bearing and housing with grease should be done in accordance with the guidelines provided under “Replenishment”.

To enable renewal of the grease fill the bearing housing should be easily accessible and easily opened. The cap of split housings and the covers of one-piece housings can usually be removed to expose the bearing. After removing the used grease, fresh grease should first be packed between the rolling elements. Great care should be taken to see that contaminants are not introduced into the bearing or housing when relubricating, and the grease itself should be protected. The use of grease resistant gloves is recommended to prevent any allergic skin reactions.

When housings are less accessible but are provided with grease nipples and exit holes, it is possible to completely renew the grease fill by relubricating several times in close succession, until it can be assumed that all old grease has been pressed out of the housing. This procedure requires much more grease than is needed for manual renewal of the grease fill. In addition, this method of renewal has a limitation with respect to rotational speeds: at high speeds it will lead to undue temperature increases caused by excessive churning of the grease.

Continuous relubrication

This procedure is used when the calculated relubrication interval is very short, e.g. due to the adverse effects of contamination, or when other procedures of relubrication are inconvenient, e.g. access to the bearing is difficult.
Due to the excessive churning of the grease, which can lead to increased temperature, continuous lubrication is only recommended when rotational speeds are low, i.e. at speed factors

- A < 150 000 for ball bearings
- A < 75 000 for roller bearings.

In these cases the initial grease fill of the housing may be 100 % and the quantity for relubrication per time unit is derived from the equations for G_p under "Replenishment" by spreading the relevant quantity over the relubrication interval.

When using continuous relubrication, check whether the grease can be adequately pumped through the ducts at the prevailing ambient temperature.

Continuous lubrication can be achieved via single-point or multi-point automatic lubricators, e.g. SYSTEM 24® or SYSTEM MultiPoint. For additional information refer to the section on "Maintenance and lubrication products", starting on **page 1069**.

Customized automatic lubrication systems, e.g. by the VOGEL® total-loss centralized single or multi-line lubrication systems, enable reliable lubrication to be achieved with extremely small quantities of grease. Fore more information about the VOGEL lubrication systems, please visit www.vogelag.com.

Table 2

SKF greases – technical specification and characteristics

Part 1: Technical specification

Designation	Description	NLGI class	Thickener/ base oil	Base oil viscosity at 40 °C	Base oil viscosity at 100 °C	Temperature limits LTL[1]	Temperature limits HTPL[2]
–	–	–	–	mm^2/s		°C	
LGMT 2	All purpose industrial and automotive	2	Lithium soap/ mineral oil	110	11	–30	+120
LGMT 3	All purpose industrial and automotive	3	Lithium soap/ mineral oil	120	12	–30	+120
LGEP 2	Extreme pressure, heavy load	2	Lithium soap/ mineral oil	200	16	–20	+110
LGLT 2	Light load and low temperature, high speed	2	Lithium soap/ diester oil	15	3,7	–55	+100
LGHP 2	High performance and high temperature	2–3	Di-urea/ mineral oil	96	10,5	–40	+150
LGFP 2	Food compatible	2	Aluminium complex/ medical white oil	130	7,3	–20	+110
LGGB 2	Biodegradable and low toxicity	2	Lithium-calcium soap/ ester oil	110	13	–40	+120
LGWA 2	Wide temperature range	2	Lithium complex soap/ mineral oil	185	15	–30 peaks:	+140 +220
LGHB 2	High viscosity and high temperature	2	Calcium complex sulphonate/mineral oil	450	26,5	–20 peaks:	+150 +200
LGET 2	Extreme temperature	2	PTFE/synthetic (fluorinated polyether)	400	38	–40	+260
LGEM 2	High viscosity with solid lubricants	2	Lithium soap/ mineral oil	500	32	–20	+120
LGEV 2	Extreme high viscosity with solid lubricants	2	Lithium-calcium soap/ mineral oil	1 000	58	–10	+120
LGWM 1	Extreme pressure, low temperature	1	Lithium soap/ mineral oil	200	16	–30	+110

[1] LTL: low temperature limit. For safe operating temperature, → section “Temperature range – the SKF traffic light concept”, starting on **page 232**
[2] HTPL: high temperature performance limit

