KLÜBER LUBRICATION

The Element That Rolls The Bearing

A bearing is only as good as its grease / Klüber offers product variety and service

Lubrication is our World

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1.0 Rolling bearing lubricants manufactured by 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 friction surfaces by means of a suitable lubricant. Ideally, the lubricant should fill all the free bearing space and completely envelop the cage and rolling elements.

Fit for new challenges

At Klüber Lubrication, several generations of experts have been developing special high-performance lubricants for half a century. The people here are aware that a rolling bearing is only as good as the lubricant it contains. At Klüber, lubricants are considered vital design elements that require constant improvement as operating conditions under which rolling bearings are expected to perform become tougher and tougher for rolling bearings are not without complexity. 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 is 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 do what they're designed for: rolling.

2.0 Basics of grease lubrication

The most important task of a lubricating grease is to separate parts moving relative to one another in order to minimize friction and prevent wear. A grease that is specifically designed for certain operating conditions will provide a reliable load-bearing wear protective lubricating film. If friction surfaces are separated in this way, one speaks of "physical lubrication".

However, rolling bearings rarely operate under ideal conditions; they are exposed to the influences of temperature or varying speeds, the lubricating film is therefore changing continuously. Under adverse conditions, the result may be contact between the two friction surfaces. The thinner the load-bearing oil film becomes, the more important is the formation of a lubricating layer on the surfaces of the friction bodies. This happens through the chemical reaction of additives and is therefore referred to as "chemical lubrication".

So what is lubrication all about?
Basically, we differentiate between three different lubricating conditions:

a) Boundary lubrication

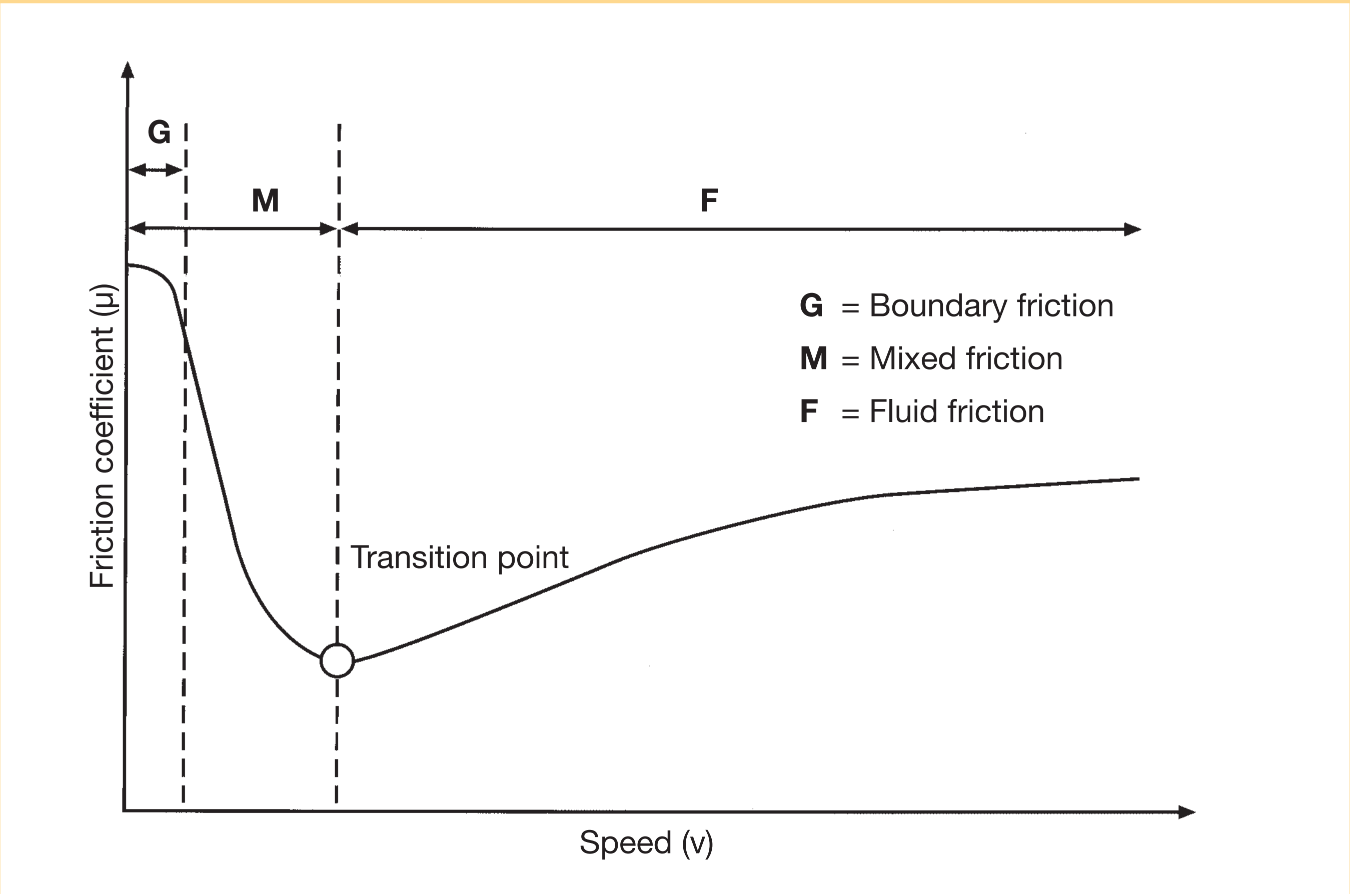
Under boundary lubrication conditions, load is transmitted via continuous surface contact. In combination with poor lubrication this may lead to extreme wear and premature bearing failure. This potentially damaging condition can be prevented by the use of extreme-pressure additives or by the use of solid lubricants. Some heavy-duty greases containing suitable additives for wear protection can also be considered. A special lubricating protective effect can also be attained by means of "sandwich lubrication" consisting of a coated surface in combination with a secondary lubricating grease.

