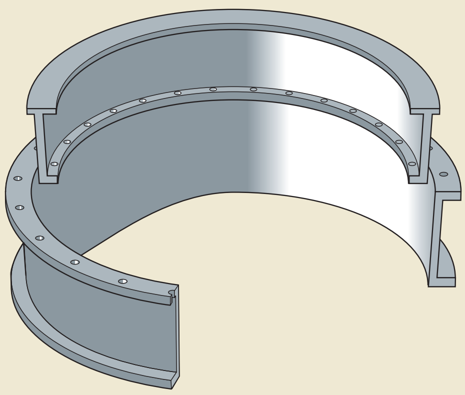
Principles of slewing bearing selection and application

Application of slewing bearings

A slewing bearing arrangement consists of a single bearing that can accommodate axial and radial loads as well as tilting moments acting either singly or in combination and in any direction. To fully utilize these bearings, each of the following design considerations must be met:

- the bearing rings must be fully supported around their complete circumference and across the entire width of the axial side faces by strong and rigid associated components (→ **fig. 1**)
- strength grade 10.9 attachment bolts are used (EN ISO 898)
- the bearing is properly sealed

Fig. 1



Strong and rigid associated components

2

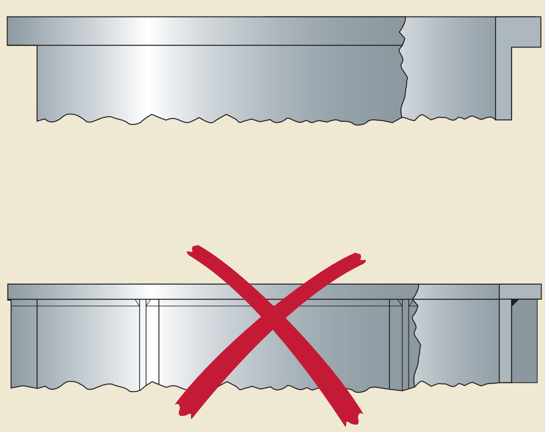
Associated components

To facilitate proper functioning of a slewing bearing arrangement, the support structure must be sufficiently strong and rigid. Furthermore the, flatness of the support surfaces must be within defined limits. For additional information about flatness tolerances, refer to **pages 22** and **23**.

Support structure

Support structures are typically welded frames or castings. Thick-walled cylindrical structures with an inside or outside flange provide better results than thin-walled fabricated structures with a trussed frame (→ **fig. 2**). Moreover, the arrangement of the walls of the sub- and superstructure should correspond with the rolling element assembly, to optimize power transmission.

Fig. 2



Support structure

The flange must support the bearing ring across its entire side face. The thickness of the support flange (→ **fig. 3**) should be in accordance with the following guideline values:

- $S \geq 0{,}05 \times d_m$, for bearings with a mean raceway diameter ≤ 500 mm
- $S \geq 0{,}04 \times d_m$, for bearings with a mean raceway diameter > 500 mm and ≤ 1 000 mm
- $S \geq 0{,}03 \times d_m$, for bearings with a mean raceway diameter > 1 000 mm

The requisite minimum wall thickness (→ **fig. 3**) of the structure can be estimated using

$S_1 = 0{,}35 \times S$

where
S = thickness of the support flange, mm
S_1 = wall thickness of the structure, mm
d_m = mean raceway diameter of the bearing, mm (→ **product tables**)

Support surfaces

Slewing bearings have limited rigidity, due to their relatively small cross sectional height compared to their diameter. The support structure should therefore be designed for maximum axial and radial rigidity. The support surfaces must be flat and free from rust, paint or burrs. Machining is mandatory and the surface roughness should be within the limits R_a = 3,2 to 6,3 µm. Additionally, the support surfaces should be thoroughly washed and dried before mounting to provide the proper frictional joint between the support surface and the bearing surface. Be sure that the support surfaces are not covered with a preservative or coated with oil or grease!

Before bolting each bearing ring to its support surface, it is essential to check the total axial run-out and flatness of the machined support surfaces, since a low section slewing bearing will be distorted by any irregularities. The flatness should be compared to that of an ideal plane surface. The deviations in height between measuring points of the actual surface drawn over the ideal plane are illustrated in **fig. 4**. The following parameters should be checked prior to mounting.

