

your global specialist

Special knowledge

The element that rolls the bearing.

Tips and advice for the lubrication of rolling bearings





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Speciality lubricants from Klüber Lubrication – always a good choice

Quality put to the test

- Klüber Lubrication has more than 110 test rigs, which include standardised equipment as well as tools Klüber Lubrication has developed to regularly test the quality of its products.
- Test results prove the high quality level and provide you with a solid basis for selecting the right lubricant.
- You can obtain products made by Klüber Lubrication in consistent quality at our production plants worldwide.

Benefit from experience

- Close cooperation with OEMs and operators since 1929
- Series supplier to many OEMs on all continents
- OEMs in all industries recommend lubricants from Klüber Lubrication for their components
- Alliances with partner companies for maximum user benefit
- The product range comprises oils, greases, pastes, waxes and bonded coatings, so the right lubricant for any application can be selected.

Time is money – we help to save you both by enabling

- Optimised processes
- Higher productivity
- Compliance with legal requirements and quality standards
- Reduction of maintenance times and repair costs
- Development partnerships giving you a head-start in innovation and differentiating yourself from the

Humans and the environment – what really counts

- Products that last a lifetime and enable minimum-quantity lubrication to be used help to save resources and reduce disposal quantities.
- Speciality lubricants optimised for higher efficiency reduce energy consumption and hence CO₂ emission.
- Clean, safe products that are easy to handle are the fundamental criteria used in the lubricant development by the experts from Klüber Lubrication.
KlüberEfficiencySupport
- Klüber Lubrication Services – Success for you from one tool box!

KlüberEfficiencySupport

Klüber Lubrication Services – Success for you from one tool box!

- **KlüberEnergy:** Services for optimum energy efficiency of your lubricant application. Reports on concrete savings
- **KlüberMaintain:** Support for your lubrication management and maintenance programme / TPM1) considering the necessary lubrication maintenance tasks
- **KlüberMonitor:** We recommend optimisations to increase your productivity on the basis of tribological analyses of your application and bench tests
- **KlüberRenew:** Services to increase the lifetime of your cost-intensive components such as large gear drives and chains including appropriate training

Lubricants for rolling bearings from Klüber Lubrication

Rolling bearings are among the most important machine elements

They may be designed as ball or roller bearings, radial or thrust bearings; what they all have in common is the transmission of load and power via rolling elements located between bearing rings. This is a simple and successful principle, at least as long as the contact surfaces remain separated. However, if the surfaces contact one another, there can be trouble ahead: the resulting damage caused may be anything from light, hardly perceptible surface roughening, pronounced sliding and scratching marks, to extensive material transfer that may promote premature bearing failure – with expensive consequences!

A vital requirement for low-wear or even wear-free operation of rolling bearings is the sustained separation of the surfaces of rolling elements and raceways, i.e. the friction bodies, by means of a suitable lubricant.

Fit for new challenges

The experts at Klüber Lubrication know from 80 years of experience in the manufacture of speciality lubricants that a rolling bearing can only be as good as the lubricant it contains. They consider lubricants to be vital design elements that require constant improvement, as operating conditions under which bearings must perform become tougher and tougher. While a few years ago, for example, 60,000 operating hours was considered a good operational lifetime for bearings in a fan motor, today 110,000 operating hours or more are expected.

Taking care of bearings worldwide

Klüber Lubrication meets these requirements by developing new, innovative speciality lubricants and offering customer-oriented service: we provide immediate solutions to difficult lubrication and application problems plus comprehensive information and reliable supply around the globe. Just call or e-mail – we will be there to assist you.

In close cooperation with customers, Klüber Lubrication develops rolling bearing lubricants – mostly greases – that are specifically tuned to the application at hand. These special lubricant developments are based on the latest know-how in tribology, contain the highest quality raw materials and have been extensively tried and tested.

Keeping the ball rolling

Whether your bearings are installed in paper-making or printing machines, household appliances, food-processing plants or even in aerospace applications, rolling bearing greases from Klüber Lubrication will help them to do what they are designed for: rolling.

Small investments make the difference

Speciality lubricants can do a lot for your rolling bearings: they extend bearing lifetime, increase the reliability of operation, lower the noise level, allow higher bearing running speeds and make bearings resistant to extreme conditions. The costs for speciality lubricants are outweighed by many benefits, so in reality the lubricant is a small investment that makes a big difference.

We are at your side – right from the start

With this brochure, we would like to provide you with valuable information on the lubrication of rolling bearings. We know that this is a complex issue, and therefore we offer you expert consulting – right from the start.

Selecting the right lubricating grease

There was a time when a conventional lithium/mineral simple soap grease was deemed adequate for most rolling bearing applications. In the future, however, lubricants that are tailored precisely to a specific application will become more and more important. Even today the variety of lubricating greases available is immense, making correct selection increasingly difficult.

In the following, the most important application selection criteria are provided to assist you in selecting the correct grease via a few simple steps. If you have any further questions, particularly in relation to complex applications, safety components, long service life or applications subject to special conditions, please contact the specialists at Klüber Lubrication, who will gladly assist you to fully utilise the potential of your equipment by selection of the optimum lubricant.

HINT: The more information provided in relation to the application, the better will be the final selection of the optimum lubricant.

The following procedure will assist you in selecting the correct lubricating grease.

Prior to lubricant selection, the following parameters are usually analysed or calculated:

- Operating temperature
- Base oil viscosity
- Speed factor
- Load ratio C

Operating temperature

Rolling resistance occurs not only between a rolling bearing's raceway and rolling elements. Depending on the bearing type, either partial sliding between the rolling elements and the bearing raceways or sliding between the cage and the rolling elements occurs, through which the lubricant is pressed and displaced.

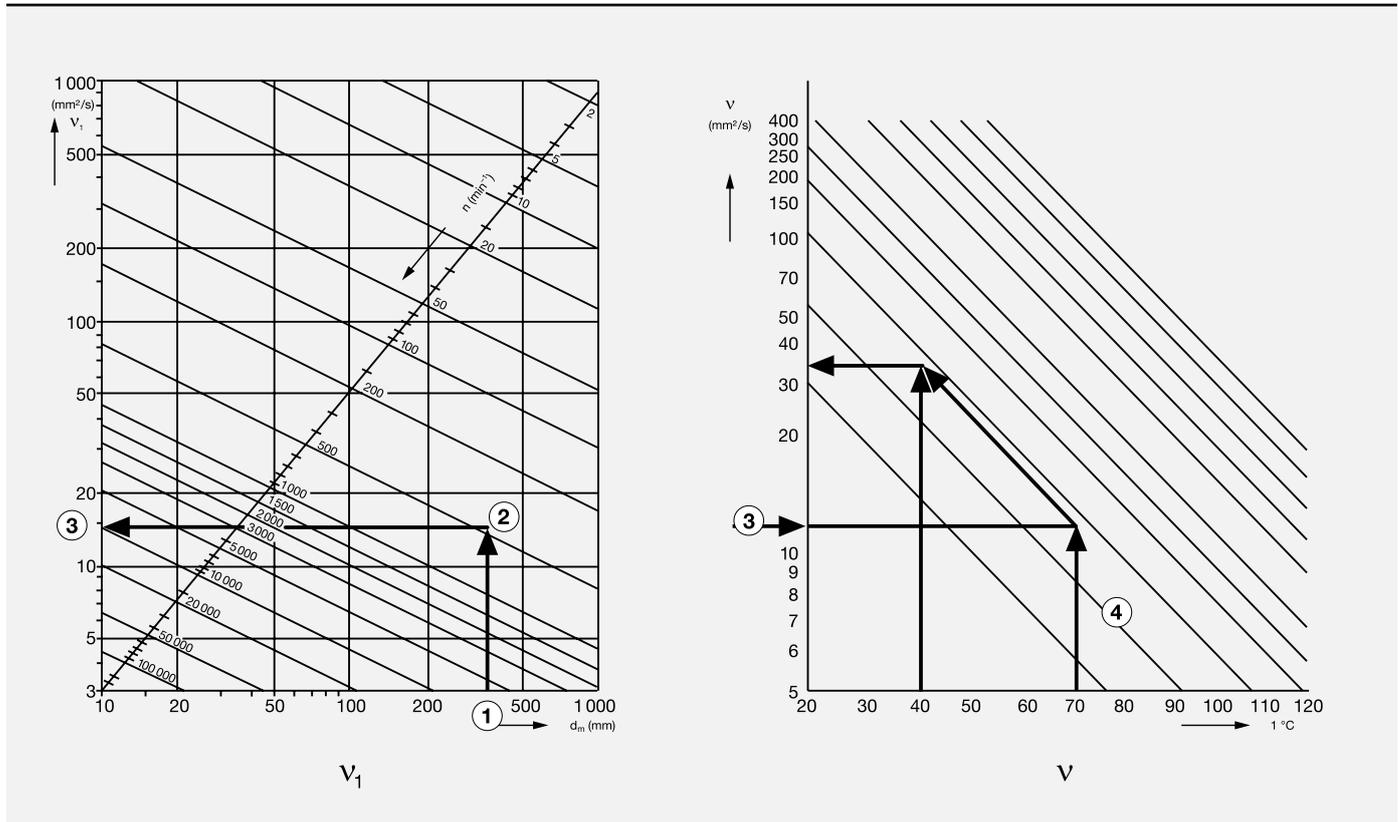
Due to internal friction, the inherent operating temperature of a bearing is likely to be somewhere between 35 °C (95 °F) and 70 °C (158 °F); however, external process-related temperature can influence the bearing such that its final operating temperature may be much higher or sometimes lower. The requirements regarding lubricants can vary substantially. Automotive manufacturers, for example, typically have to consider temperatures between –40 °C (–40 °F) and +160 °C (320 °F). Aviation applications require service temperatures as low as –50 °C (–58 °F), as the bearings are subject to extremely low temperatures when exposed to high altitude. Stoving temperatures for lacquers can easily reach 200 °C (392 °F). In certain applications temperatures may be even more extreme. Therefore, when choosing a grease, one should make sure that the lubricant's service temperature range is sufficient to easily cope with any additional temperature influences that may be encountered in practice.

HINT: In order to attain a satisfactory grease life, a grease should be selected whose upper service temperature limit is considerably higher than the maximum operating temperatures to be expected.

Determination of minimum base oil viscosity

For determination of minimum base oil viscosity, the mean bearing diameter d_m in [mm], the bearing speed and the bearing temperature under standard operating conditions are used. The required minimum base oil viscosity for the example shown at 40 °C (104 °F) = 38 mm²/s:

To calculate the correct viscosity ratio for oil and grease, you should use the published base oil viscosities at 40 and 100 °C and apply them to the v-T diagram. Now figure out the viscosity v of the base oil at the operating temperature.



① – ④ Steps 1-4 explain the order in which base oil viscosity is determined.

Legend	
Bore	340 mm
Outer diameter	420 mm
① Mean bearing diameter	380 mm
② Speed	500 min ⁻¹
③ Base oil viscosity at operating temperature	14 mm ² /s
④ Temperature	70 °C

NOTE: All statements according to GfT worksheet 3, edition May 1993 apply to mineral oils only. We will be pleased to provide information on synthetic oils upon request.



The actual base oil viscosity ν should be $\nu_1 \cdot 1 \dots 4$. The following is generally used as a parameter indicating the expected lubrication condition:

- $\kappa^* = \nu / \nu_1 =$ viscosity ratio
- ν = viscosity under standard operating conditions
- ν_1 = required minimum viscosity, depending on mean bearing diameter and speed

The following table provides an overview of the anticipated lubricating conditions indicating whether antiwear additives, EP additives or solid lubricants are required.

Lubrication condition κ	
4	Full fluid-film lubrication
> 4	In the regime of full fluid-film lubrication + cleanliness + moderate loads = no fatigue
< 4	Mixed friction. Lubricating greases containing antiwear additives have to be used
1	The basic rating life of the rolling bearing is achieved
< 0.4	Mixed friction with increased solid contact; the grease has to contain EP additives or solid lubricants

HINT: If $\kappa > 4$, the operating temperature may rise due to increased internal friction from the lubricant.