b) Mixed lubrication

Under mixed-friction lubrication conditions, variable load is transmitted partly between the surface asperities across the roughness peaks in contact with one another, and partly via a lubricant film. Wear protection additives should be used under these conditions to prevent excessive wear.

c) Full-film lubrication

Full-film lubrication is the optimum lubrication condition characterized by complete separation of the surfaces by a load-bearing lubricant film. Depending on the internal friction of the lubricant, extremely low friction coefficients can be attained.



Stribeck curve

Friction

Theoretically, the resistance met by the rolling elements when contacting the bearing raceways is assumed to be of a purely rolling nature. In practice, however, partial sliding may occur between the rolling elements and the raceways. Sliding between the cage and the rolling elements can also occur resulting in churning or displacement of the lubricant.

The frictional moments, and hence the friction coefficient μ, are dependent on the load, the lubricating condition and the bearing speed. The Stribeck diagram (see Fig.) shows the friction coefficient μ relative to the speed v. In the diagram, we can discern the three different lubricating conditions:

- ❑ boundary lubrication
- ❑ mixed lubrication
- ❑ full-film lubrication

The curve of the friction coefficient μ indicates the increase and decrease of the frictional moments that occur in line with a temperature increase and decrease in the bearing.

3.0 Overview of rolling bearing greases

There are a large variety of grease options to be considered by the manufacturers and users of rolling bearings. In the following overview you will find a selection of available types along with their relevant characteristics such as service temperature range, drop point, water resistance, corrosion protection, extreme-pressure

Greases	Indications		
Thickener	**Base oil**	**Service temperature range**[1] [°C]	**Drop point** [°C]
Calcium soap	Mineral oil	-20 to 50	< 100 some < 130
Lithium soap	Mineral oil PAO Ester oil Silicone oil	-35 to 130 -50 to 150 -65 to 150 -60 to 170	< 200 < 200 < 200 < 200
Sodium soap	Mineral oil	-20 to 100	< 130
Aluminium complex soap	Mineral oil	-30 to 160	> 230
Barium complex soap	Mineral oil PAO	-30 to 140 -50 to 150	> 220 > 220
Sodium complex soap	Mineral oil Silicone oil	-30 to 160 -50 to 200	> 220 > 220
Calcium complex soap	Mineral oil Ester oil	-30 to 130 -40 to 120	> 220 > 220
Lithium complex soap	Mineral oil PG Ester oil Silicone oil	-30 to 140 -30 to 150 -40 to 180 -40 to 180	> 230 > 230 > 230 > 230
Bentonite	Mineral oil	-20 to 160	–
Polyurea	Mineral oil PAO Ester oil	-20 to 160 -40 to 160 -40 to 180	> 250 > 230 > 230
Synthetic (PE, PTFE, FEP)	Silicone oil Alkoxy fluorine oil	-50 to 200 -40 to 250	> 230 not measurable