Table 2

SKF greases – technical specification and characteristics

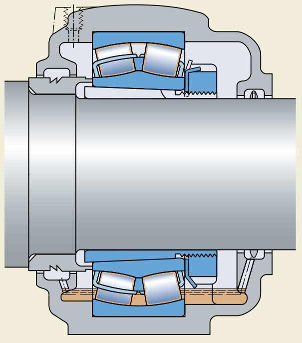
Part 2: Characteristics

Designation	High temperature, above +120 °C	Low temperature[1]	Very high speed	Very low speed or oscillations	Low torque, low friction	Severe vibrations	Heavy loads	Rust inhibiting properties	Water resistance
LGMT 2			o	-	+	+	o	+	+
LGMT 3			o	-	o	+	o	o	+
LGEP 2			o	o	-	+	+	+	+
LGLT 2		+	+	-	+	-	-	o	o
LGHP 2	+	o	+	-	o	+	o	+	+
LGFP 2			o	-	o	o		+	+
LGGB 2		o	o	o	o	+	+	o	+
LGWA 2	+		o	o	o	+	+	+	+
LGHB 2	+		o	+	-	+	+	+	+
LGET 2			Contact the SKF application engineering service						
LGEM 2			-	+	-	+	+	+	+
LGEV 2		-	-	+	-	+	+	+	+
LGWM 1		+	o	o	o	-	+	+	+

Symbols: + Recommended
o Suitable
- Not suitable

Where no symbol is indicated the relevant grease may be used – however it is not recommended.
For further information please contact the SKF application engineering service
[1] For safe operating temperature, → section "Temperature range – the SKF traffic light concept", starting on **page 232**

Fig. 6



Oil lubrication

Oil is generally used for rolling bearing lubrication when high speeds or operating temperatures preclude the use of grease, when frictional or applied heat has to be removed from the bearing position, or when adjacent components (gears etc.) are lubricated with oil.

In order to increase bearing service life, all methods of bearing lubrication that use clean oil are preferred, i.e. well filtered circulating oil lubrication, oil jet method and the oil-spot method with filtered air and oil. When using the circulating oil and oil-spot methods, adequately dimensioned ducts must be provided so that the oil flowing from the bearing can leave the arrangement.

Methods of oil lubrication

Oil bath

The simplest method of oil lubrication is the oil bath (→ **fig. 6**). The oil, which is picked up by the rotating components of the bearing, is distributed within the bearing and then flows back to the oil bath. The oil level should be such that it almost reaches the centre of the lowest rolling element when the bearing is stationary. The use of oil levellers such as the SKF LAHD 500 is recommended to provide the correct oil level. When operating at high speed the oil level can drop significantly and the housing can become overfilled by the oil leveller, under these conditions, please consult the SKF application engineering service.

Oil pick-up ring

For bearing applications where speeds and operating temperature are such that oil lubrication is necessary and high reliability is required, the oil pick-up ring lubrication method is recommended (→ **fig. 7**). The pick-up ring serves to bring about oil circulation. The ring hangs loosely on a sleeve on the shaft on one side of the bearing and dips into the oil in the lower half of the housing. As the shaft rotates, the ring follows and transports oil from the bottom to a collecting trough. The oil then flows through the bearing back into the reservoir at the bottom. SKF plummer block housings in the SONL series are designed for the oil pick-up ring lubrication method. For additional information please consult the SKF application engineering service.

Circulating oil

Operation at high speeds will cause the operating temperature to increase and will accelerate ageing of the oil. To avoid frequent oil changes and to achieve a fully flooded condition, the circulating oil lubrication method is generally preferred (→ **fig. 8**). Circulation is usually produced with the aid of a pump. After the oil has passed through the bearing, it generally settles in a tank where it is filtered and, if required, cooled before being returned to the bearing. Proper filtering leads to high values for the factor η_c and thus to long bearing service life (→ section "SKF rating life", starting on **page 52**).

Cooling the oil enables the operating temperature of the bearing to be kept at a low level.