Fig. 3

Support flange and wall thickness

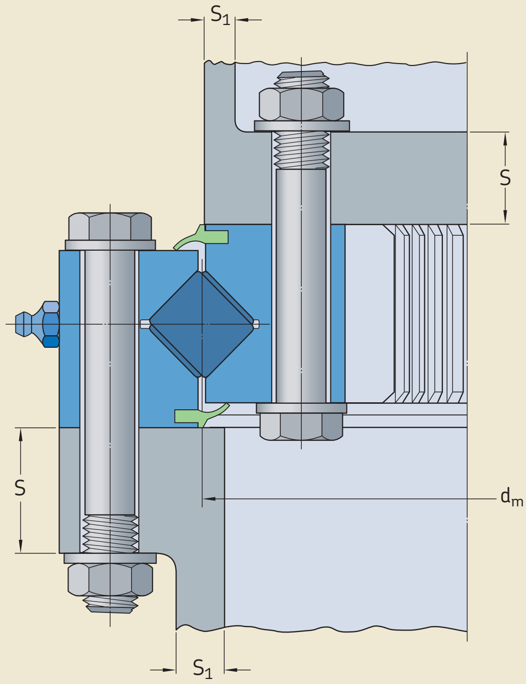
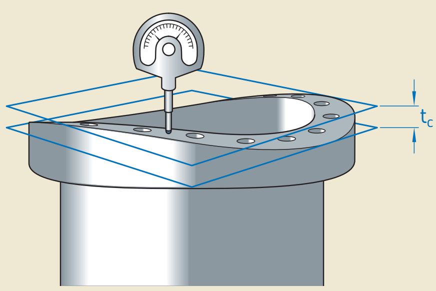


Fig. 4

Overall flatness tolerance



Overall flatness tolerance

The tolerance of the overall flatness in a circumferential direction of the support surfaces (→ **fig. 4**) is limited to

$t_c = (d_m + 1\,000)/10\,000$

where
t_c = maximum permissible deviation from flatness, mm
d_m = mean raceway diameter of the bearing, mm

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Flatness in the circumferential direction

The flatness variation, the difference between the measurements of two consecutive points, as well as the variation in inclination (→ **fig. 5**), is of great importance. It is measured by dividing the circle into small segments of the length "n" smaller or equal to the distance of the attachment bolt hole.

Deviations in the same direction away from the nominal plane, such as measurements "t_{ca}" and "t_{cb}", or "t_{cc}" and "t_{cd}" between two consecutive points, should not exceed the guideline value

$$t_{ca} - t_{cb} \leq 0{,}0002 \times n$$

If however, the inclination changes direction, as at point P in **figure 5**, the sum of the deviations, such as measurements "t_{cb}" and "t_{cc}", should not exceed the guideline value

$$t_{cb} + t_{cc} \leq 0{,}0002 \times n$$

where

$t_{ca} - t_{cb}$ = permissible flatness variation between 2 consecutive measurements, where inclination is constant, mm

$t_{cb} + t_{cc}$ = permissible flatness variation between 2 consecutive measurements, where inclination changes direction, mm

n = distance between two consecutive measuring points, mm

Flatness in the radial direction

Flatness in the radial (transverse) direction, e.g. the conicity (→ **fig. 6**), measured across the width of the support surface is limited to

$$t_t = B / 1000$$

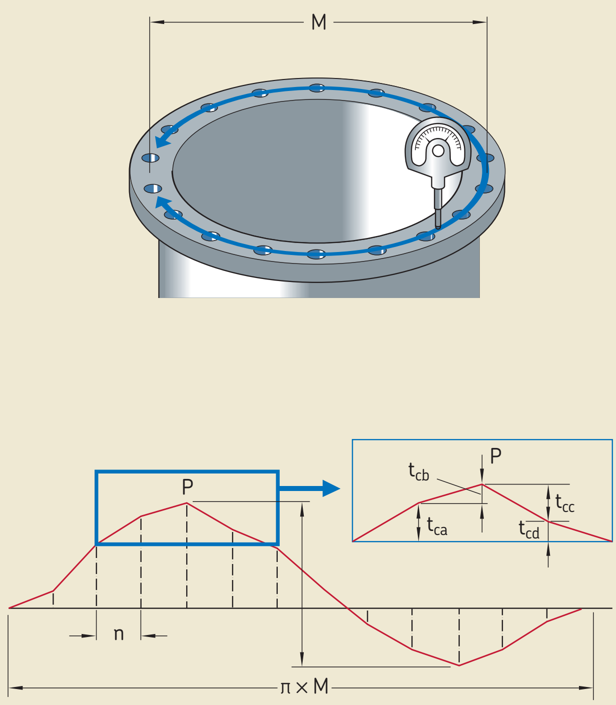
where

t_t = permissible deviation of axial run-out in the radial (transverse) direction, mm

B = width of the support surface, mm

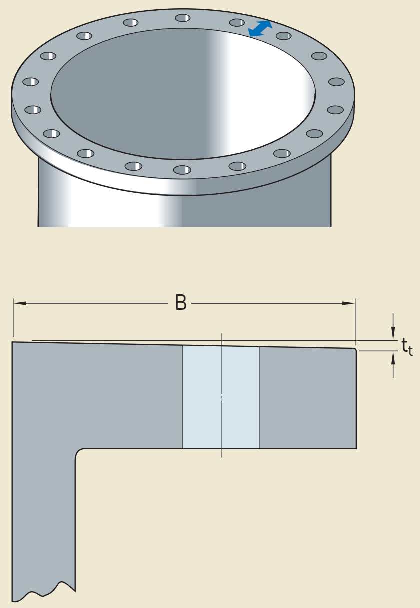
In applications where it is not possible to obtain the permissible tolerances, contact the SKF application engineering service.