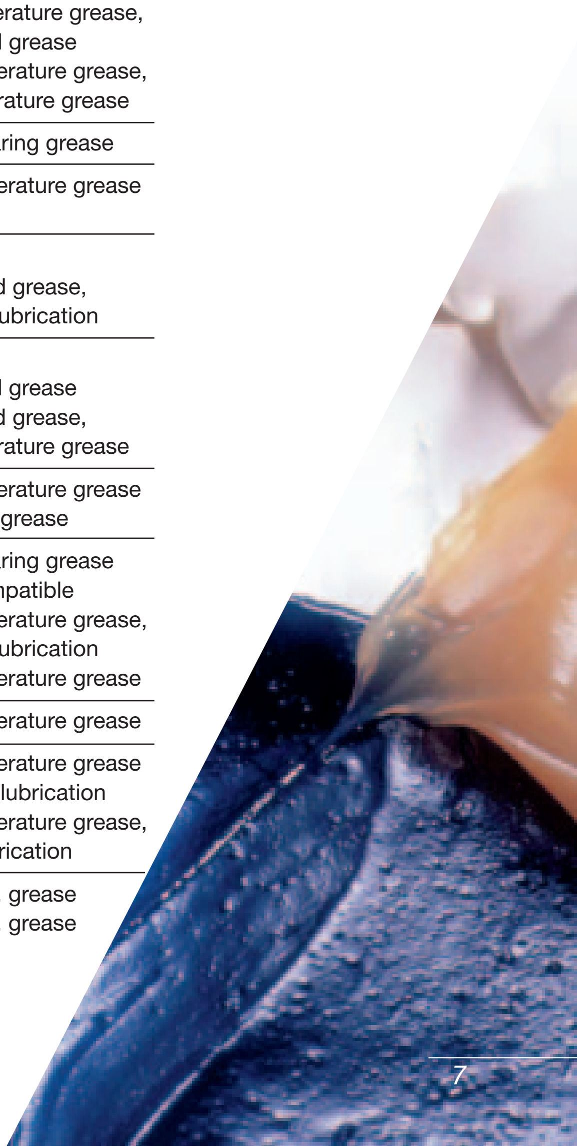
[1] *see page 63*

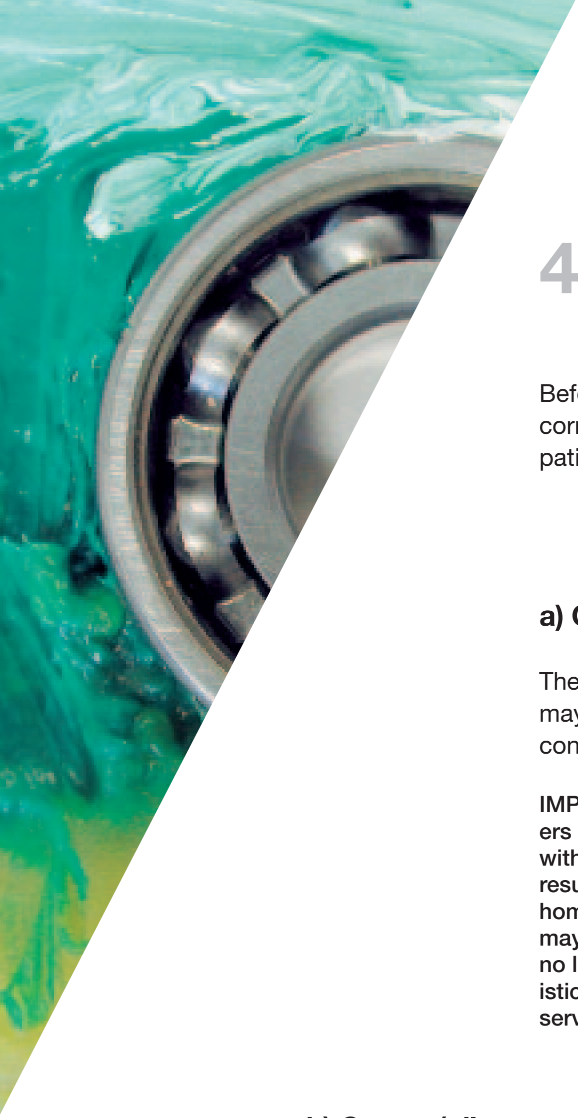
characteristics and suitability in rolling bearings as well as notes on possible applications.
NLGI consistency classes 2 or 3 are selected for the majority of rolling bearing applications.

Legend

+++	very good
++	good
+	satisfactory
–	sufficient
– –	poor

Water resistance	Corrosion protection	Pressure resist-ance	Suitability for rolling bearings	Application notes
+++	++	++	–	Rolling bearing grease
++	++	+	+++	Rolling bearing grease
++	++	++	++	Low-temperature grease
+	+	+	+++	Low-temperature grease, high-temperature grease, high-speed grease
++	–	–	++	High-temperature grease, low-temperature grease
–	+++	+	++	Rolling bearing grease
+++	+++	++	+++	High-temperature grease
+++	+++	+++	+++	EP grease
+++	+++	+++	+++	High-speed grease, long-term lubrication
+	+++	++	+++	EP grease, high-speed grease
++	+	–	+++	High-speed grease, low-temperature grease
++	+++	++	+++	High-temperature grease
++	++	++	++	Long-term grease
+	++	++	+++	Rolling bearing grease
+	++	++	++	EPDM-compatible
++	++	++	+++	High-temperature grease, long-term lubrication
++	++	–	+	High-temperature grease
++	–	–	++	High-temperature grease
+++	+	–	++	High-temperature grease
+++	++	+	++	Long-term lubrication
+++	++	+	+++	High-temperature grease, lifetime lubrication
+++	+	–	++	High-temp. grease
+++	+	++	++	High-temp. grease





4.0 Miscibility of greases

Before mixing different greases, or greases and oils (e.g. anti-corrosion oils), both substances should be checked for compatibility to prevent occurrence of the following problems:

a) Grease/grease

The mechanical stability of the mixture may suffer; negative changes to grease consistency may occur!

IMPORTANT: Different types of thickeners or base oils may not prove miscible with one another. When mixed, the resulting substance may not be fully homogeneous (two separate phases may result). The grease "mixture" may no longer maintain its original characteristics becoming extremely unreliable in service!

b) Grease/oil

Anticorrosion oils originally applied to the bearing may not necessarily be as pure as the rolling bearing grease selected. Mixing the two substances may therefore lead to a loss of purity, thereby affecting the low-noise operating characteristics. The upper service temperature limit of high-temperature grease may also suffer from the influence of "standard" mineral-oil-based anticorrosion oil due to its chemical decomposition at elevated temperatures.