Speed factor

The speed factor $n \cdot d_m$ for rolling bearings

Bearing $n \cdot d_m$ value is determined by the speed of the bearing at standard operating conditions n in $[\text{min}^{-1}]$ multiplied by the mean bearing diameter d_m in $[\text{mm}]$.

The speed factor $n \cdot d_m$ for lubricating greases

The attainable speed factor of a lubricating grease depends largely on its base oil type, viscosity, thickener type, and of course the bearing type used. Under high-speed bearing operating conditions it is important to achieve a constant oil supply at a defined rate within the bearing combined with optimum lubricant adhesion to the bearing surfaces if successful lubrication is to be achieved.

For most rolling bearing greases from Klüber Lubrication, the maximum speed factors for use in deep groove ball bearings are specified. They should not be lower than the speeds to be expected in a given application. Please contact Klüber Lubrication for further assistance in this respect.

The following table contains the anticipated speed factors for a number of greases:

Lubricating greases / base oil viscosities and their effect on speed factors

Grease types	Base oil viscosity at approx. 40 °C (104 °F) $[\text{mm}^2/\text{s}]$	Speed factor $n \cdot d_m$
Mineral oil/lithium/MoS ₂	1 000 to 1 500	50 000
Mineral oil/lithium complex	400 to 500	200 000
Mineral oil/lithium complex	150 to 200	400 000
Ester/polyurea	70 to 100	700 000
Ester/lithium complex	15 to 30	1 000 000
Ester/polyurea	15 to 30	2 000 000



Load ratio C/P

The ratio between the bearing's basic dynamic load rating C in [N] and its actual equivalent dynamic load P in [N] under standard operating conditions allows conclusions regarding the requirements to be met by the grease. The values in the following table should be observed for the selection of a suitable grease.

Load ratio C/P

C/P	Load	Criteria for grease selection
> 30	Very low loads	Max. permissible load for silicone greases
20–30	Low loads	Dynamically light greases
8–20	Medium loads	Greases containing antiwear additives
4–8	High loads	A grease with EP and antiwear additives is to be used. Reduced grease/bearing life to be expected
< 4	Extremely high loads	A grease containing EP additives + solid lubricants is to be used. A considerably reduced grease/bearing life is to be expected

Grease application in rolling bearings

Around 90 % of all rolling bearings are lubricated with grease. Grease lubrication poses far less sealing problems than oil lubrication and allows much simpler machine designs. A further benefit of today's high-speed grease formulations are operational speed factors up to 2 million $n \cdot d_m$ – more than twice of what used to be possible! It is not surprising therefore that grease lubrication of rolling element bearings is on the increase compared to the former use of oil lubrication methods.

With grease-lubricated rolling bearings we differentiate between lifetime lubrication and bearings which require relubrication. In general terms lifetime lubrication does not depend on the bearing but on the requirements of the particular application.

a) Lifetime lubrication of rolling bearings

Depending on the bearing type, size and its intended application, the initial lubrication at the bearing manufacturer can be quite a costly affair, especially for low-noise bearings, high-precision bearings or high-speed spindle bearings. Rolling bearing manufacturers have developed their own initial lubrication techniques for application of grease to newly manufactured rolling bearings. The chosen technique normally involves a central lubricating system conveying the grease from its original container to the filling station, from where it is applied to the bearing via nozzles.

Certain special greases from Klüber Lubrication may be applied to the bearing in minimum quantities during initial lubrication. Minimum grease quantities reduce the need for lengthy running-in times. In certain cases it may be possible to eliminate the need for running-in altogether.

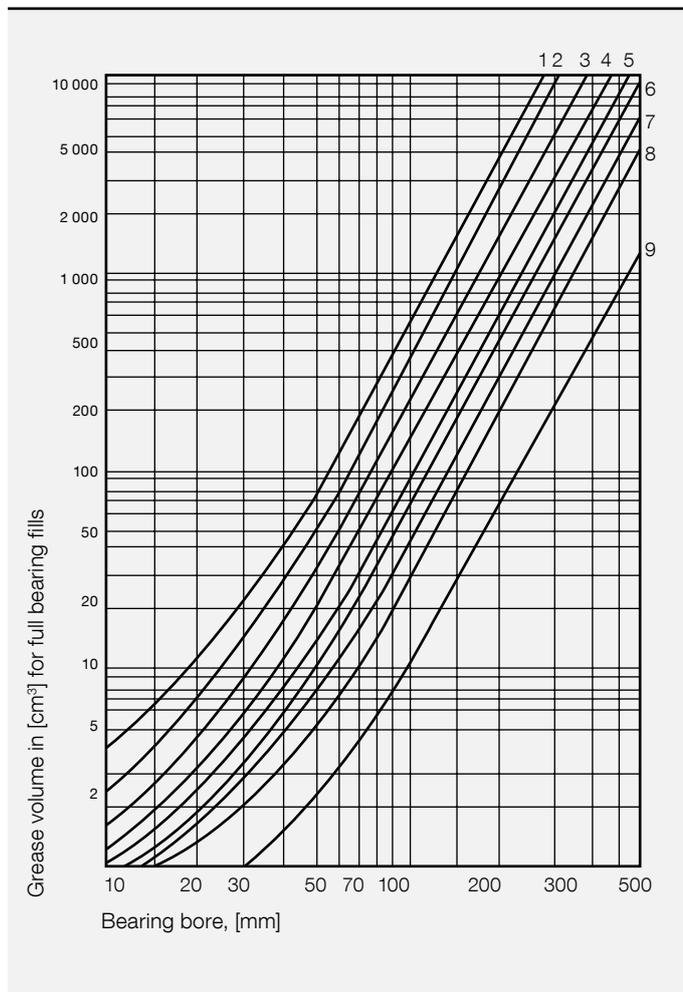
b) Loss lubrication

Loss lubrication means that the rolling bearing has to be relubricated with a precise quantity of lubricant from time to time in order to attain the specified bearing life. This lubrication frequency may vary tremendously, from once every few years to almost continuous application.

By the use of optimum relubrication quantities and intervals, machine users can attain considerable savings. Klüber Lubrication provides high-performance greases of the highest quality that help to minimise costs through attainment of the longest possible relubrication interval. Lubricating greases can be applied to the bearing by means of hand-operated or automatic grease guns, centralised lubricating systems etc.

How much grease does the bearing need?

For determination of grease quantities, once again the differentiation between lifetime lubrication and loss lubrication is of importance. The following diagram can be used to determine the free space in different types of bearings for initial lubrication purposes.



Reference values for filling quantities (density approx. 0.95 g/cm³)

Bearing free space according to Schaeffler:

The bearing free space indicated in the diagram applies to Schaeffler bearings and may only serve as a reference value for bearings made by other manufacturers.

Bearing series	Curve
Deep groove ball bearing	
618 T-cage	8–9
618 M-cage	9
160	7
60	6
62	4
63	2–3
64	1
Angular contact ball bearing	
70	6
72B	4
73B	2–3
Tapered roller bearing	
302	3–4
303	2
313	2
320	6
322	3–4
323	1–2
329	7–8
330	5
331	4
332	4
Cylindrical roller bearing	
NU10	7
NU2	5
NU22	4
NU23	2
NU3	3
NU4	2
NN30K	5
NNU49	7
Spherical roller bearing	
213	3
222	4
223	2
230	6
231	4
232	3–4
239	8
240	5
241	3

Calculation of the bearing free space

According to the GfT worksheet 3, bearing free space can be determined by means of the formula below. Deviating from the GfT worksheet, the formula uses volume units instead of weight units in order to avoid calculation errors due to the different densities of greases.

$$V \approx [\pi/4 \cdot B \cdot (D^2 - d^2) \cdot 10^{-9} - G/7\,800] \text{ m}^3$$

wherein

d = bearing bore diameter [mm]

D = outer bearing diameter [mm]

B = bearing width [mm]

G = bearing weight [kg]

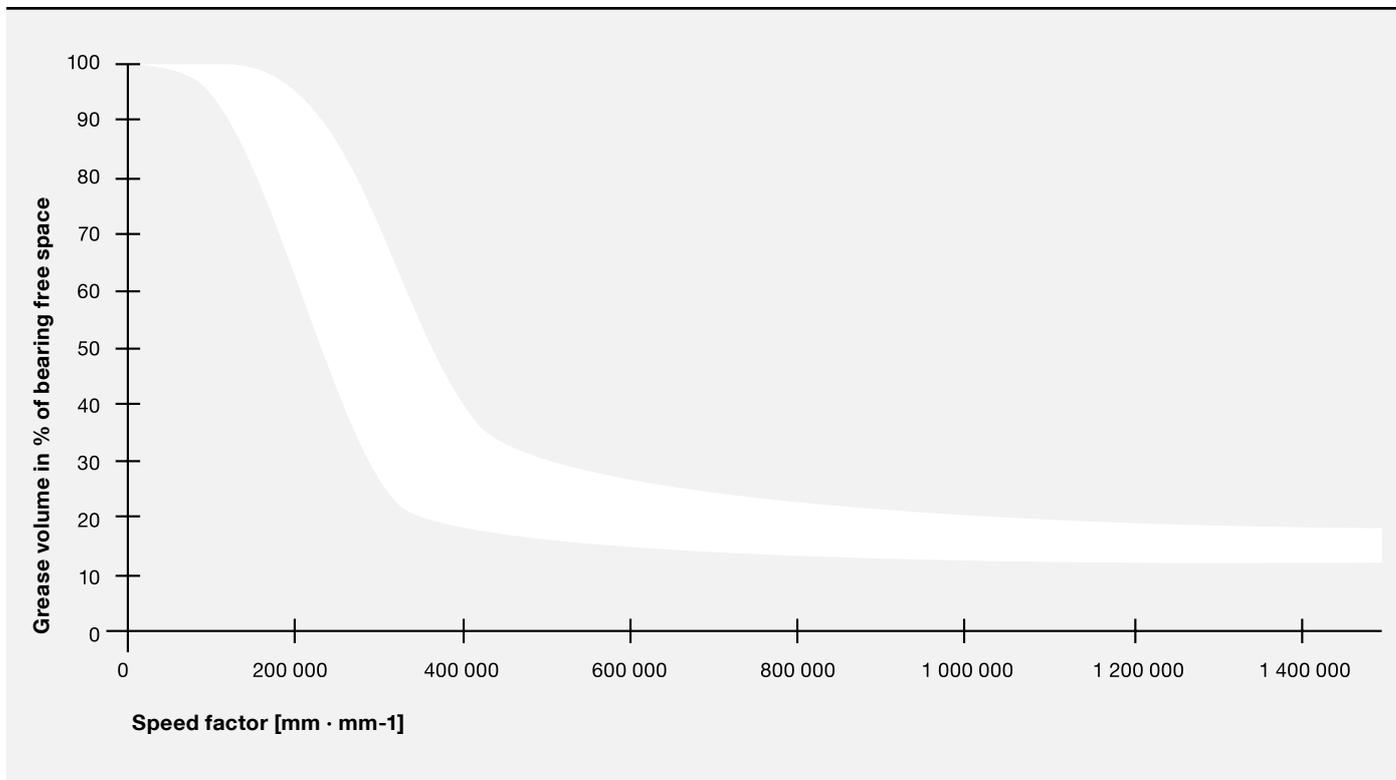
It should be noted that due to the many different bearing types, cages and designs, the above-mentioned formula can only provide a rough “rule of thumb” estimation of bearing free space. It is advisable therefore to seek consultation with the bearing OEM to determine the actual bearing free space in each specific case.

Once the bearing free space has been determined, the required grease quantity is calculated as a percentage of the available free space. The correct quantity is important to ensure proper lubrication of all contact surfaces. Overlubrication can be just as detrimental as underlubrication: for example, too much grease in high-speed bearings may lead to overheating or the development of higher starting and running torque.

A rule that should generally be observed is:

Low operating temperatures = long service life of both the grease and the bearing. The following diagram provides an overview of the required grease quantities as a percentage of bearing free space for various speed factors in [mm · min⁻¹].

In addition to speed factor, bearing type, environmental factors and grease quantity, compatibility with any elastomer seals and orientation of the bearing should also be taken into account.