Fig. 5



Flatness in the circumferential direction

Fig. 6



Flatness in the radial direction

Attachment bolts

Hexagonal head bolts in accordance with DIN EN ISO 4014:1999 in the 10.9 strength grade (EN ISO 898) are suitable for securing slewing bearings to their support structures. The minimum clamp length of bolted joints (→ **fig. 7**) should be

$L_K = 5 \times G$

where
L_K = the minimum length of bolt joint, mm
G = the bolt thread diameter, mm

Surface pressure in bolt joints

For 10.9 strength grade bolts and nuts, SKF recommends using hardened or quenched and tempered flat washers beneath the bolt head and nut, to avoid excessive surface pressure on the support surfaces. Spring washers of any type should **never** be used.

The recommended tightening torque values for nuts and bolts are provided in **table 1**. Under normal operating conditions, the recommended bolt torque values will provide a reliable and safe connection to the support surface and the application. However, when the arrangement is subjected to very heavy loads, shock loads and/or vibrations, consult the SKF application engineering service.

Calculation of bolted joints

The SKF rules to calculate bolted joints are based on experience in practice and standardized calculation rules. When considering slewing bearing arrangements, a distinction has to be made between supported or suspended bearings (→ **figs. 2** and **3** on **page 9**). In the case of suspended bearing arrangements, consult the SKF application engineering service.

Fig. 7

Bolt joints

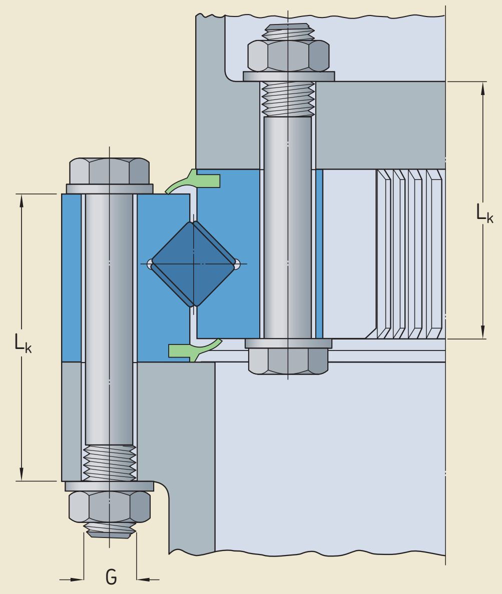


Table 1

Tightening torque and preload of attachment bolts

Attachment bolts/nuts Size[1]	**Tightening torque and assembly preload for bolts to strength grade 10.9** (**EN ISO 898**) M_A[2]	F_M[3]	F_M[4]
–	Nm	kN	kN
M 6	14	13.2	–
M 8	34	24.2	–
M 10	67	38.5	–
M 12	115	56	–
M 14	185	77	–
M 16	285	106	–
M 18	395	129	–
M 20	560	166	–
M 22	770	208	–
M 24	970	239	283
M 27	1 420	315	372
M 30	1 930	385	454
M 33	2 630	480	564
M 36	3 380	560	664

1) ISO general purpose metric threads (DIN 13-1)
2) Tightening torque for coefficient of friction in the bolt head/nut contact surface and the thread μ_K-μ_G = 0,14.
In case of different friction coefficients the tightening torque should be adjusted accordingly
3) Bolt preload corresponding to coefficient of friction in the thread μ_G = 0,14
4) Bolt preload to 90% of the yield point stress. For torsion free tightening, use an HYDROCAM bolt tensioner

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Sealing arrangements

The efficiency of the sealing arrangement has a decisive influence on the service life of every bearing. SKF slewing bearings are normally equipped with contact seals made of acrylo-nitrile-butadiene rubber (NBR), which seal against the shoulder or the side face of the inner or outer ring (→ **fig. 8**).

Depending on the application and the environmental conditions, a secondary seal might be necessary to prevent solid contaminants and moisture from penetrating into the bearing. This secondary seal, for example, might be a large V-ring, which is commercially available (→ **fig. 9**). It could also be designed as a sheet steel cover, bolted to either the rotating or stationary part of the bearing arrangement (→ **fig. 10**).