IMPORTANT: Optimum adhesion between a grease and metallic surfaces can only be ensured if no other substance (e.g. anticorrosion oil) is present between the two, the only exception being anticorrosion oils that are specifically tuned to the particular grease used. Greases based on PFPE oils require clean surfaces for attainment of maximum adhesion.

The following tables provide an overview regarding miscibility of thickeners and base oils. For this purpose, mixing ratios of 50:50 are assumed.

HINT: Since additives may also have undesirable effects when mixed, we recommend consulting the manufacturer of the particular lubricating grease prior to use.

4.1 Miscibility of thickeners

Legend

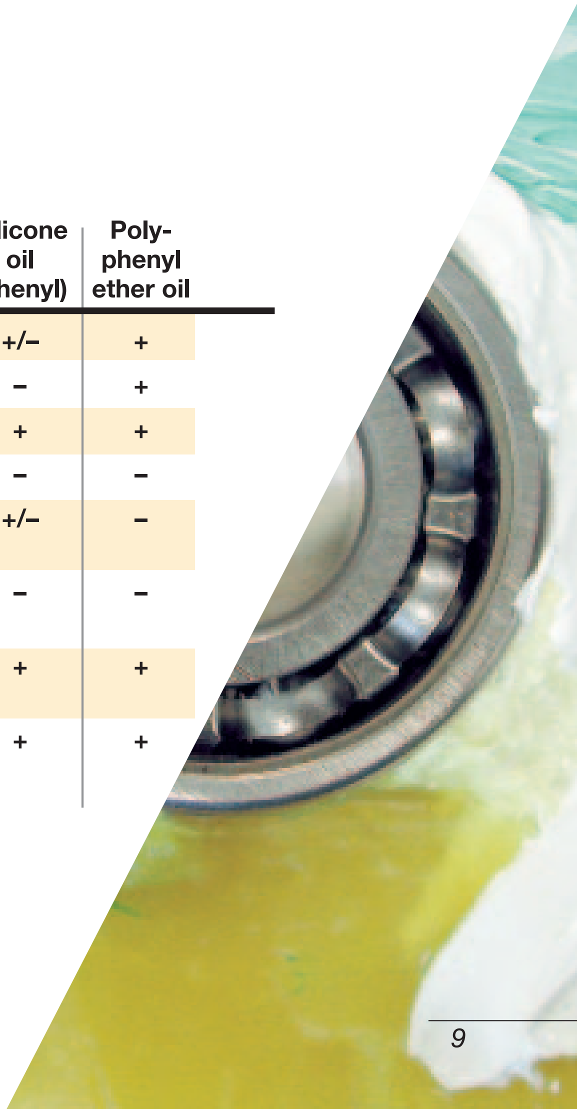
+	miscible
+/–	partially miscible
–	not miscible

Base oils must be miscible

		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	++	+	+	+	+	+	+	+	+	+	+	+

4.2 Miscibility of base oils

	Mineral oil	Synth. hydro-carbon	Ester oil	Poly-glycol	Silicone oil (methyl)	Perfluoro-alkyl ether	Silicone oil (phenyl)	Poly-phenyl ether oil
Mineral oil	+	+	+	–	–	–	+/–	+
Synthetic hydrocarbon	+	+	+	–	–	–	–	+
Ester oil	+	+	+	+	–	–	+	+
Polyglycol	–	–	+	+	–	–	–	–
Silicone oil (Methyl)	–	–	–	–	+	–	+/–	–
Perfluoro-alkyl ether	–	–	–	–	–	+	–	–
Silicone oil (Phenyl)	+/–	–	+	–	+/–	–	+	+
Poly-phenyl ether oil	+	+	+	–	–	–	+	+



5.0 Compatibility with elastomers and plastics

Besides miscibility with other greases, the compatibility of a lubricant with elastomers and plastics should be tested prior to its use.
Such tests normally consist of immersing materials into the grease at the required operating temperature for several hours or even up to one week. When removed, change in volume, Shore hardness, tensile strength and elongation at tear are measured.
Based on our many years of experience with materials compatibilities, our tables a) elastomers and b) plastics provide some basic hints as to which material combinations should be normally preferred and which avoided. To make sure, however, lubricant and elastomer/plastic compatibility, tests should be performed.

Legend	
+	resistant
+/–	partially resistant
–	not resistant

a) Elastomers

	Mineral oil	Synth. hydro-carbon	Ester oil	Poly-glycol	Silicone oil	PFPE	Poly-phenyl ether
NBR	+	+*	+/–	+/–	+	+	+
HNBR/NEM	+	+	+/–	+/–	+	+	+
FPM/FKM	+	+	+	+	+	+	+
EPDM	–	–	–	+	+	+	-
ACM	+	+	+/–	+/–	+	+	+
AU	+	+/–	+/–	+/–	+	+	+/–

b) Plastics

	Mineral oil	Synth. hydro-carbon	Ester oil	Poly-glycol	Silicone oil	PFPE	Poly-phenyl ether
POM	+	+	+	+	+/–	+	+
PA	+	+	+	+	+	+	+
PE	+/–	+/–	+/–	+	+	+	+/–
PC	+**	+***	–	–	+	+	–
ABS	+**	+***	–	+/–	+	+	–
PTFE	+	+	+	+	+	+	+

* *slight shrinkage in most cases*
** *with white oil*
*** *without additives*

6.0 Selecting the correct 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 chart, 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 utilize the potential of your equipment by selection of the optimum lubricant.