The area marked in white indicates the grease fill as a function of the speed factor



Loss lubrication

In some applications, the relubrication of bearings is unavoidable. In the following you will find systematic instructions on how to determine relubrication quantities and intervals plus additional information regarding loss lubrication in general.

a) Lubrication intervals

Lubrication intervals for a particular application may vary significantly with different greases. It makes sense therefore for development and design engineers to decide at an early stage whether a central lubricating system will be needed to deliver the required grease. In existing machines, relubrication intervals and grease consumption quantities can often be reduced by selection of a higher specification lubricant. At the same time this usually increases operational reliability.

Relubrication intervals should be approx. 0.5 to 0.7 x the theoretical reduced grease service life F_{10q} . For the calculation of the theoretical reduced grease service life F_{10q} , see the respective paragraph of this chapter.

b) Lubricating quantities

For the initial lubrication of bearings, whether subject to lifetime or loss lubrication conditions, quantities are determined in the same manner as described in the chapter "How much grease does the bearing need?". For calculating relubrication intervals, the GfT worksheet 3 (made by the German Society of Tribology) differentiates between three different cases:

1. Relubrication once per week or once per year

The relubrication quantity M1 – for relubrication once per week to once per year – is calculated by applying the formula

M1 = D · B · X, with X standing for

weekly: X = 0.002

monthly: X = 0.003

yearly: X = 0.004

M1 in cm³

D = bearing diameter in [mm]

B = bearing width in [mm]

This shows that the relubrication quantity M1 depends on both the calculated and chosen relubrication interval. In order to attain an improved flushing effect, especially in bearings with long relubrication intervals, the relubrication quantity M1 can be increased up to three-fold.



2. Relubrication at extremely short intervals

The relubrication quantity M2 for relubrication at extremely short intervals is calculated by applying the formula

$$M2 = (0.5 \dots 20) \cdot V \text{ [cm}^3\text{/h]}$$

with

$$V = \text{bearing free space [cm}^3\text{]}$$

as described in the chapter “Grease application in rolling bearings”.

Applications with short relubrication intervals are those incorporating centralised lubricating systems. When selecting the grease, it has to be taken into consideration that lines with a big diameter and long lines as well as progressive distributors cause high pressure loss in the lines. Soft greases (e.g. NLGI grades 1 or 0) are the best choice for such applications. Depending on the calculated and chosen relubrication interval, a flow factor between 0.5 and 20 is selected. Such applications are normally found where high operating temperatures prevail. It should be noted that the grease is often exposed to high temperatures during its way through the central lubricating system pipework, i.e. it is often subject to thermal stress well before it ever reaches the bearing friction point!

Depending on factors such as application service temperature and theoretical relubrication interval, the grease within the centralised lubrication system, the housing and bearing free space should be replaced completely once every six months to once every year. This will ensure the highest possible safety margin and operational reliability.

3. Relubrication after several years' standstill

The relubrication interval M3 – before start-up of a machine after several years' standstill – is calculated by applying the formula:

$$M3 = D \cdot B \cdot 0.01 \text{ [cm}^3\text{]}$$

It is important that the bearing be filled with the correct M3 grease quantity prior to start-up. If the machine is relubricated by a centralised lubricating system, we recommend checking the grease's pumpability in the system. This is especially important if the system contains long feed lines incorporating small bore pipes with automatic distributor blocks.

The passage of the grease to the bearing should ensure that the lubricant is forced directly through the bearing, completely displacing the old used grease. Entry and exit paths for new and old grease, respectively, should be as short as possible. If it is not possible to provide an exit for the old grease, sufficient free space should be made available, which must then be emptied from time to time.



Grease distribution and running-in

For most slow and medium speed rolling bearing applications, special grease distribution and running-in techniques are not necessary, as the necessary operational speed factors can easily be obtained without special running-in pre-treatment. For high-speed precision bearings, however, grease distribution and running-in is essential.

Bearing speed factors can be increased considerably by implementation of a running-in programme. During the running-in process the initial grease charge is evenly distributed around the bearing elements, thus enabling oil release to the friction surfaces within the bearing. The separation of oil from the thickener is therefore optimised in a way that the friction surfaces are wetted with just the right oil quantity, meaning that the rolling elements and the cage do not entrain the entire lubricating grease, but just the required oil quantity.

Optimised running-in may also considerably increase the performance and lifetime of the bearing. Rolling bearing manufacturers, of course, have their own empirical values in this respect, which means that their instructions as to the ideal running-in procedure may differ.

The spindle bearing experts at Schaeffler KG provide the following recommendations for their spindle bearings B..., HS..., and HC... :

**a. Speed factor = $0.5 \cdot n_{\max}$
in five steps 20 s running and 2 min rest period**

**b. Speed factor = $0.75 \cdot n_{\max}$
in five steps 20 s running and 2 min rest period**

**c. Speed factor = n_{\max}
in five steps 20 s running and 2 min rest period
in ten steps 30 s running and 2 min rest period
in ten steps 1 min running and 1 min rest period**

Speed in [min^{-1}]

According to this recommendation, the cycles involving a longer running and a shorter rest period should be carried out in such a way that a steady-state temperature is achieved at n_{\max} . This process clearly shows how time- and cost-intensive grease distribution running-in can be.



Determination of theoretical service life for special lubricating greases from Klüber Lubrication

For each of the rolling bearing greases presented in the following chapters, there is a diagram “Grease service life as a function of temperature”. Using this diagram, the theoretical grease service life F_{10} in [h] can be determined according to the temperature of your bearing.

HINT: If the actual bearing temperature is above the maximum value indicated in the diagram, you should select an alternative lubricant with a higher thermal capacity. If the actual bearing temperature is below the minimum value indicated in the diagram, you should select the value most applicable to the lowest bearing temperature.

Having determined the theoretical grease service life F_{10} in [h], the correction factor for the speed factor has to be calculated. For this purpose, determine the actual speed factor $n \cdot d_m$ in $[\text{min}^{-1} \cdot \text{mm}]$ as well as the factor K_n by means of the tables on the next few pages on speciality lubricating greases.

HINT: If the actual speed factor of your bearing is not covered by the diagram, you should choose K_n max. 4 or K_n min. 0.5.

Based on the diagram “Bearing type”, choose the factor K_B for your bearing.

Formula from Klüber Lubrication to calculate the theoretical reduced grease service life:

$$F_{10q} = F_{10} \cdot K_n \cdot K_B \cdot F_1 \cdot F_2 \cdot F_3 \cdot F_4 \cdot F_5 \cdot F_6 \text{ [h]}$$

Bearing design	K_B
Deep groove ball bearing	
single-row	0.9 to 1.1
double-row	0.7
Angular contact ball bearing	
single-row	0.6
double-row	0.5
Four-point contact ball bearing	0.6
Self-aligning ball bearing	0.8 to 0.6
Thrust ball bearing	0.2 to 0.15
Angular contact thrust ball bearing	
double-row	0.7
Cylindrical roller bearing	
single-row	0.3 to 0.35
double-row	0.3
full compliment-type	0.04
Spherical roller bearing	
without flanges "E" type	0.1 to 0.15
with centre flange	0.08 to 0.15
Needle bearing	0.3
Tapered roller bearing	0.25
Barrel bearing	0.10
Cylindrical roller thrust bearing	0.01

Other influencing factors to consider are:		
1.	Effect of dust and humidity on the functional bearing surfaces	
	moderate	$F_1 = 0.7$ to 0.9
	strong	$F_1 = 0.4$ to 0.7
	very strong	$F_1 = 0.1$ to 0.4
2.	Effect of shock loading, vibration or oscillation	
	moderate	$F_2 = 0.7$ to 0.9
	strong	$F_2 = 0.4$ to 0.7
	very strong	$F_2 = 0.1$ to 0.4
3.	Effect of high load	
	C/P = 10 to 7	$F_3 = 1.0$ to 0.7
	C/P = 7 to 4	$F_3 = 0.7$ to 0.4
	C/P = 4 to 3	$F_3 = 0.4$ to 0.1
4.	Effect of air flow through the bearing	
	low flow	$F_4 = 0.5$ to 0.7
	high flow	$F_4 = 0.1$ to 0.5
5.	Rotating outer ring	$F_5 = 0.6$
6.	Vertical shaft arrangements depending on sealing effect	$F_6 = 0.5$ to 0.7

For any influencing factor that does not apply, use factor 1.

Special lubricating greases

There are many rolling bearing greases which have been “tailored” to individual applications. The particular strength from Klüber Lubrication is in developing the right lubricant for each application requirement from a wide range of base oils and special thickeners. This brochure only contains a small selection of the overall range of bearing lubricants, but these are suitable for many applications. Nevertheless, if you cannot find the right product for your application, just contact us – we will be pleased to assist in meeting your needs.

In addition to key product data, the following charts provide information on the theoretical service life of greases whilst explaining how to convert these values to match your own specific application.

BARRIERTA KM 192

BARRIERTA KM 192 is also based on perfluoropolyether and PTFE-thickener. It is the preferable option where long bearing lifetimes are desired under widely fluctuating service temperatures. Again, the friction points should be thoroughly cleaned prior to initial lubrication to ensure optimum adhesion.

Klübersynth BHP 72-102

Klübersynth BHP 72-102 belongs to a new generation of lubricating greases and is based on a patented hybrid grease formulation suitable for both low and high temperature conditions. Klübersynth BHP 72-102 consists of ester oil, PFPE oil and polyurea thickener.

Klübersynth BEP 72-82

Klübersynth BEP 72-82 is based on synthetic ester oil and polyurea thickener. Such greases have been successfully used in the automotive industry for both low- and high-temperature applications for many years. They ensure a long service life for lifetime lubrication at high operating temperatures.

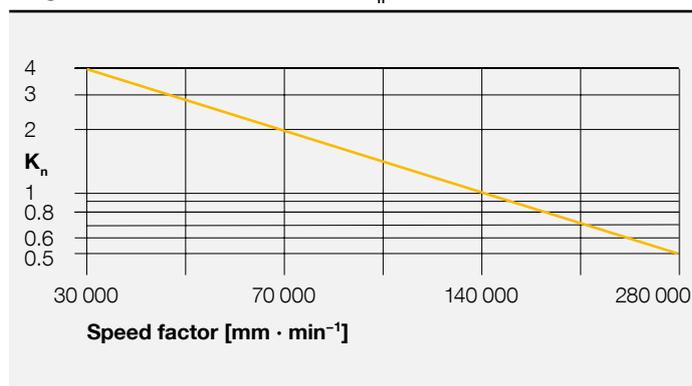
High-temperature greases

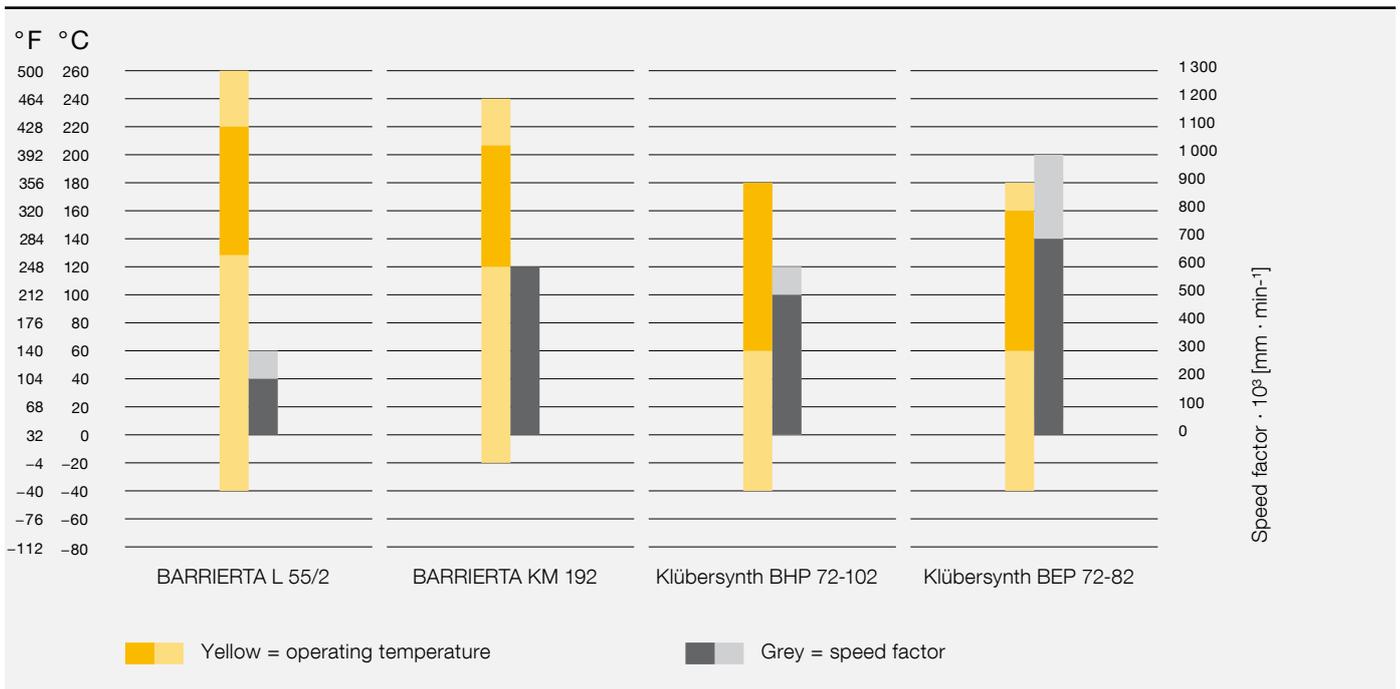
High-temperature greases from Klüber Lubrication consist of thermally stable, preferably synthetic base oils incorporating organic or inorganic thickeners. The maximum upper operating temperature limit for Klüber’s high-temperature lubricating greases today is approximately 300 °C (572 °F). For lifetime lubrication, however, Klüber Lubrication recommends operating temperatures which are considerably lower in order to achieve acceptable running times.