Fig. 7

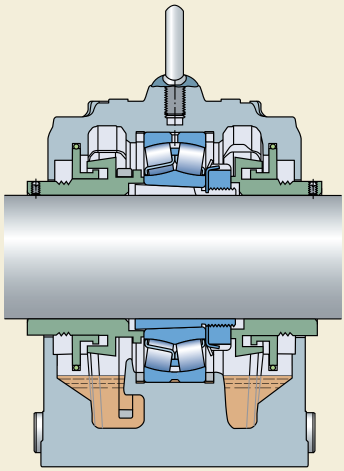


Fig. 8

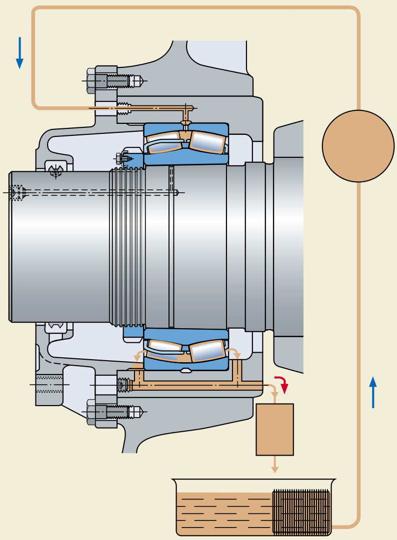


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Fig. 9

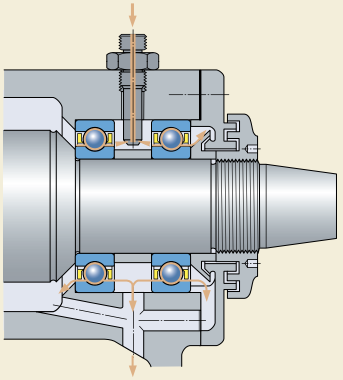
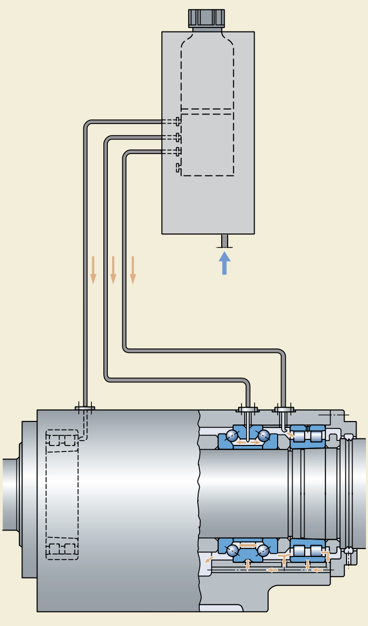


Fig. 10



Oil jet

For very high-speed operation a sufficient but not excessive amount of oil must be supplied to the bearing to provide adequate lubrication, without increasing the operating temperature more than necessary. One particularly efficient method of achieving this is the oil jet method (→ **fig. 9**) where a jet of oil under high pressure is directed at the side of the bearing. The velocity of the oil jet must be sufficiently high (at least 15 m/s) to penetrate the turbulence surrounding the rotating bearing.

Oil-spot

With the oil-spot method (→ **fig. 10**) – also called the oil-air method – very small, accurately metered quantities of oil are directed at each individual bearing by compressed air. This min-imum quantity enables bearings to operate at lower temperatures or at higher speeds than any other method of lubrication. The oil is supplied to the leads by a metering unit, such as the VOGEL OLA oil + air systems, at given intervals. The oil is transported by compressed air; it coats the inside of the leads and "creeps" along them. It is projected to the bearing via a nozzle or it just flows to the bearing raceways by a surface tension effect. The compressed air serves to cool the bearing and also produces an excess pressure in the bearing arrangement to prevent contaminants from entering.

For more information about the design of oil-air lubrication arrangements, please refer to the VOGEL publication 1-5012-3 "Oil + Air Systems" or visit www.vogelag.com.

Oil mist

Oil mist lubrication has not been recommended for some time due to possible negative environmental effects.

A new generation of oil mist generators permits to produce oil mist with 5 ppm oil. New designs of special seals also limit the amount of stray mist to a minimum. In case synthetic non-toxic oil is used, the environmental effects are even further reduced. Oil mist lubrication today is used in very specific applications, like the petroleum industry.