HINT: The more information provided in relation to the bearing, its application, environment and operating parameters, the better will be the final selection of the optimum lubricant.

The following procedure will hopefully assist you in selection of the correct choice of lubricating grease.

6.1 Operating temperature

Due to internal friction, the inherent operating temperature of a bearing is between 35 °C and 70 ˚C; however, external temperatures can influence the bearing such that its final temperature may be much higher or sometimes lower. Automotive manufacturers, for example, have typically to consider temperatures between minus 40 ˚C and plus 160 ˚C. 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.

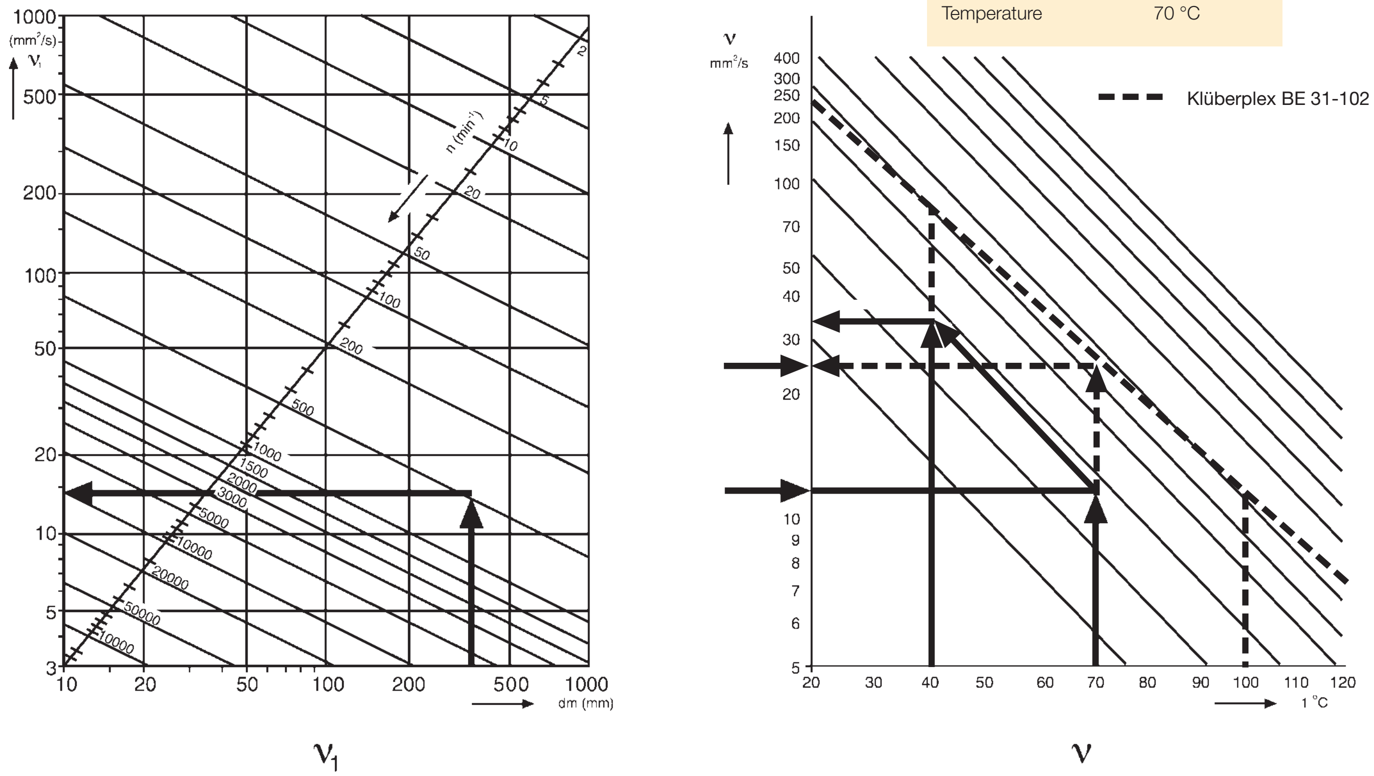
HINT: In order to attain a satisfactory grease life, a grease should be selected whose upper service temperature limit is considerably higher than the maximum operating temperatures to be expected.

6.2 Determination of minimum base oil viscosity

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

Legend

Bore	340 mm
Outer diameter	420 mm
Mean bearing diameter	380 mm
Speed	500 min⁻¹
Temperature	70 °C



NOTE: This diagram applies to mineral oils. We will be pleased to provide information for synthetic oils upon request.