BARRIERTA L 55/2

BARRIERTA L 55/2 is a lubricating grease based on perfluoropolyether and PTFE. For many years, this grease has proven successful for high-temperature applications up to 260 °C (500 °F). Before application of this special grease, bearings require thorough cleaning to enable maximum adhesion of the grease film.

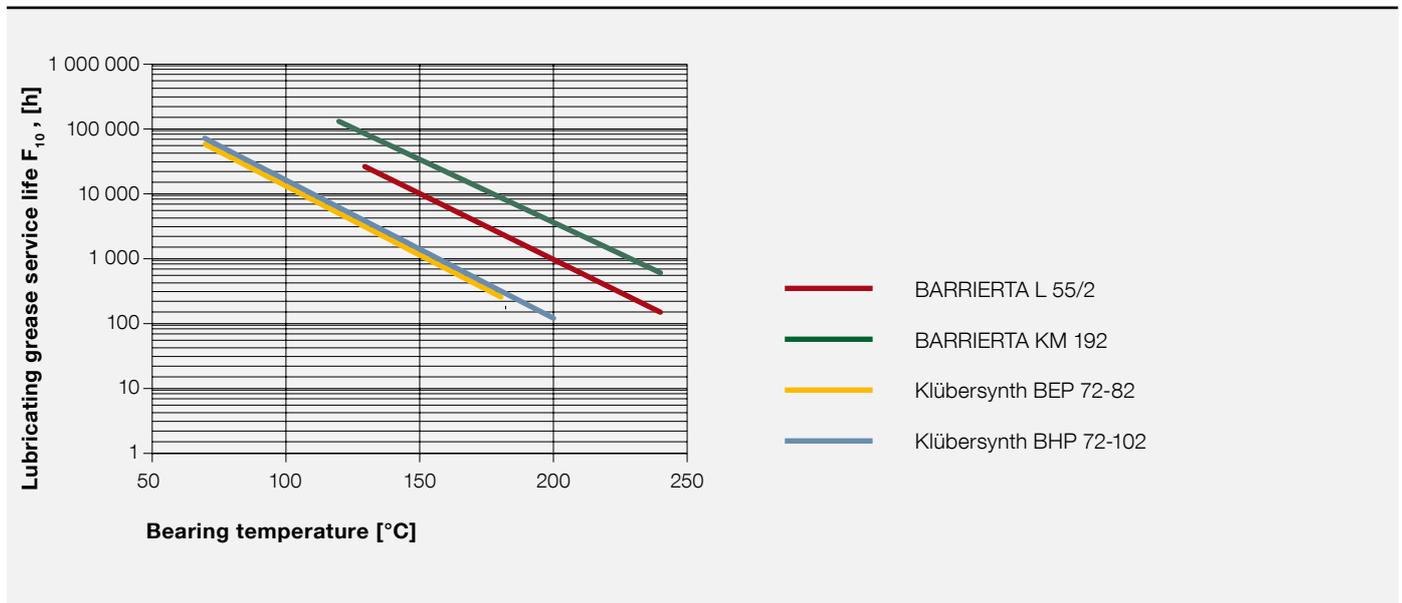
Diagram for the determination of K_n





The darker areas are the target if lifetime rolling bearing lubrication is required.

Lubricating grease service life as a function of temperature



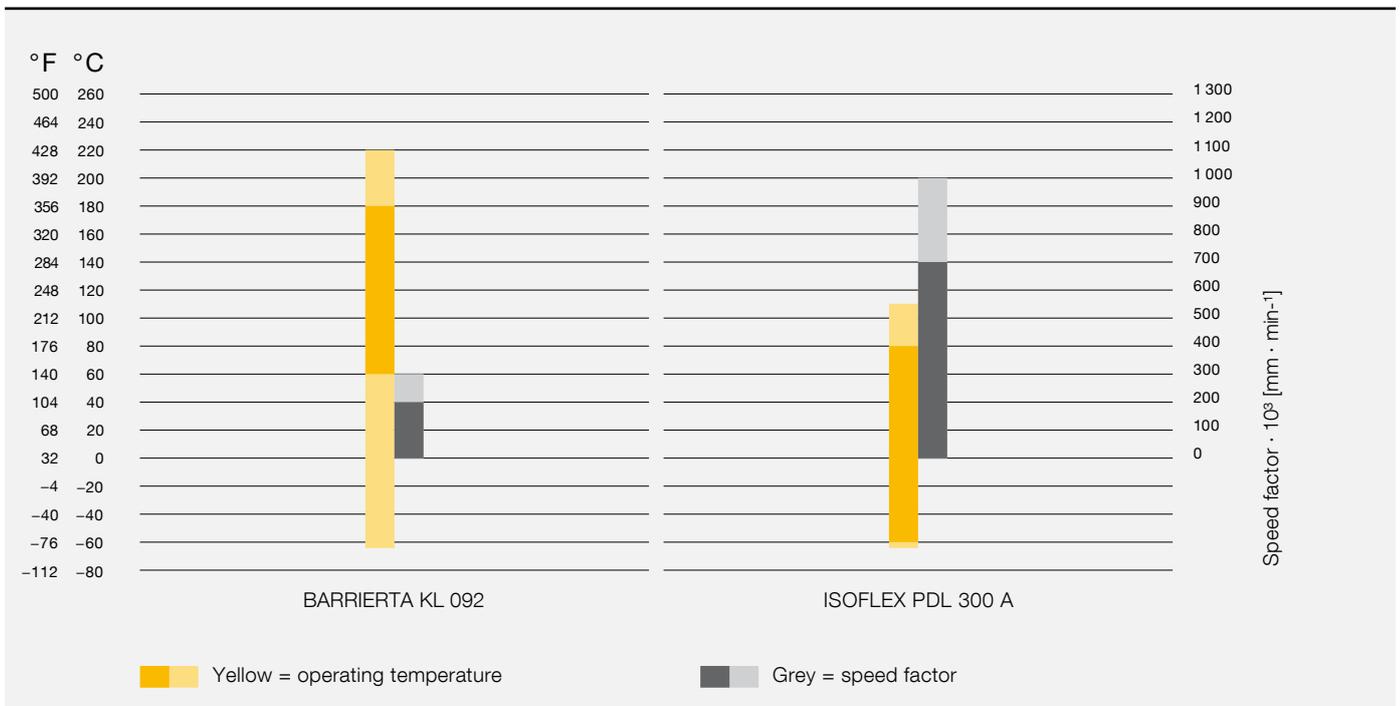
Low-temperature greases

Lubricating greases exhibiting minimal consistency increase at low temperatures provide excellent low-temperature stability. Suitable base oils for low-temperature duty are synthetic esters, PFPE oils and polyalphaolefins. The general criterion defining low-temperature stability is the flow pressure test in accordance with DIN 51 805 or the low-temperature torque test according to IP 186. The temperature at which a flow pressure of 1,400 mbar is generated will be stated as lowest service temperature of our rolling bearing greases.

A grease which shows good low-temperature stability will often perform poorly in high-temperature applications. The automotive industry in particular often requires low temperatures of $-40\text{ }^{\circ}\text{C}$ ($-40\text{ }^{\circ}\text{F}$) while the actual day-to-day operating temperature of the unit is for example $+100\text{ }^{\circ}\text{C}$ ($212\text{ }^{\circ}\text{F}$).

Two grease types are shown whose lower operating temperature range is clearly below $-40\text{ }^{\circ}\text{C}$ ($-40\text{ }^{\circ}\text{F}$):

- BARRIERTA KL 092
- ISOFLEX PDL 300 A



BARRIERTA KL 092 and ISOFLEX PDL 300 A are lubricating greases which are particularly suitable for low-temperature applications. Please contact our technical consultants for an estimation of the grease service life in your application.

The operating temperature range and the maximum speed factor $n \cdot d_m$ can be read from the diagram. The darker areas are preferred if lifetime lubrication is the objective.

High-purity and low-noise greases

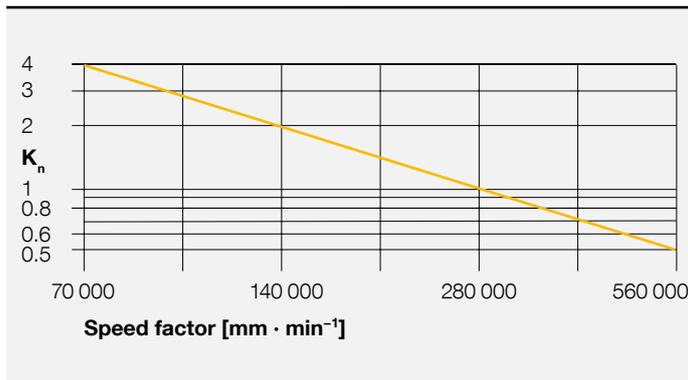
Such greases are used to reduce the running noise of rolling element bearings, e.g. in audio & video equipment, precision bearings in disk drives, linear and oscillating actuators in computer sensors and printers. Low-noise high-purity greases are also a vital component for the production of precision equipment. The use of a high-purity grease can significantly extend the operational lifetime of a rolling bearing.

Bearing specifics		Lubrication specifics
Bearing surface (roughness, waviness)	—	— Additives
Contamination in the bearing	—	— Grease volume
Sealing material	—	— Thickener
Bearing dimensions	—	— Consistency
Cage material	—	— Grease texture
Seal type	—	— Grease distribution
Vibration	—	— Grease application
Oscillation	—	— Base oil viscosity
Bearing size	—	— Manufacturing technology
Temperature	—	— Contamination in the grease (purity)
Materials	—	
Load	—	
Internal clearance	—	
Precision	—	
Speed factor	—	
Cage type	—	

Factors influencing noise generation in rolling bearings

The entire system is used to measure the combined noise behaviour of the rolling bearing and lubricant. It is therefore often difficult to identify which influencing factors are responsible for generation of both solid-borne sound and air-borne noise.