Fig. 8

Integrated seals

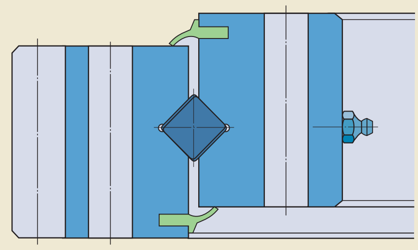


Fig. 9

Secondary seals

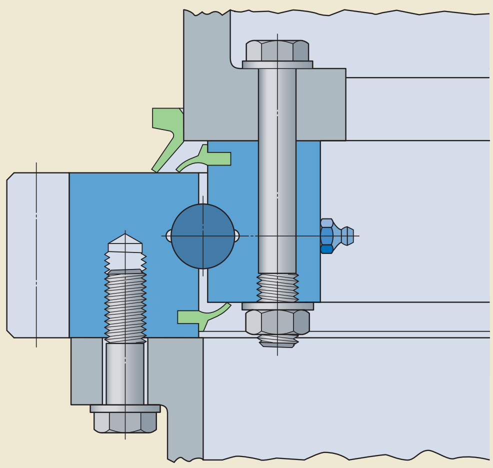
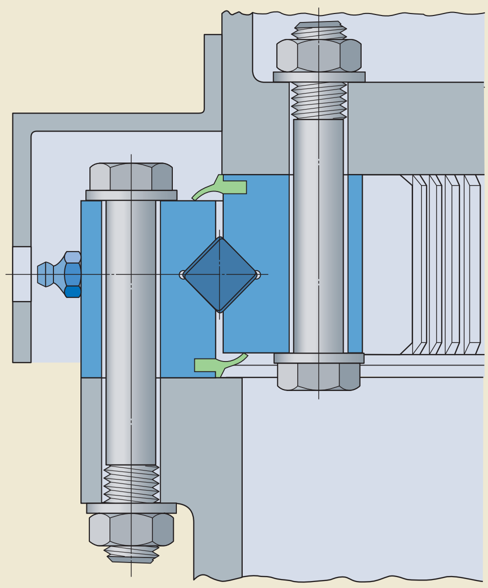


Fig. 10

Sheet steel cover



Slewing bearing gear

Generally, one ring of a slewing bearing comprises a 20° involute cylindrical gear (→ **fig. 1**). These gears have been proven to be the most suitable for heavily loaded slewing bearing arrangements running at low speeds. The module, the number of teeth, the reference diameter and, where necessary, the addendum modification of the gear are listed in the product tables. The permissible tooth forces are also listed in the product tables and are valid for unhardened gears, where

$T_{fnormal}$ = tangential tooth force for normal operating loads based on fatigue stress at the tooth base
T_{fmax} = maximum permissible tangential tooth force, based on fracture at the the tooth base

To provide proper gear performance, the pinions also should be furnished with a 20° involute spur gear. There is a choice between two types of pinion drive arrangements (→ **fig. 2**):

- a drive pinion fixed in relation to the slewing bearing axis (**a**)
- a drive pinion that rotates around the bearing axis (**b**)

Gear backlash

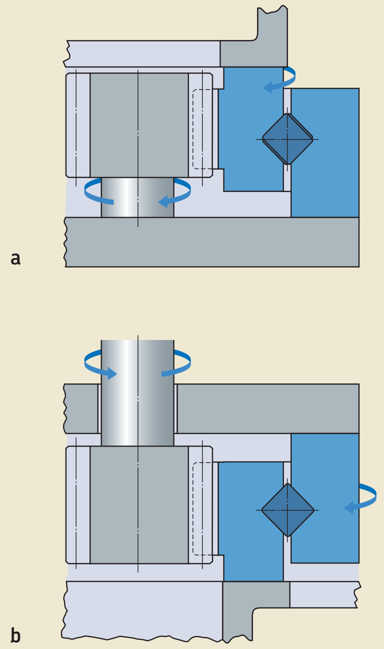
Backlash is defined as the smallest gap between the trailing face of the driving tooth and the leading face of the tooth behind it on the driven gear (→ **fig. 3**). Gear backlash should be checked after positioning the pinion. The measurement should be made at the position where there is a blue marking on the gear (→ bearing markings from **page 40** to **page 45**). This mark indicates:

- the point of the largest distance to the centre, for a bearing with an external gear
- the point of the shortest distance to the centre, for a bearing with an internal gear

Fig. 1

20° involute cylindrical gear

Fig. 2

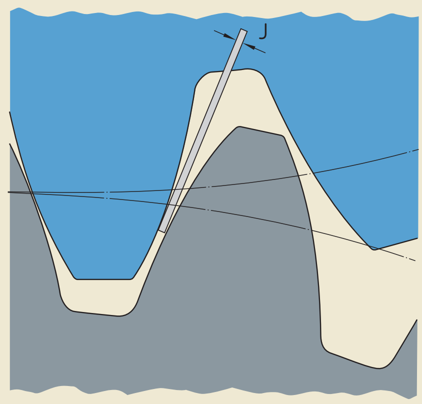


Pinion drive arrangements

This blue marking should face the pinion when determining backlash. To do this, insert the blade of a feeler gauge between two teeth (→ **fig.3**). Applicable backlash values are provided in **table 1**. If the attained values are not within the guideline values, correct backlash by adjusting the centres of the gearwheels. Otherwise, there will be excess pressure between the two sets of gear teeth. Practical experience has shown that zero backlash can produce structural overloads, which will significantly reduce gear life.