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

* Note: To calculate the correct viscosity ratio when using a grease you should use the given base oil viscosities for 40 and 100 °C and apply them to the ν-T diagram. Now figure out the viscosity ν of the base oil at operating temperature (e.g. Klüberplex BE 31-102 at 70 °C:
$\nu_1 = 12$; $\nu = 25$; $\kappa = \frac{25}{12} = 2.1$).

6.3 Speed factor

6.3.1 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 [min^{-1}] multiplied by the mean bearing diameter d_m in [mm].

6.3.2 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 Klüber Lubrication rolling bearing greases, 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 expected 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 [mm^2/s]	**Speed factor**[2] $n \cdot d_m$
Mineral / lithium / MoS_2	1000 to 1500	50,000
Mineral / lithium complex	400 to 500	200,000
Mineral / lithium complex	150 to 200	400,000
Ester / polyurea	70 to 100	700,000
Ester / lithium complex	15 to 30	1,600,000
Ester / polyurea	15 to 30	2,000,000

[2] *see page 63*

6.4 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.

7.0 Grease application in rolling bearings

Around 90% of all rolling bearings are lubricated with grease. The use of 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 bearings where synthetic greases are required. 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 Klüber special greases 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 two years to almost continuous application.

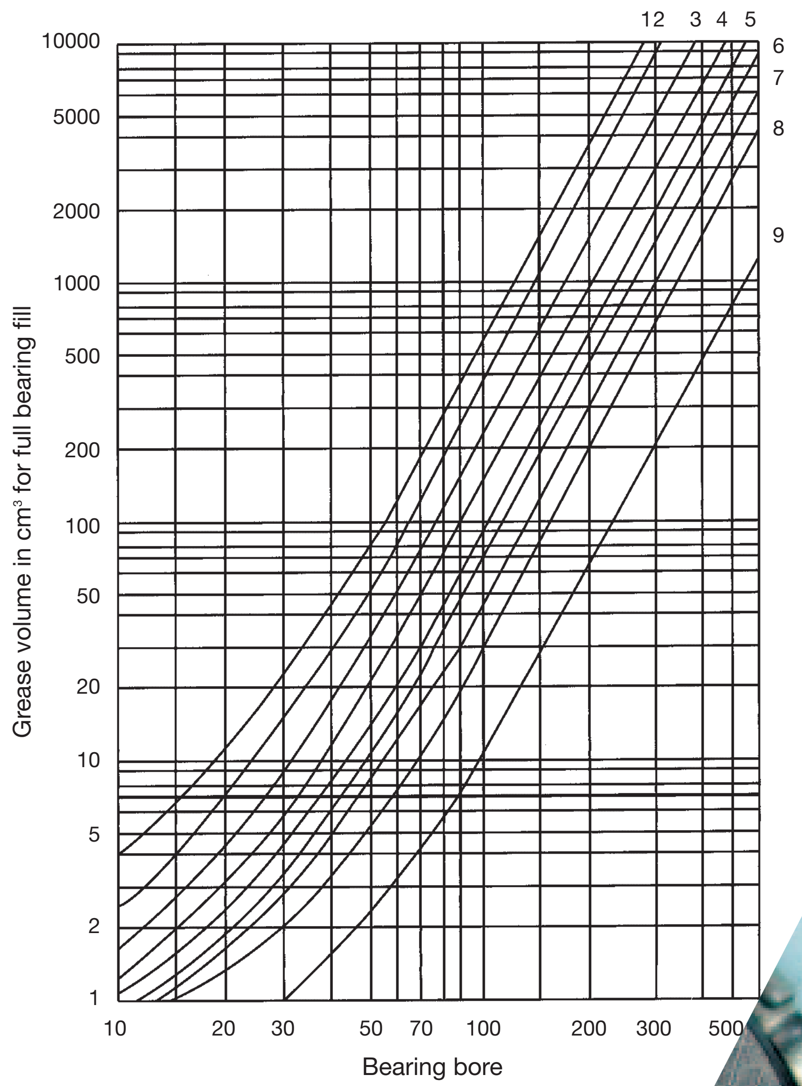
By the use of optimum relubrication quantities and intervals, machine users can attain considerable savings. Klüber provides high-performance greases of the highest quality that help to minimize costs through attainment of the longest possible relubrication interval. Lubricating greases can be applied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

7.1 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.