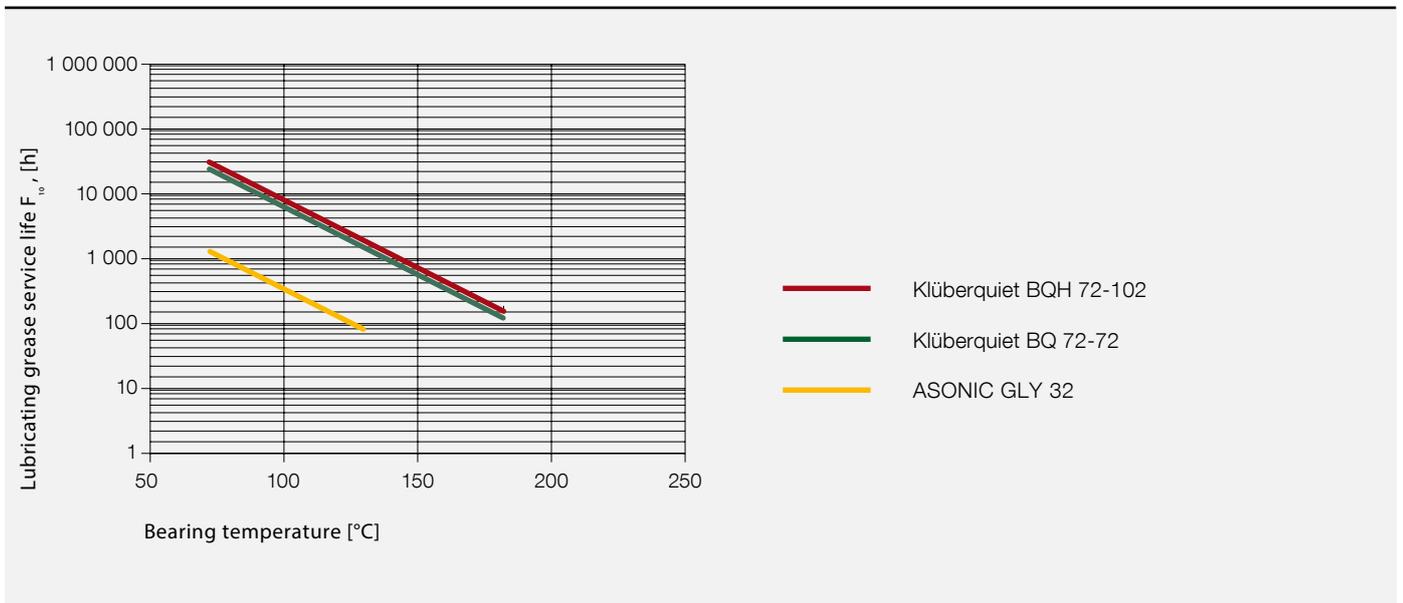
Diagram for the determination K_n





The operating temperature range and the maximum speed factor $n \cdot d_m$ can be read from the diagram. The darker areas are the target if lifetime lubrication is required.

Lubricating grease service life as a function of temperature

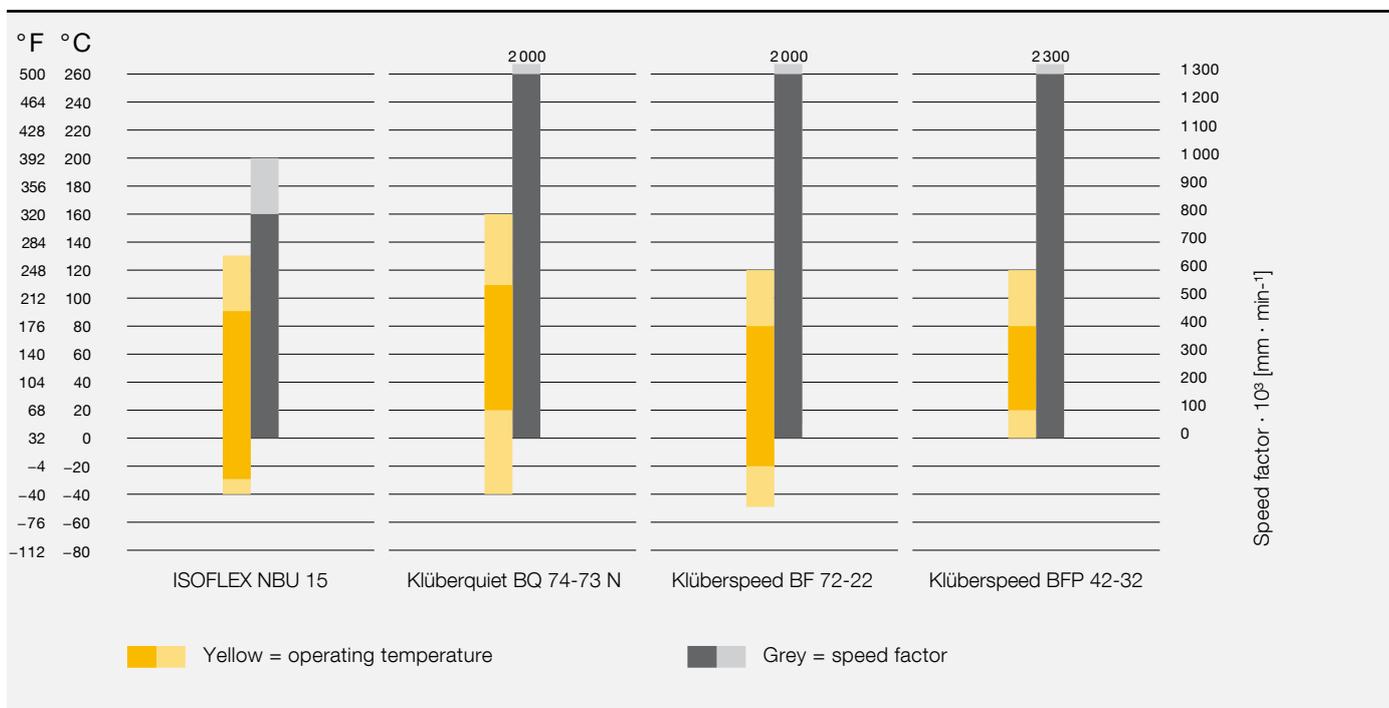




High-speed greases

High-speed lubricating greases easily cope with speeds which can normally only be achieved through the use of lubricating oils. Their consistency corresponds to that of usual rolling bearing greases (e.g. NLGI grades 1 or 2). For speed factors below 1 million [$\text{mm} \cdot \text{min}^{-1}$], high-speed rolling bearing greases have provided excellent operational performance for a great many years. More recently, new extreme-speed greases have been developed enabling operational speed factors in excess of 2 million [$\text{mm} \cdot \text{min}^{-1}$]. These greases fulfil lifetime lubrication conditions in, e.g. machine tool spindles enabling lowest operating temperatures.

ISOFLEX LDS SPECIAL A has proven successful for many years. Klüberspeed BF 72-22 and Klüberspeed BFP 42-32 are the latest developments in high-speed bearing lubrication. Klüberspeed BF 72-22 may be used at speed factors up to 2 million [$\text{mm} \cdot \text{min}^{-1}$] and Klüberspeed BFP 42-32 up to 2.3 million [$\text{mm} \cdot \text{min}^{-1}$].



The darker areas are the target if lifetime rolling bearing lubrication is required.

In applications with speed factors $n \cdot d_m$ of 1 million and more, the lubricating grease's service life is determined primarily by high peripheral speeds and the resulting forces. The temperature which develops in such high-speed applications must be closely monitored and should be no higher than 80 °C (176 °F) for the above-mentioned greases. The bearing temperature should be around 40 – 50 °C (104 – 122 °F). Higher temperatures may be reduced by external cooling.

The focus of high-speed grease lubrication is definitely towards increasing the maximum attainable speed factor. It is therefore not possible to describe the lubricating grease service life as a function of temperature. Please contact our technical consultants for an estimation of grease service life in your application.

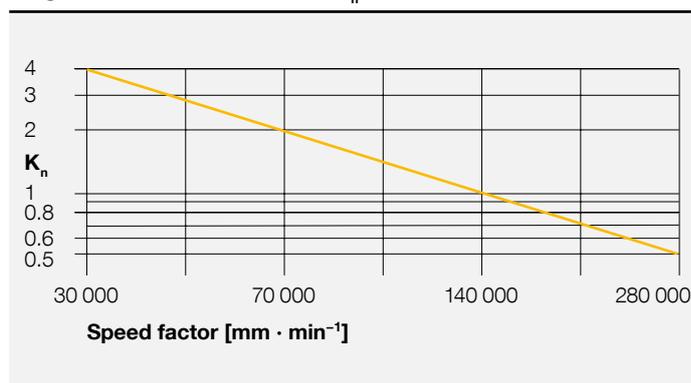
Special greases for the heavy industry

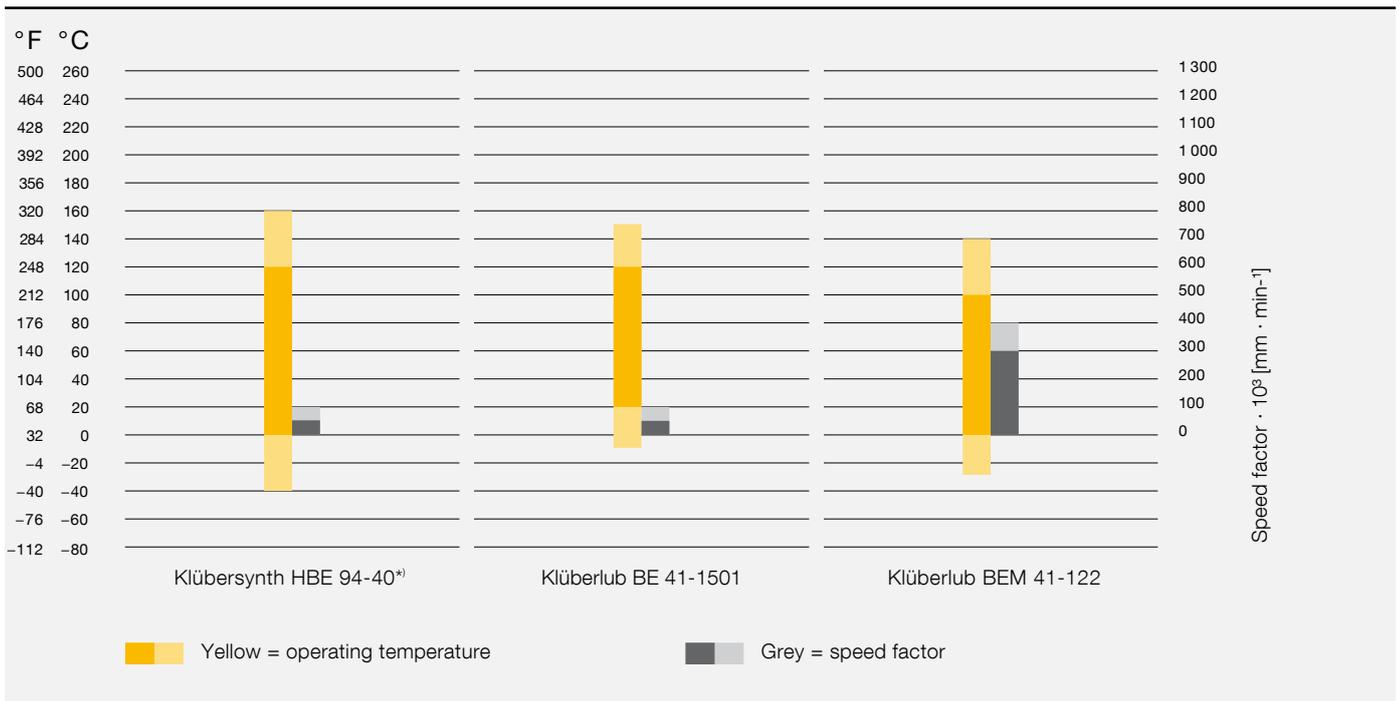
Greases of this type are subject to specific EP requirements. Indicating the presence of EP (extreme pressure) additives, which together with special thickeners and base oils impart high load-carrying capacity. EP greases perform extremely well under boundary and mixed friction regimes.

EP greases should be used for rolling bearings with a C/P load ratio of less than 10.

Types containing special additives have been developed to minimise wear under high load conditions. Klüberlub BE 41-1501 is an exceptional extreme-pressure grease containing molybdenum disulphide and graphite as solid lubricants. This composition enables its use under extreme load conditions, C/P ratio > 2.