Table 1 shows the recommended minimum backlash values for satisfactory meshing under heavy load. On a position of the bearing's circumference other than at the blue marking, higher backlash can occur. This is due to normal form tolerances and has no negative impact.

Fig. 3 *Gear backlash*

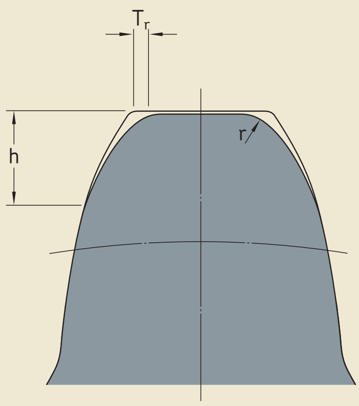


Pinions

The most commonly used pinions are hardened and ground. They should extend past the bearing gear on both sides by approximately 5 mm.

Additionally, a tip relief of 0,01 × module is recommended (→ **fig. 4**) to avoid meshing interference, which may occur at the tooth root area of unhardened bearing gear teeth driven by a hardened pinion. This type of wear (→ **fig. 5**), which manifests itself as increased noise, is not really harmful. The degree of wear will become progressively smaller and the noise level should decrease.

Fig. 4 *Pinion tooth tip relief*



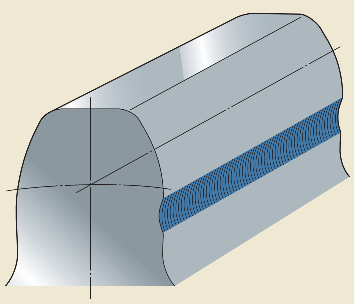
Tip relief T_r = 0,01 × module
Height h = 0,4 ... 0,6 × module
Radius r = 0,1 ... 0,15 × module

Table 1

Required backlash at blue marking

Module		**Backlash** J	
over	incl.	min	max
mm		mm	
3,15	**6,3**	0,25	0,375
6,3	**10**	0,3	0,45
10	**12,5**	0,45	0,675
12,5	**16**	0,6	0,9
16	**20**	0,8	1,2
20	**25**	1	1,5

Fig. 5 *Meshing interference*



Lubrication

For a slewing bearing to function properly and provide maximum service life, proper relubrication and regular maintenance intervals are essential. The primary function of a lubricant is to create an oil film between the rolling elements and raceways as well as between the gears, to prevent metal-to-metal contact.

Slewing bearings are generally lubricated with grease, which also provides added protection against the ingress of water and contaminants.

As slewing bearings normally operate at slow speeds, the free space between the rings can be filled entirely with grease.

Bearing lubrication

Unless otherwise specified, SKF slewing bearings are filled with an NLGI class 2 mineral oil based EP-grease containing a lithium soap thickener. This grease provides extremely good corrosion inhibiting properties and excellent mechanical stability. The grease has a temperature range of –20 up to +110 °C. Reliable lubrication according to the SKF traffic light concept is in the operating temperature range of +30 to +110 °C.

SKF recommends relubricating slewing bearings with SKF LGEP 2, a mineral oil based grease with a consistency of 2 on the NLGI scale. In special cases, where the bearing must operate reliable at low temperature, an NLGI grease with a consistency of 1 or 0 can be used.

Information about appropriate SKF greases can be found in **table 1**.

Slewing bearings should be greased immediately after mounting, until fresh grease starts to escape from the seals around the whole circumference.

Gear lubrication

The gear of a new bearing is normally coated with a preservative but is not greased.

After the bearing has been mounted, a lubricant needs to be applied to the gear. This lubricant, which is usually grease, should have

- a base oil viscosity of at least 500 mm^2/s at 40 °C
- good adhesive properties
- a high resistance to water washout.

In addition, the grease should be able to withstand temperatures of at least +100 °C.

Table 1

SKF greases for slewing bearings

SKF designation	Permissible temperature range (°C) min	max	Remark
LGEP 2	-20	+110	
LGLT 2	-50	+110	
LGGB 2	-20	+110	Bio degradable
LGHB 2	-20	+150	

Relubrication intervals and quantities

Bearings

Relubrication should always be undertaken at a time when the condition of the existing lubricant is still satisfactory. This time depends on many related factors including bearing type and size, operating temperature, frequency of operation, grease type and the bearing environment. In order to facilitate good grease distribution, the bearing should always be relubricated while it is in operation.

The relubrication interval t_f for the raceway of slewing bearings mounted on a horizontal support structure under normal and clean conditions can be obtained from the blue line of **diagram 1**, as a function of the number of operating hours per week.