Lubricating oils

Straight mineral oils are generally favoured for rolling bearing lubrication. Oils containing EP, antiwear and other additives for the improvement of certain lubricant properties are generally only used in special cases. The remarks covering EP additives in the section "Load carrying ability: EP and AW additives" on **page 234** also apply to those additives in oils.

Synthetic versions of many of the popular lubricant classes are available. Synthetic oils are generally only considered for bearing lubrication in extreme cases, e.g. at very low or very high operating temperatures. The term synthetic oil covers a wide range of different base stocks. The main ones are polyalphaolefins (PAO), esters and polyalkylene glycols (PAG). These synthetic oils have different properties to mineral oils (→ **table 3**).

With respect to bearing fatigue life the actual lubricant film thickness plays a major role. The oil viscosity, the viscosity index and the pressure-viscosity coefficient influence the actual film thickness in the contact area for a fully flooded condition. For most mineral oil based lubricants, the pressure-viscosity coefficient is similar and generic values obtained from literature can be used without large error. However, the response of viscosity to increasing pressure is determined by the chemical structure of the base stocks used. As a result of this there is considerable variation in pressure-viscosity coefficients for the different types of synthetic base stocks. Due to the differences in the viscosity index and pressure-viscosity coefficient, it should be remembered that the lubricant film formation, when using synthetic oil, may differ from that of a mineral oil having the same viscosity. Accurate information should always be sought from the individual lubricant supplier.

In addition, additives play a role in the film formation. Due to differences in solubility, different types of additives are applied in synthetic oils when compared with the mineral oil based counterparts.

Table 3

Properties of oil types

Properties	**Base oil type** Mineral	**PAO**	**Ester**	**PAG**
Pour point (°C)	–30 .. 0	–50 .. –40	–60 .. –40	appr. – 30
Viscosity index	low	moderate	high	high
Pressure-viscosity coefficient	high	moderate	low to moderate	high

Selection of lubricating oils

Selecting oil is primarily based on the viscosity required to provide adequate lubrication for the bearing at the bearing operating temperature. The viscosity of oil is temperature dependent, becoming lower as the temperature rises. The viscosity-temperature relationship of an oil is characterized by the viscosity index VI. For rolling bearing lubrication, oils having a high viscosity index (little change with temperature) of at least 95 are recommended.

In order for a sufficiently thick oil film to be formed in the contact area between rolling elements and raceways, the oil must retain a minimum viscosity at the operating temperature. The minimum kinematic viscosity ν_1 required at the operating temperature to provide adequate lubrication can be determined from **diagram 5**, **page 254**, provided a mineral oil is used. When the operating temperature is known from experience or can otherwise be determined, the corresponding viscosity at the internationally standardized reference temperature of 40 °C, i.e. the oil ISO VG viscosity class, can be obtained from **diagram 6**, **page 255**, which is compiled for a viscosity index of 95.

Certain bearing types, e.g. spherical roller bearings, toroidal roller bearings, taper roller bearings, and spherical roller thrust bearings, normally have a higher operating temperature than other bearing types, e.g. deep groove ball bearings and cylindrical roller bearings, under comparable operating conditions.

When selecting the oil the following aspects should be considered:

- Bearing life may be extended by selecting an oil where the kinematic viscosity ν at the operating temperature is higher than the viscosity ν_1 obtained from **diagram 5**. A $\nu > \nu_1$ can be obtained by choosing a mineral oil of higher ISO VG viscosity class or by taking an oil with higher viscosity index VI, whereby this oil should have at least the same pressure-viscosity coefficient. Since increased viscosity raises the bearing operating temperature there is frequently a practical limit to the lubrication improvement that can be obtained by this means.
- If the viscosity ratio $\kappa = \nu/\nu_1$ is less than 1, an oil containing EP additives is recommended and if κ is less than 0,4 an oil with EP additives must be used. An oil with EP additives may also enhance operational reliability in cases where κ is greater than 1 and medium and large-size roller bearings are concerned. It should be remembered that some EP additives may have adverse effects (→ "Load carrying ability: EP and AW additives" on **page 234**).
- For exceptionally low or high speeds, for critical loading conditions, or for unusual lubricating conditions please consult the SKF application engineering service.