Diagram for the determination K_n

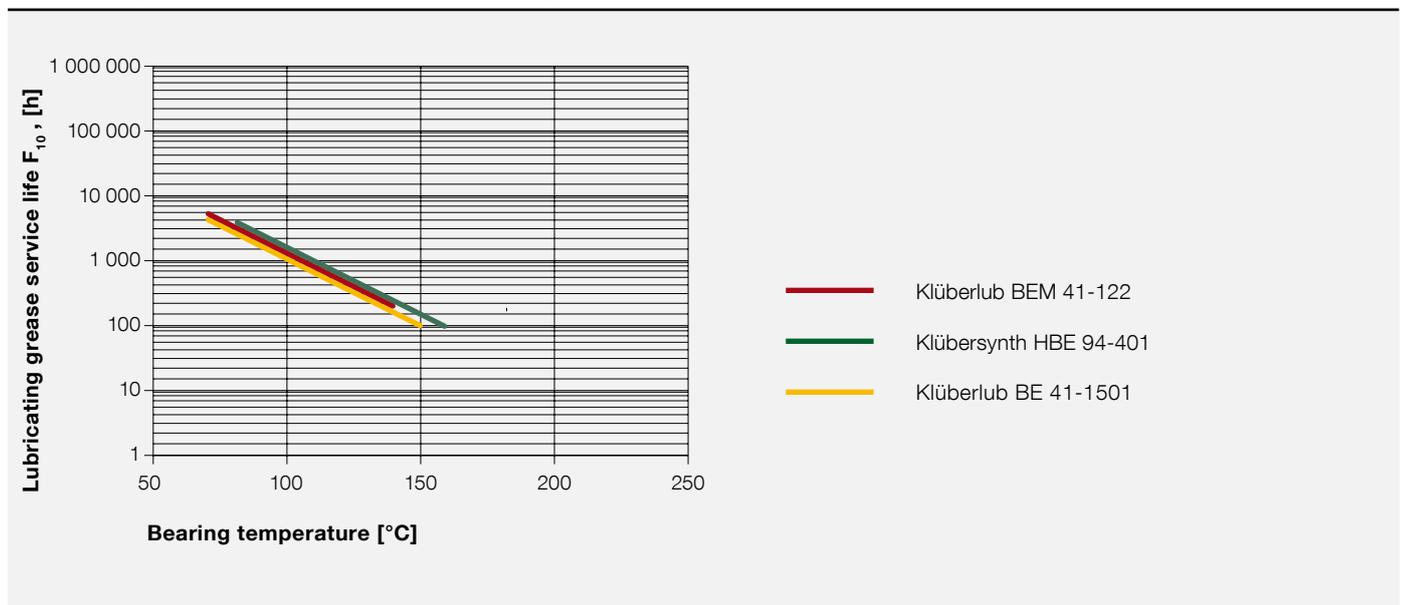




The darker areas are the target if lifetime rolling bearing lubrication is required.

*) The upper service temperature for this heavy-duty grease was determined on the FAG FE-8 rolling bearing grease tester.

Lubricating grease service life as a function of temperature





Special greases for other industries

Lubricating greases for oscillating movements

Rolling bearings can operate under extreme conditions, such as oscillating movements. Permanent start/stop operation prevents the development of a stable separating layer between the friction partners, leading to what is known as boundary friction. The wear risk increases and the lifetime of the rolling bearing can decrease as a consequence.

In oscillating rolling bearings mounted on a horizontal shaft, the effect of gravity draws the lubricant gradually downwards. If the oscillating amplitude is small, the upper part of the rolling element may not be sufficiently covered with lubricant. Additionally, the amount of fresh lubricant entering the space between the friction partners is very small, leading to difficult lubrication conditions for which a special lubricant is required. Test results obtained with rotating movements cannot be applied to oscillating movements.¹⁾

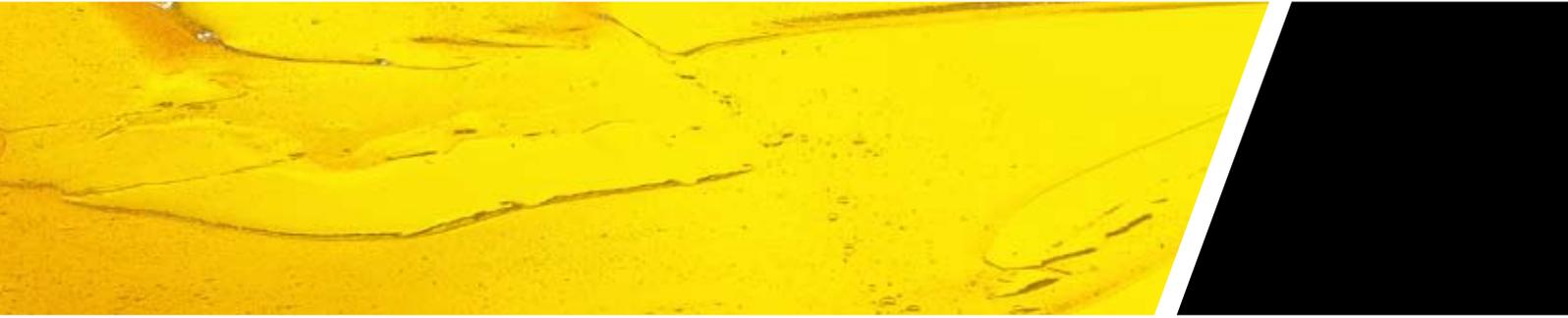
If oscillating amplitudes are constantly very small, the rolling element cannot rotate to redistribute the lubricant. The resulting effect may be bearing damage with ball or roller-shaped brinell marks occurring to the loaded bearing rings. This effect is referred to as the False Brinelling Effect and is a typical wear pattern of tribocorrosion.

The same effect is also observed when linear movement occurs, e.g. in linear guides with ball and roller screw systems, ball bushings or ball screws.

The right lubricant for oscillating movements, e.g. with special combinations of solid lubricants allows the formation of a tribological reaction layer from the start for sustainable protection against brinelling wear and component failure.

Ruptures in the separating layer quickly lead to failure. Intermittent operation (interrupted drive movement), small oscillating amplitudes and low temperatures have a negative effect on the separating layer and the lifetime.¹⁾ It is therefore essential to discuss operating conditions as precisely as possible to determine the right lubricant and the ideal lubrication method for the bearing design in each kind of application.

1) Worksheet on research project no. 315/1 "Wirkung von Schmierstoffen bei langsamen oszillierenden Gleit- und Wälzbewegungen", Forschungsvereinigung Antriebstechnik e.V., Version July 99.



Lubricating greases for roller bearings

Roller bearings are a particular lubrication challenge due to their tribological characteristics, as they often operate under extreme conditions like high pressure at low rotational speeds.

Lubricants for these conditions need to have special characteristics to cope with rolling friction in the linear contact zone between the roller and the raceway and, in some cylindrical and tapered roller bearings, sliding friction at the flange. On the one hand, high pressure resistance is required, which can be attained with higher base oil viscosities and/or special additives. On the other hand, sufficient oil release must be provided to the sliding contact between the face of the roller and the flange. Synthetic base oils combined with special soap-based thickeners like lithium, lithium complex, calcium complex or barium complex have proven their effectiveness in practice.

Barium complex soap greases are particularly resistant against potentially contaminating media.

The wear resistance of such special lubricating greases is normally analysed with the DIN standard testing machine FAG FE8, testing the wear resistance of the lubricant in the raceways, rolling elements and the cage.

Klüber Lubrication has developed speciality lubricants to meet these requirements, with tried-and-tested solutions for a range of roller bearing applications.



Food-grade greases

All speciality lubricants from Klüber Lubrication for the food-processing and pharmaceutical industries have been developed and tested on the basis of our international experience and research. They are registered as NSF H1/H2.

The USDA (United States Department of Agriculture) used to be the registration authority for food-grade lubricants. Currently the NSF (National Sanitation Foundation) is responsible for food-grade lubricant registrations.

Legally binding raw materials lists are the basis for NSF registrations in two categories: NSF H1 lubricants are suitable for friction points with unforeseeable contact with products and packaging materials in the food-processing, cosmetics, pharmaceutical or animal feeds industries, whereas NSF H2 lubricants are suitable for use in the food-processing and pharmaceutical industries provided that product contact can be excluded.

To have lubricants registered as NSF H1, the lubricant manufacturer must prove that the product ingredients comply with FDA (Food and Drug Administration) requirements 21 CFR § 178.3570.

Compliance with FDA requirements is also important when it comes to the Klüber H1-lubricant's suitability for quality management according to GMP in the pharmaceutical industry. To avoid contamination, the manufacture of Klüber H1 lubricants is subject to stringent hygiene standards. Most production sites from Klüber Lubrication are already certified according to NSF ISO 21469.

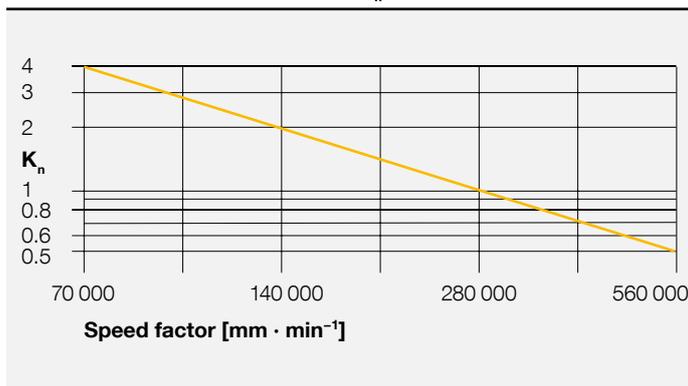
The use of NSF H1-lubricants can contribute to increase the reliability of your production processes. We nevertheless recommend conducting an additional risk analysis, e.g. HACCP.

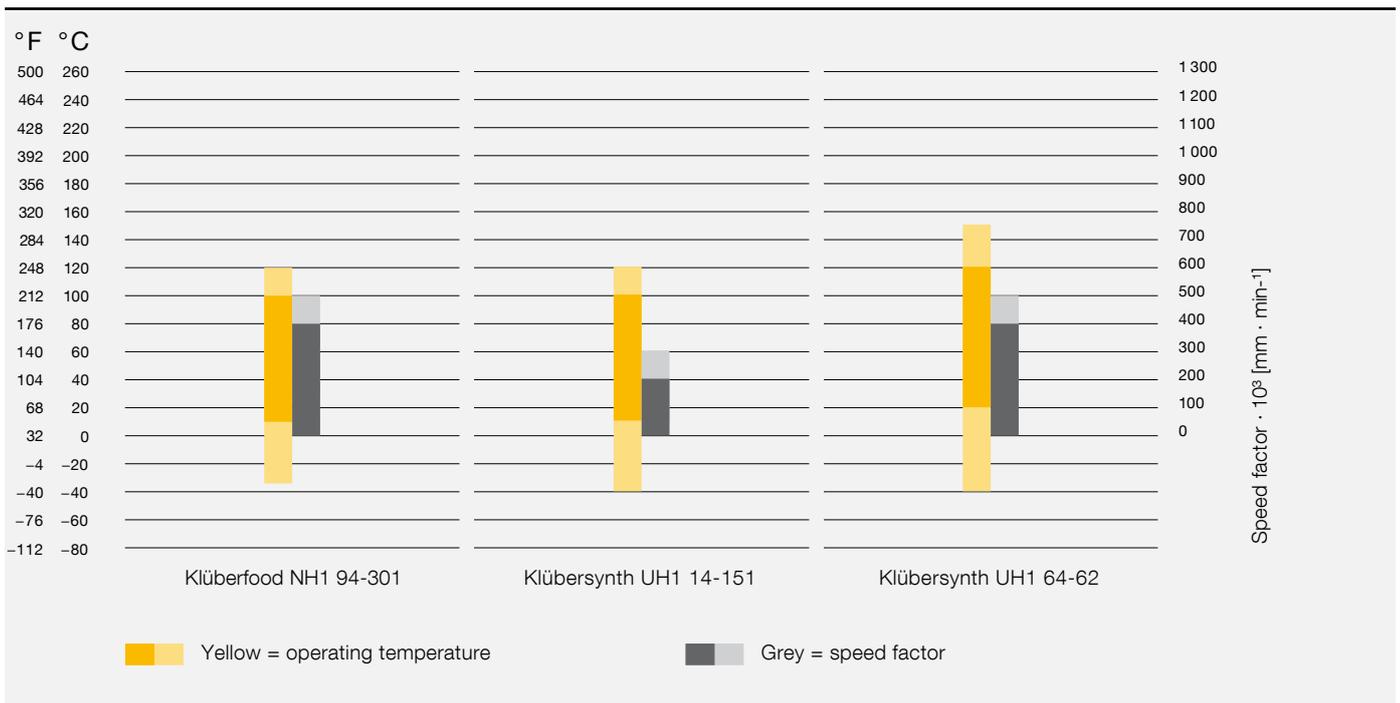
To improve process reliability in the manufacture of pharmaceutical products, it is recommended that H1-products be used exclusively in the production site so that contamination of pharmaceutical products with non-H1 lubricants can be excluded (as there is no risk of confusing products).