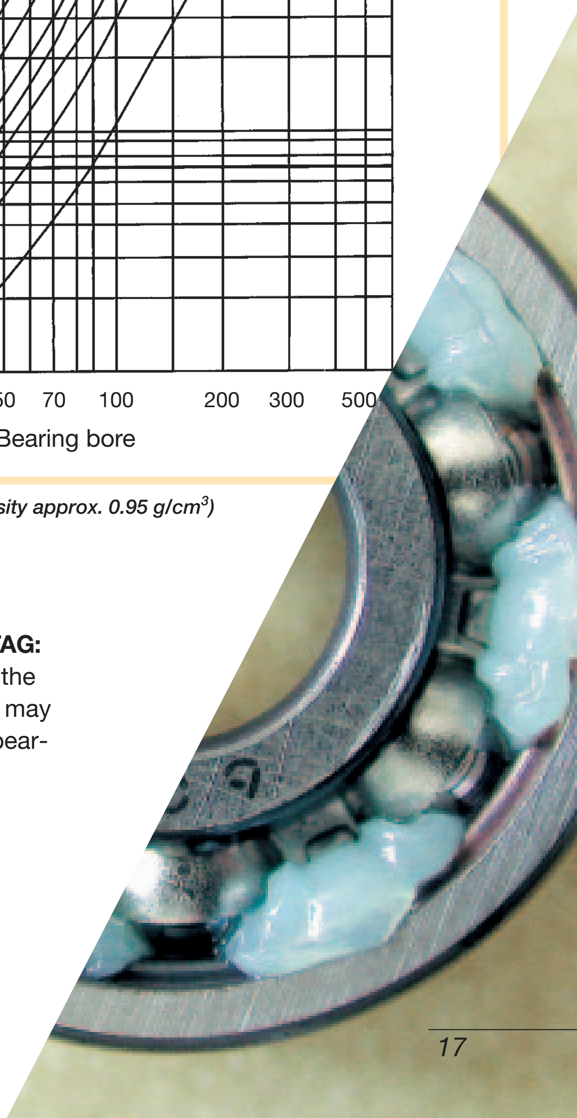
The following diagram can be used to determine the free space in different types of bearings for initial lubrication purposes.

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
Taper 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	
NU1O	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



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

Bearing Free Space according to FAG:
The bearing free space indicated in the diagram apply to FAG bearings and may only serve as a reference value for bearings made by other manufacturers.



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 [cm^3, dm^3] instead of weight units [g, kg] in order to avoid calculation errors (up to 100%) due to the different densities of greases

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

wherein

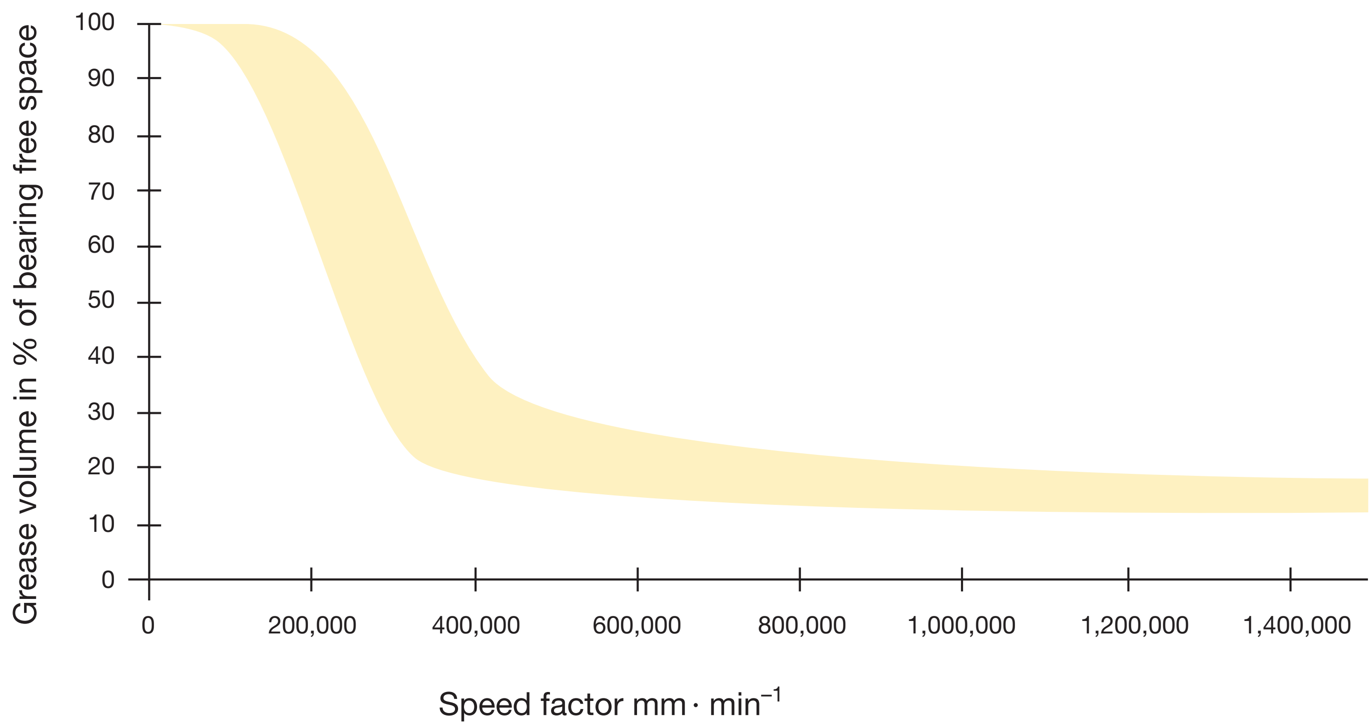
- d = **bearing bore diameter** [mm]
- D = **outer bearing diameter** [mm]
- B = **bearing width** [mm]
- G = **bearing weight** [kg]

Because of different bearing types, cages and designs, the a.m. formula does only give a rough estimation. Therefore we recommend to consult the bearing OEM about the exact bearing free space.