Example

A bearing having a bore diameter d = 340 mm and outside diameter D = 420 mm is required to operate at a speed n = 500 r/min. Therefore $d_m = 0,5 (d + D) = 380$ mm. From **diagram 5**, the minimum kinematic viscosity ν_1 required for adequate lubrication at the operating temperature is approximately 11 mm^2/s. From **diagram 6**, assuming that the operating temperature of the bearing is 70 °C, it is found that a lubricating oil of ISO VG 32 viscosity class, i.e. a kinematic viscosity ν of at least 32 mm^2/s at the reference temperature of 40 °C, will be required.

Oil change

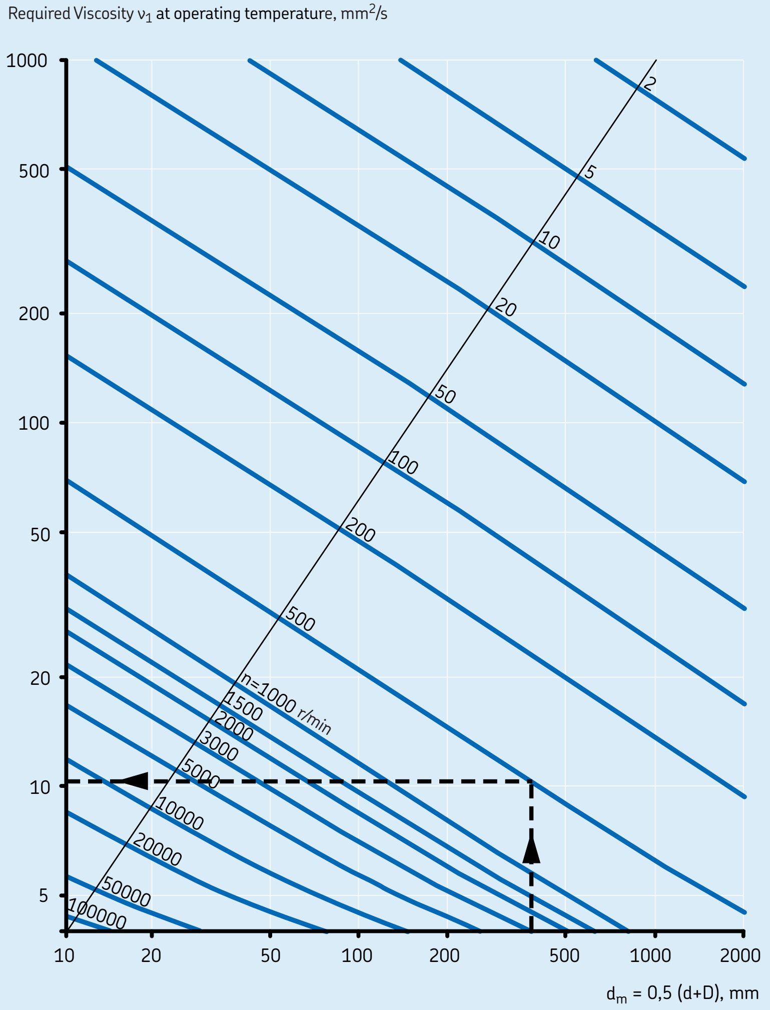
The frequency with which it is necessary to change the oil depends mainly on the operating conditions and the quantity of oil.

With oil bath lubrication it is generally sufficient to change the oil once a year, provided the operating temperature does not exceed 50 °C and there is little risk of contamination. Higher temperatures call for more frequent oil changes, e.g. for operating temperatures around 100 °C, the oil should be changed every three months. Frequent oil changes are also needed if other operating conditions are arduous.

With circulating oil lubrication, the period between two oil changes is also determined by how frequently the total oil quantity is circulated and whether or not the oil is cooled. It is generally only possible to determine a suitable interval by test runs and by regular inspection of the condition of the oil to see that it is not contaminated and is not excessively oxidized. The same applies for oil jet lubrication. With oil spot lubrication the oil only passes through the bearing once and is not recirculated.

Diagram 5

Estimation of the minimum kinematic viscosity ν_1 at operating temperature



Conversion to kinematic viscosity ν at reference temperature (ISO VG classification)