Food-processing and pharmaceutical companies invest a lot of time and money to increase the efficiency, operational reliability and performance of their machines. The special requirements regarding process reliability add to that. KlüberAssetSupport was introduced to help you protect your assets while increasing the efficiency of your production lines. Nevertheless, KlüberAssetSupport requires close cooperation on both sides, starting with a pre-audit in which areas of improvement are identified and quantified.

Please contact your local Klüber Lubrication specialist for more information. He will name you the local KlüberAssetSupport Project Manager and organise a pre-audit with you.

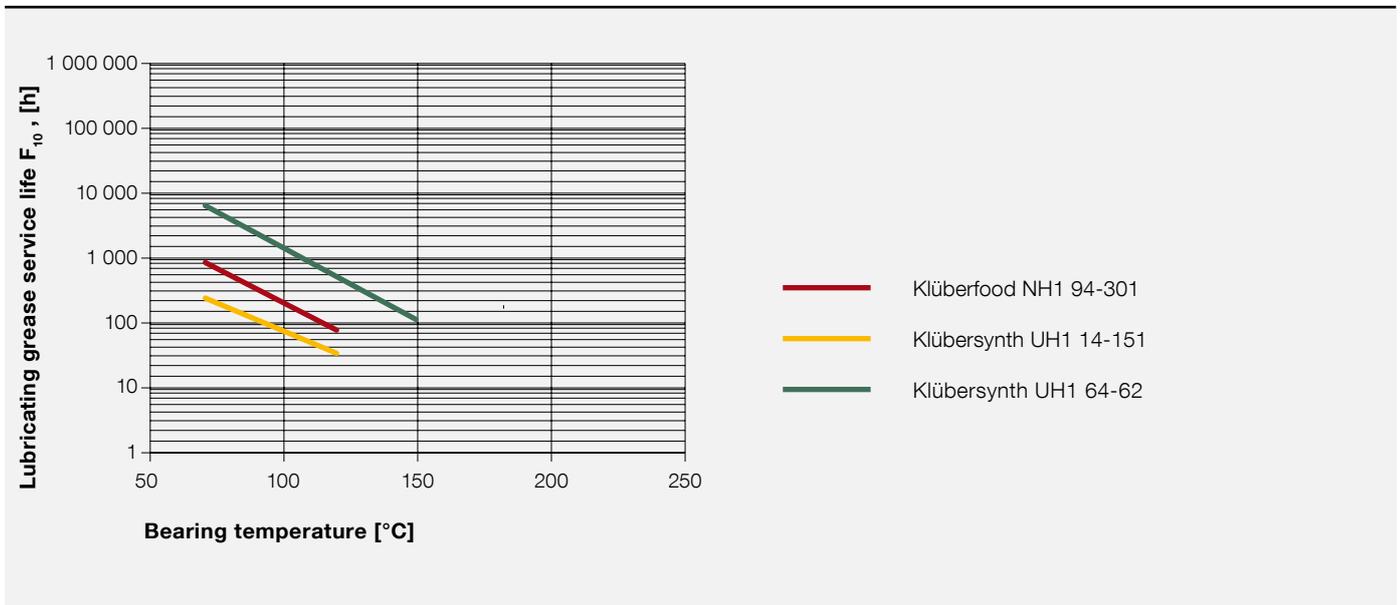
Diagram for the determination of K_n





The darker areas are the target if lifetime rolling bearing lubrication is required.

Lubricating grease service life as a function of temperature



Electrical conductivity

An electric charge may develop in a bearing within a split second leading to discharge via the bearing balls and raceways. This phenomenon can result in serious bearing damage. Equipment transporting plastic foil or paper are particularly at risk due to the potential for static electrical build up and discharge. Electric motor bearings and generators (wind power stations...) may also suffer similar electrical discharge damage failures.

Electrical current passage through the bearing may result in electrical arcing damage to balls and raceways which can appear as craters or grooves, often with a "bar-code" like symmetry. Craters may be formed due to localised melting of the surfaces of the bearing raceways and balls. Fragments of molten metal may well be removed and re-deposited in other areas of the raceways where they are rolled over into the raceway substrate. Tell-tale electrical erosion grooves are formed as a result of the simultaneous stressing of the rolling elements and raceways in the load area where the current flow is most apparent. It is normal to have to replace a damaged bearing once electrical erosion damage has taken place, no form of repair is possible.

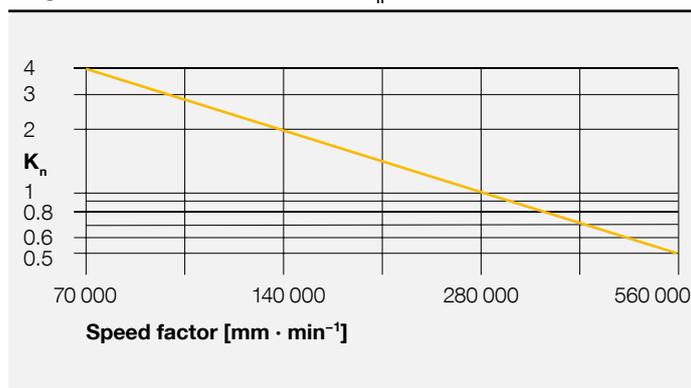
In an attempt to prevent electrical erosion damage the operator or equipment designer can either change machinery construction elements or select and use an electrically conductive lubricant, particularly when only low voltage currents occur. Such lubricants are able to conduct the electrical current through the bearing so that point-to-point flashovers are eradicated. It should be noted that specially developed electrically conductive greases have a very low electrical resistance in the region 10^5 ohms · cm

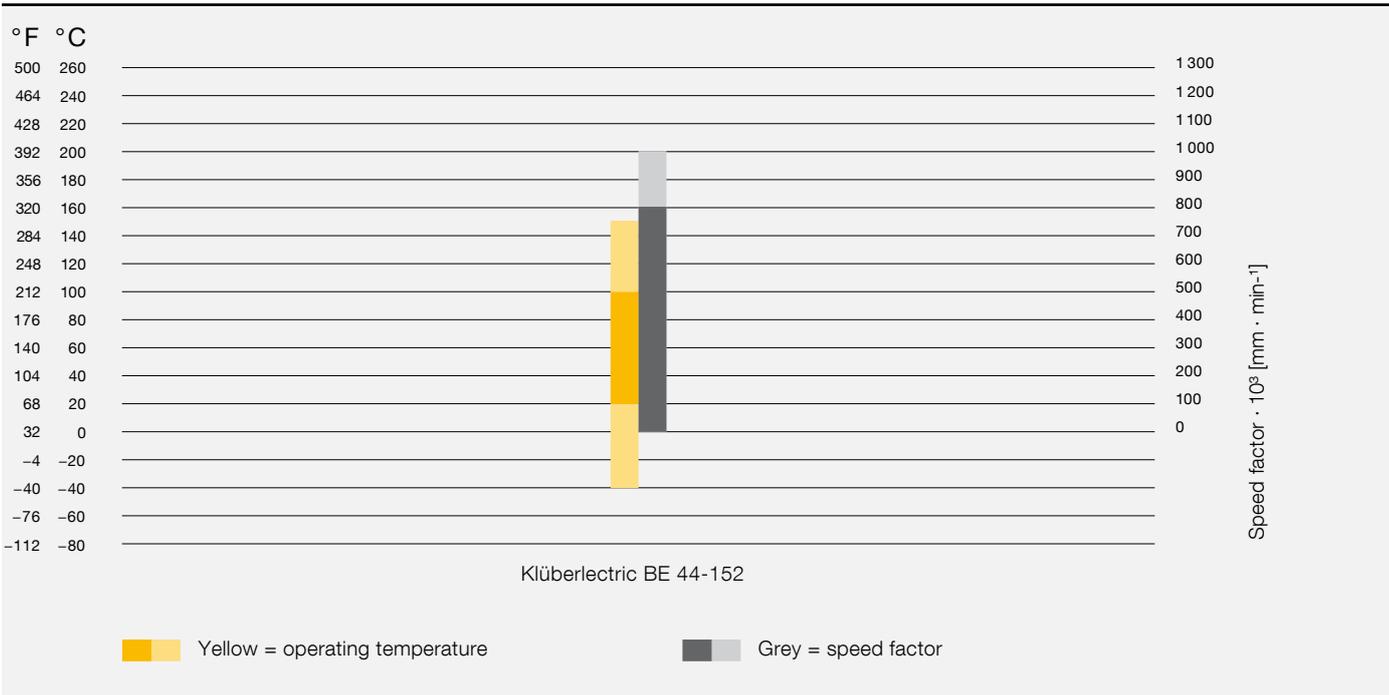
Klüberlectric BE 44-152 by Klüber Lubrication is a rolling bearing grease with a specific electrical resistance of $\sim 10^5$ ohms · cm, enabling it to conduct a current some 1000 times greater than a grease with a specific resistance of 10^8 ohms · cm when subject to a given current intensity. The manageable current intensity even increases by factor 10^6 when compared to a standard grease with a specific resistance of 10^{11} Ohms · cm.

To illustrate the difference between electroconductive greases and standard greases, Klüber Lubrication determined the electrical resistance of greases according to the former DIN standard 53482. In addition to this static value, Klüber Lubrication used their dynamic test rig for the purpose of development and optimisation of this special grease.

Besides the electrical properties described above, an electrically conductive rolling bearing grease must also offer sufficient operational lifetime capacity and reliability. Klüberlectric BE 44-152 can be used across a wide service temperature range from -40 to $+150$ °C (-40 - 302 °F) and across an extensive performance spectrum.

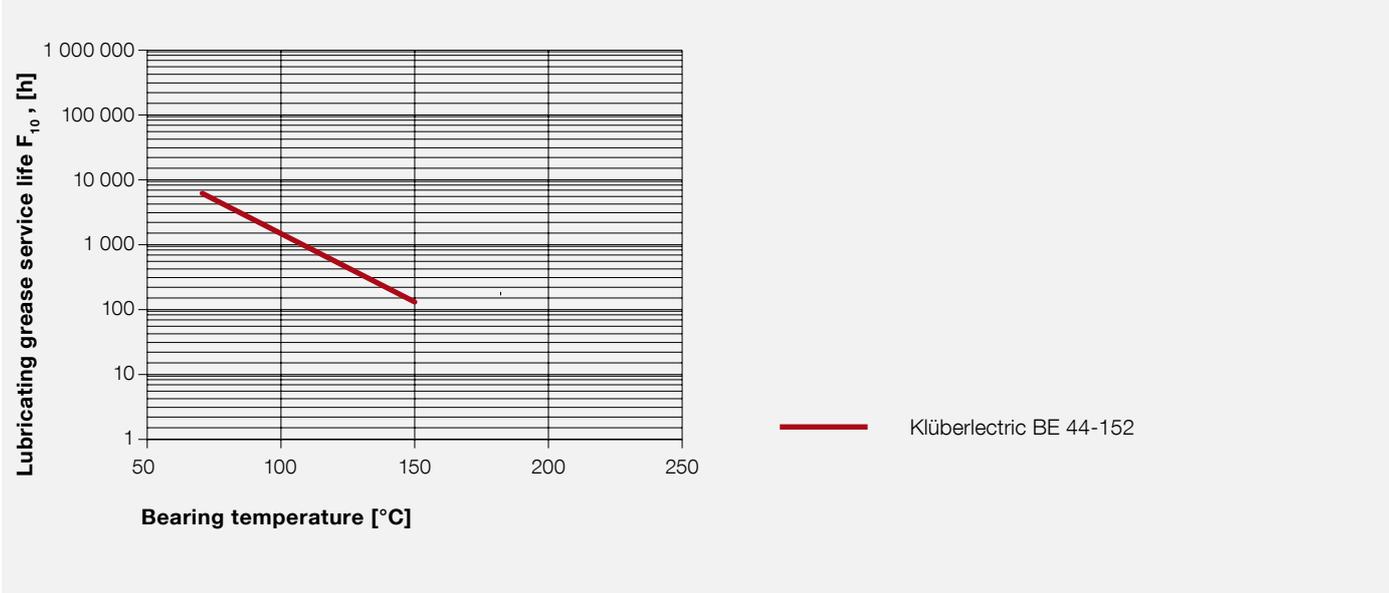
Diagram for the determination of K_n





The darker areas are the target if lifetime rolling bearing lubrication is required.