The relubrication interval t_f is an estimated value, valid for an operating temperature of 70 °C, using a good quality grease. If there are severe operating conditions, such as very dirty or damp environments or if operating temperatures exceed 70 °C, more frequent relubrication may be necessary. For additional information, contact the SKF application engineering service.

The quantity of fresh grease depends on the bearing size. Suitable quantities for single row slewing bearings can be obtained from the red line of **diagram 2** as a function of the mean raceway diameter.

The new grease must be identical to, or miscible with, the grease already contained in the bearing. A mixture of two immiscible greases will impair the efficiency of the lubricant.

Gears

The relubrication interval, t_f, for the gears can be obtained from the red line of **diagram 1** as a function of the number of operating hours per week.

Before regreasing the gear, the teeth should be cleaned of any impurities.

The lubricant can be brushed or sprayed onto the gear or by any other suitable method, e.g. a SKF lubricating pinion (→ **fig. 3** on **page 31**). The grease quantity depends on the method chosen.

Diagram 1

Relubrication interval t_f for slewing bearings and gears

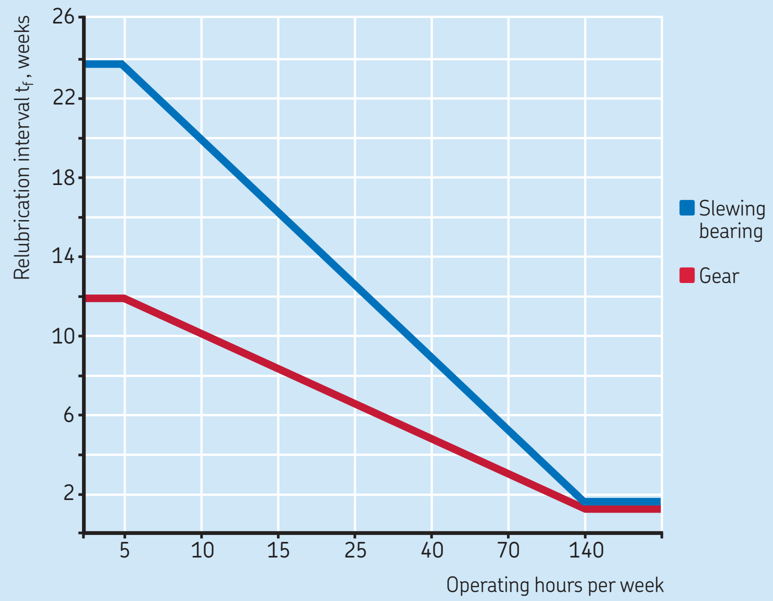
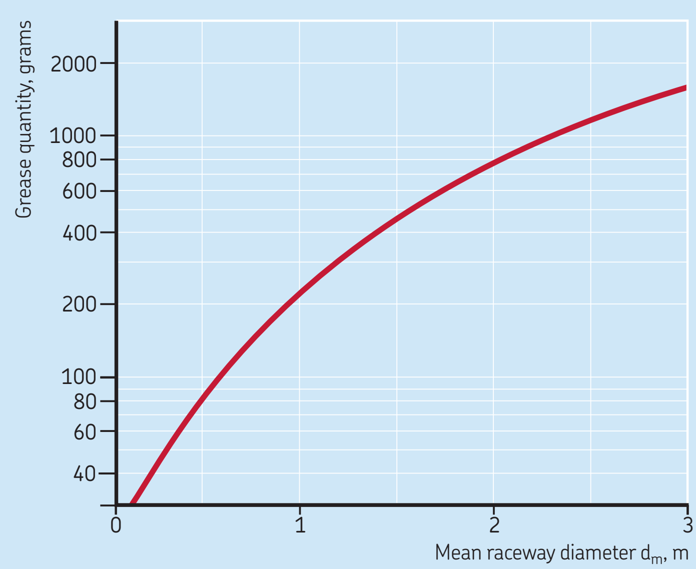


Diagram 2

Suitable grease quantities for bearing replenishment



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Relubrication procedures

Manual relubrication

Light series and medium size bearings can be relubricated through four equally spaced cone type grease fittings to DIN 71412:1987, design A, in the inner and/or outer ring (→ **fig. 1**). Appropriate grease guns are available from SKF. Additional information about SKF maintenance products can be found in the publication MP3000 "SKF Maintenance and Lubrication Products" or online at www.mapro.skf.com.

Automatic relubrication

An automatic relubrication system is typically used when the calculated relubrication interval is very short, e.g. due to contamination, or when the bearing is not easy to access.

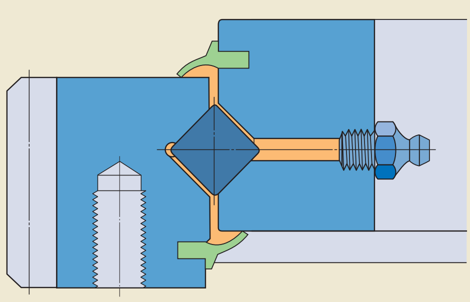
When using automatic relubrication, check whether the grease can be adequately pumped through the ducts at the prevailing ambient temperature.