Lubricating grease service life as a function of temperature



Cleaning of rolling bearings

Why do rolling bearings require cleaning?

For both the initial and relubrication of rolling bearings, careful preparation is very important. The friction points should be perfectly clean, i.e. free from residues and dirt, as contamination may lead to bearing damage and hence premature bearing failure. Cleaning also helps to exclude problems related to the incompatibility of the anti-corrosion agent and lubricant and finally, the lubricant can only adhere properly to the bearing surface if it is free from foreign contamination. Thorough cleaning is therefore an indispensable precondition for achieving the best possible lubrication results.

The cleansing fluid Klüberalfa XZ 3-1 evaporates quickly, is residue-free and should be selected for use with lubricating greases based on PFPE/PTFE.

Klüberalfa XZ 3-1 can also be used as a solvent or as a dispersing agent for PFPE greases, which permits lubricant application in very thin layers.

Ensure containers are fully sealed after use to prevent evaporation losses!



Cleaning and dispersing agents

	Klüberalfa XZ 3-1
Solvent	PFPE
Colour	colourless
Texture	liquid
Application notes	Solvent and cleaning agent for pre-cleaning and dispersing PFPE/PTFE lubricants enabling maximum metal adhesion characteristics

Corrosion protection of rolling bearings

Why do rolling bearings require corrosion protection?

Many rolling bearing components are manufactured using carbon steel. When exposed to atmospheric humidity, the most commonly used steel, 100Cr6, has no long-term resistance to corrosion. This affects operational reliability. Unwanted corrosion particles which may form on an unprotected bearing surface may gradually find their way into the bearing leading to increased running noise and thereafter premature bearing failure.

False Brinelling

So-called False Brinelling is the formation of undesirable wear on the bearing raceways and takes place under non-rotational conditions. This phenomenon occurs due to minute oscillating movements in the contact areas of bearings, for example in automotive wheel bearings during transportation of cars or in standby (off-line) compressors. False Brinelling may be prevented by replacing the conventional bearing anti-corrosion oil with a corrosion protection oil containing special additives, such as Klübersynth BZ 44-4000.

Why should an anti-corrosion agent offer more than just corrosion protection?

Compatibility with the lubricant used

As indicated, incompatibility of grease with the bearing's anti-corrosion protection film may result in insufficient adhesion of the grease to the bearing surface. The grease may simply skid on top of the oil film without establishing a firm connection to the bearing material which may eventually lead to lubricant loss from the bearing.

Support of grease distribution in the bearing

Due to restrictions in time and costs, rotation of a bearing to facilitate grease distribution following initial lubrication is extremely rare. However, insufficient lubrication of the bearing during its first few rotations may cause initial damage shortening the expected life of the bearing. This problem can be prevented by using a high-performance anti-corrosion oil, such as Klübersynth MZ 4-17.

Wear scars due to external vibration when the bearing is not operating – False Brinelling.



Noise and corrosion protection

A low-noise rolling bearing lubricated with a low-noise lubricating grease, such as Klüberquiet BQ 72-72, may be contaminated by misuse of a corrosion protection oil which does not offer sufficient purity or is incompatible with the grease such that the bearing is no longer able to fulfil its requirements. Klübersynth MZ 4-17 was developed to complement our range of low-noise Klüberquiet greases and can, of course, also be used in combination with many other products.

Compatibility with plastics and elastomers

As with a lubricating grease, the anti-corrosion oil must be compatible with the plastics (cage) and elastomers (seals) used in the bearing. Klüber Lubrication will be pleased to provide details on materials compatibility if so required.

The use of a high-performance anti-corrosion agent enables improved and extended bearing functionality and ultimately cost savings for the user. The additional investment in an appropriate high-performance corrosion protection film lubricant always pays off.

Anti-corrosion agents for rolling bearings

	Klübersynth BZ 44-4000	Klübersynth MZ 4-17
Application	Synthetic lubricating and anti-corrosion fluid with additives to protect against False Brinelling bearing damage	Synthetic lubricating and anti-corrosion oil for rolling bearings
Base oil	Synthetic hydrocarbon	Ester oil/synthetic hydrocarbon
Thickener	Lithium soap	Not applicable
Viscosity DIN 51562 [mm ² /s] at approx. 40 °C (approx. 104 °F)	40	22
Colour	beige	brown
Aspect/Texture	milky/liquid	liquid

Changeover of lubricating greases

Used grease removal and relubrication of bearings with a new grease

Having made the decision to use new grease in a rolling bearing, the old grease should be removed completely from the rolling bearings prior to applying the new grease. Alternatively, it may be possible in certain cases to purge the bearing with the new grease thus forcing out the original grease fill.

Purging should only be undertaken in rolling bearings equipped with a grease relief outlet to enable the existing grease to drain completely from the bearing. In systems lubricated-for-life or in oil-tight systems, relubrication should not be implemented as this could result in malfunctions or severe bearing damage.

Prior to initiating the changeover procedure, the rolling bearings should be inspected. If there are fitting deficiencies, internal clearance issue or if bearing damage exists, the lubricant changeover may not prove worthwhile.

Preliminary inspections

Grease compatibility

Is the new grease really compatible with the old one? Compatibility should be checked with great care. If the two greases are incompatible, liquefaction, overheating or bearing damage can be the consequence. You will find an overview of various compatible lubricant compositions on the next page. If you have any further questions, please do not hesitate to contact our specialists.

The right amount of grease in the bearing

The correct quantity of grease will vary based on the bearing type and bearing rotational speed. It is therefore important to determine the precise grease quantity for the bearings prior to changeover. Purging of a bearing with fresh grease will involve completely filling the bearing with grease. This method may prove unsuitable for instance when considering high-speed bearings which require an extremely low percentage of grease fill.

Changeover from industrial grease to food-grade grease with NSF H1-registration

As described in the chapter “Food-grade greases”, particular attention is paid to applications under hygienically critical conditions. To attain the “H1 condition” as quickly as possible, relubrication intervals have to be reduced, particularly after the grease changeover process. The more frequently NSF H1-registered grease is applied to the bearing, the sooner the industrial grease is squeezed out completely.

How it's done:

To remove the old grease from the bearing, with hand rotation or slow idling, pump the fresh grease slowly into the rotating bearing until colour and consistency of the grease leaking out of the bearing correspond to that of the new grease. This change indicates that almost no old grease is left in the bearing and the feed channels are cleared. In case of a pillow-block housing, remove the cap and scrape out the grease in the free space of the housing by hand.

Repeat the relubrication process after 1-2 operating hours or during continuous operation. The first two relubrication intervals should be reduced: Implement the first relubrication after one week and the second after the second week of operation. Afterwards, relubrication can be undertaken at normal intervals. Once the lubricating grease has been changed, relative power and current consumption, relubrication intervals etc. have to be inspected in detail. If everything works according to plan or even better, changeover has been successful.

HINT: Clean the grease nipples prior to applying new grease to ensure contaminants are not forced into the bearing contact zones. Lubricate bearings whilst they are rotating. Pump the grease slowly and carefully into the bearing to prevent overheating.

Do you have any questions regarding grease changeover? Please do not hesitate to contact our experts.



Miscibility of base oils

	Mineral oil	Synth. hydrocarbon	Esteroil	Polyglycol	Silicone oil (methyl)	Perfluoroalkyl-ether	Silicone oil (phenyl)	Polyphenyl-ether oil
Mineral oil	+	+	+	-	-	-	+/-	+
Synth. hydrocarbon	+	+	+	-	-	-	-	+
Ester oil	+	+	+	+	-	-	+	+
Polyglycol	-	-	+	+	-	-	-	-
Silicone oil (Methyl)	-	-	-	-	+	-	+/-	-
Perfluoroalkylether	-	-	-	-	-	+	-	-
Silicone oil (Phenyl)	+/-	-	+	-	+/-	-	+	+
Polyphenylether oil	+	+	+	-	-	-	+	+

+ miscible +/- partially miscible - not miscible

Miscibility of thickeners*)

		Metal soaps				Complex soaps					Other thickeners		
		Al	Ca	Li	Na	Al	Ba	Ca	Li	Na	Bentonite	Polyurea	PTFE
Metal soaps	Al	+	+/-	+	+/-	+	+/-	+	+	+/-	+	+	+
	Ca	+/-	+	+	+	+	+	+	+/-	+	+	+	+
	Li	+	+	+	-	+	+	+	+	-	+/-	+/-	+
	Na	+/-	+	-	+	+	+	+/-	+/-	+	-	+	+
Complex soaps	Al	+	+	+	+	+	+	+/-	+	+/-	+/-	+/-	+
	Ba	+/-	+	+	+	+	+	+/-	+/-	+	+	+/-	+
	Ca	+	+	+	+/-	+/-	+/-	+	+	+	+/-	+	+
	Li	+	+/-	+	+/-	+	+/-	+	+	+/-	+	+/-	+
	Na	+/-	+	-	+	+/-	+	+	+/-	+	-	+	+
Other thickeners	Bentonite	+	+	+/-	-	+/-	+	+/-	+	-	+	+	+
	Polyurea	+	+	+/-	+	+/-	+/-	+	+/-	+	+	+	+
	PTFE	++	+	+	+	+	+	+	+	+	+	+	+

+ miscible +/- partially miscible - not miscible

*) Base oils must be miscible

Bearing assembly using suitable pastes

What is fretting corrosion?

Fretting corrosion is caused by two highly loaded metal surfaces rubbing against each other, resulting in the formation of iron oxide. Fretting corrosion is compounded by the abrasive effect of the corrosion particles. This phenomenon is found particularly in components which are subject to high loads and vibration (e.g. in plunger blocks). Migration of abrasive particles into the bearing, especially in the actual contact areas, may lead to increased bearing noise and often to premature bearing failure.



Fretting corrosion on the outer ring



Fretting corrosion on the inner ring



Preventing fretting corrosion

Assembly pastes

The easiest way to effectively prevent fretting corrosion is to use an assembly paste. The bearing and shaft surfaces are permanently separated by the paste, which often contains solid lubricants, thus preventing abrasive wear. The result is a long and reliable bearing life.

Further means to prevent fretting corrosion

- Abrasive wear can be minimised by increasing surface hardness of the bearing materials.
- Incorporation of suitable barriers to prevent ingress of fretting corrosion particles into the bearing. This is only possible through design modifications

	Klüberpaste ME 31-52	Klüberpaste HEL 46-450	Klüberpaste UH1 84-201
Application	Tried-and-tested paste protecting against fretting corrosion for mounting rolling bearings	High-temperature paste for mounting rolling bearings and for positive connections. Above 200 °C (392 °F) dry lubrication.	For use in the food-processing and pharmaceutical industries. Recommended for use in combination with food-grade greases.
Base oil	Mineral oil	Ester oil/PAG	Synthetic hydrocarbon
Thickener/solid lubricant	Calcium complex soap/inorganic solid lubricants	Solid lubricant	PTFE/solid lubricant
Colour	white to beige	black	white
Texture	homogeneous/short-fibred	homogeneous/short-fibred	homogeneous/long-fibred
Service temperature range, approx.	-15 to 150 °C 5 to 302 °F	-40 to 1 000 °C -40 to 1 832 °F	-45 to 120 °C -49 to 248 °F



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Klüber Lubrication – your global specialist

Innovative tribological solutions are our passion. Through personal contact and consultation, we help our customers to be successful worldwide, in all industries and markets. With our ambitious technical concepts and experienced, competent staff we have been fulfilling increasingly demanding requirements by manufacturing efficient high-performance lubricants for more than 80 years.



A company of the Freudenberg Group