Automatic lubrication can be achieved via single-point automatic lubricators, multi-point lubricators or centralized lubrication systems, depending on the demands of the application. SKF SYSTEM 24 is a single-point lubricator that can be screwed directly into one of the threaded holes used for grease fittings (→ **fig. 2**). SKF SYSTEM Multipoint can lubricate up to 8 lubrication points and is refillable. Additional information about SKF automatic lubricators can be found in the publication MP3000 "SKF Maintenance and lubrication products" or online at www.mapro.skf.com. Centralized lubrication systems (→ **fig. 3**) typically consist of:

- grease pumps (**1**), one to grease the bearing and one to grease the gear, optionally with electronic control and/or an exchangeable container
- a progressive distributor (**2**)
- a lubricating pinion (**3**) for automatic and even lubricant distribution across the entire gear
- a lubricant collector (**4**) for the environmentally friendly removal of used lubricant from the gear

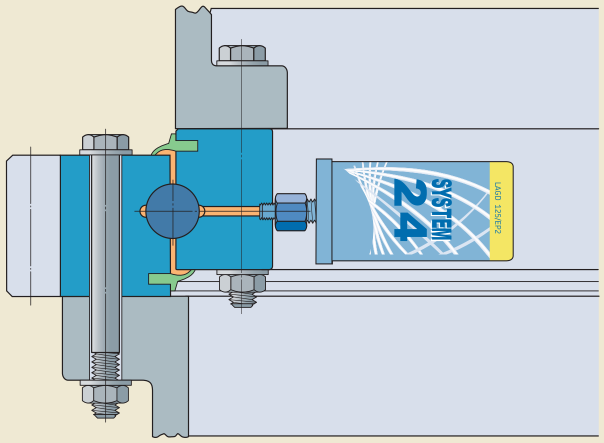
Additional information about SKF lubrication systems is available online at www.skf.com, or contact the SKF application engineering service.

Fig. 1



Manual relubrication via grease fittings

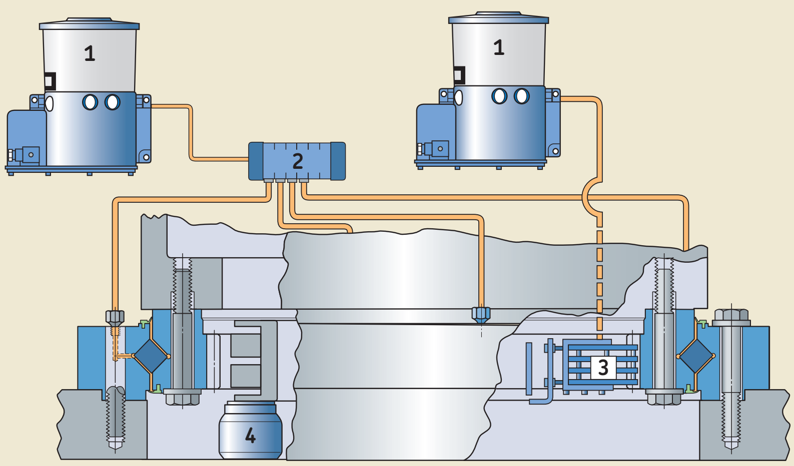
Fig. 2



Continuous relubrication via single-point automatic lubricators

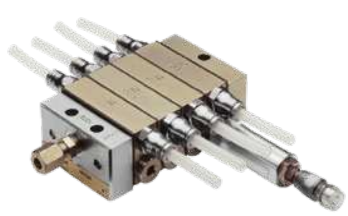
Continuous relubrication via centralized lubrication systems

Fig. 3



1

2



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4

Application data sheet for slewing bearing arrangements

Customer

Company:

Street, ZIP code, City:

Contact:

Telephone: Telefax: Email:

Date of inquiry: Date of reply required:

Signature:

Delivery requirements

Required quantities: Quantity per year: Date of first delivery:

Special delivery requirements:

Application

Description of application:

Position of axis: ☐ Vertical ☐ Horizontal ☐ Changing

Position of bearing: ☐ Supported ☐ Suspended

Existing/chosen bearing, Designation:

Bearing load

Type of load	Operating conditions					
	Normal load amount	% of time	**Maximum load** amount	% of time	**Maximum** test load	**Extreme loads** (out of operation)
Axial loads F_a (kN) parallel to axis of rotation						
Radial loads F_r (kN) at 90 ° to axis of rotation						
Resulting moment M_t (kNm)						
Rotational speed (r/min)						
Slewing working angle (degrees)						

Tangential forces

Tooth force (kN): Normal force: | Maximum force: | Number of drives:

Motion

☐ Continuous rotation ☐ Slewing motion ☐ Intermittent

Dimensional limitations

Outside diameter (mm): | Preferred: | Minimum/maximum:

Inner diameter (mm): | Preferred: | Minimum/maximum:

Bearing height (mm): | Preferred: | Minimum/maximum:

Gear data

☐ Internal gear ☐ External gear ☐ Without a gear

Reference diameter (mm): | Preferred: | Minimum/maximum:

Tooth height (mm): | Preferred: | Minimum/maximum:

Module: | Preferred: | Minimum/maximum:

Sealing arrangements

On top: ☐ Yes ☐ No ☐ Internal ☐ External

At the bottom: ☐ Yes ☐ No ☐ Internal ☐ External

Attachment bolt hole

Outer ring ☐ Through holes ☐ Tapped holes ☐ Number of bolts:

Bolt hole diameter (mm): | Preferred: | Minimum/maximum:

Bolt hole pitch circle diameter (mm): | Preferred: | Minimum/maximum:

Lubrication of raceways

☐ Grease ☐ Manual relubrication ☐ Central grease lubrication system

☐ Oil bath ☐ Central oil lubrication system ☐ Other

Lubrication of gear

☐ Manual grease lubrication ☐ Central grease lubrication system

Temperatures

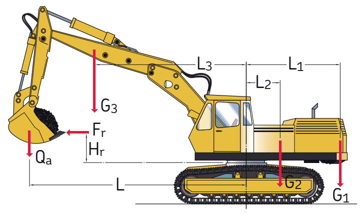
Operating temperatures (°C): ☐ Minimum ☐ Maximum

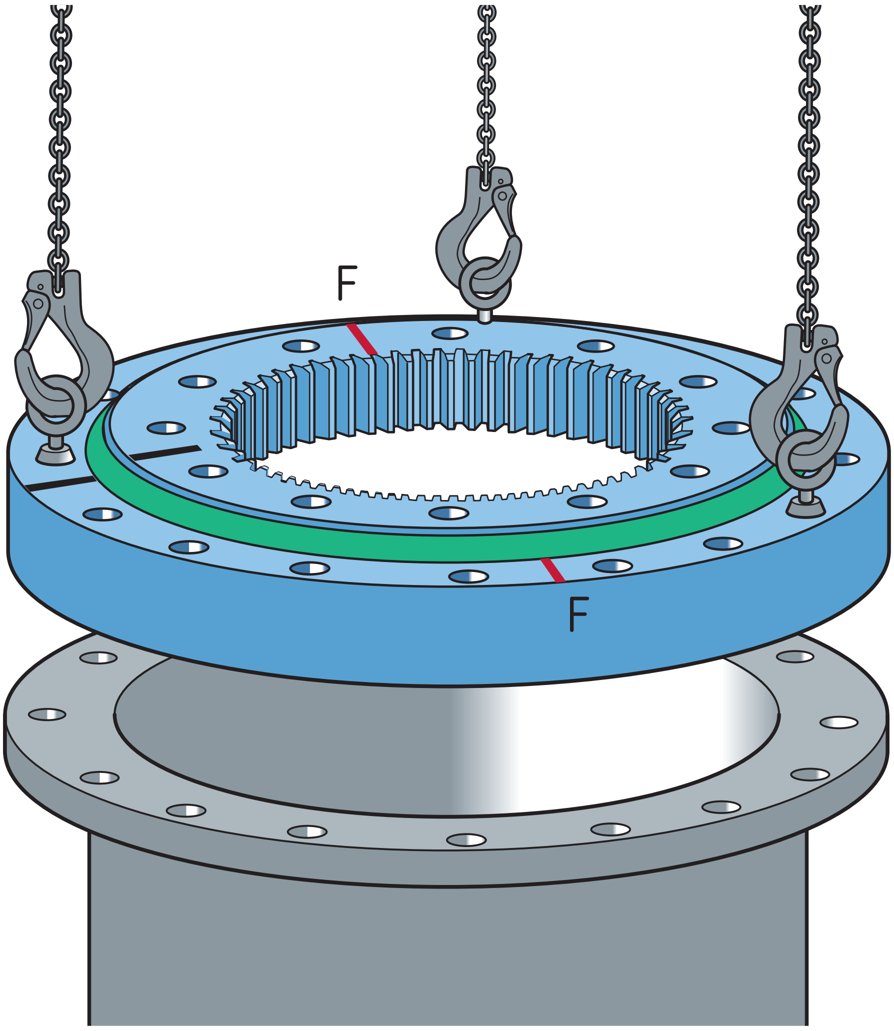
Ambient temperatures (°C): ☐ Minimum ☐ Maximum

Special requirements

Centring recesses / Required accuracy / Required lubricant / Ring material / Inspection and/or certification requirements

Engineering layout

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