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 be generally observed is:
low operating temperatures = long service life of both the grease and the bearing. The following table provides an overview of the required grease quantities as a percentage of bearing free space for various speed factors in [$mm \cdot min^{-1}$].

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.



Grease fill as a function of the speed factor

7.2 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 in their work 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_{10}. For the calculation of the theoretical reduced grease service life F_{10}, see chapter 8.

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 (made by the Germany Society of Tribology) differentiates between three different cases:

1. Relubrication once per week to once per year

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

$$\mathbf{M1 = D \cdot B \cdot X,}$$

with X standing for:

weekly: X = 0.002,
monthly: X = 0.003,
yearly: X = 0.004

M1 in cm^3
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 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

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

with

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

as described in the chapter 7.1 "How much grease does the bearing need?".

Applications with very short relubrication intervals are those incorporating centralized lubricating systems. 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 reaches the bearing point!

Depending on factors such as application service temperatures and theoretical relubrication interval, the grease within the centralized lubrication system, the housing and bearing free space should be replaced completely once every six months to one year. This ensures 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:

$$\mathbf{M3 = D \cdot B \cdot 0.01}\ [cm^3]\,.$$

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 centralized lubricating system we recommend checking of the system to determine whether the grease is being discharged to all points as required. 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 rotating 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. The most effective solution consists of a vent hole or seal through which the old grease can escape from the bearing.

7.3 Grease distribution and running-in

For most slow and medium speed rolling bearing applications special grease distribution and running-in techniques are not necessary. For high-speed precision bearings, however, distribution and running-in is essential.

Bearing speed factors can be increased considerably by implementation of a running-in program. Running-in modifies the texture of the grease's thickening agent ensuring correct localized oil release in the direction of the bearing raceways. This ensures that the required oil volume reaches the contact zone within the bearing allowing low friction and long operational performance.

Grease distribution 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 statements as to the ideal grease distribution running-in procedure may differ.

FAG Aircraft/Super Precision Bearings GmbH provides the following recommendation for their spindle bearings B ..., HS ..., and HC ...:

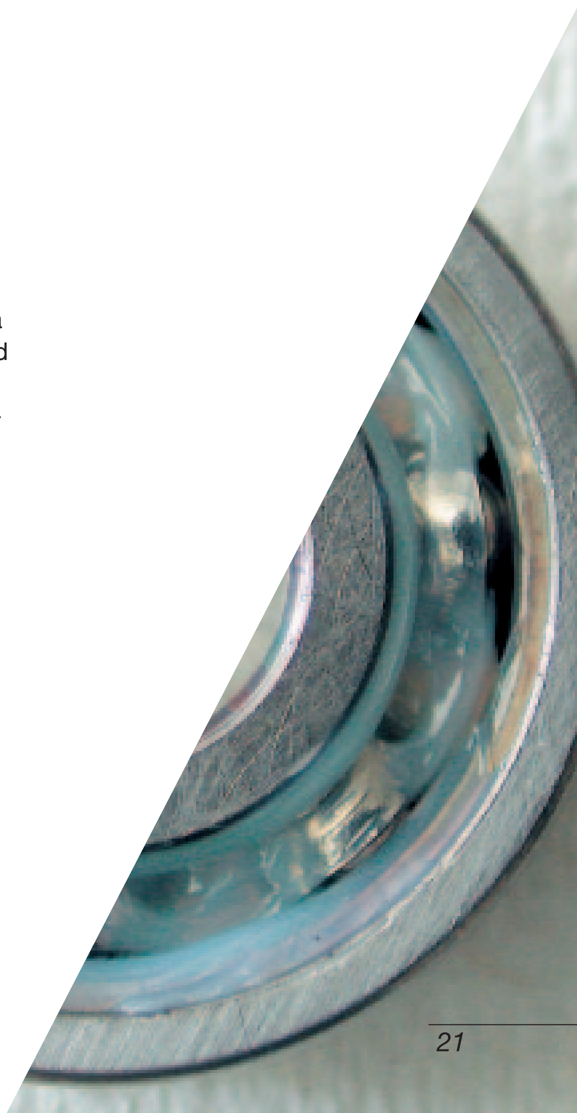
a) **Speed factor = max. 0.5 · n**
In five steps 20 s running and 2 min rest period

b) **Speed = max. 0.75 · n**
In five steps 20 s running and 2 min rest period

c) **Speed = 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 2 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.



8.0 Special lubricating greases

There are many rolling bearing greases which have been "tailor-made" for individual applications. These special products constitute only a small part of the overall range of bearing lubricants but in reality solve many extreme application problems. If you have a specific problem requiring development of a special lubricating grease, please contact Klüber Lubrication, who 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.

8.1 Determination of theoretical service life for Klüber special lubricating greases

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 exceeds the maximum temperature in the diagram, you should select an alternative lubricant with a higher thermal capacity. If the actual bearing temperature is below the 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 $[min^{-1} \cdot mm]$ as well as the factor K_n by means of the chart which you will find on the same page as the diagram "grease service life as a function of temperature".

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_f for your bearing.

Bearing design	K_f
Deep groove ball bearing single-row double-row	 0.9 to 1.1 1.5
Angular contact ball bearing single-row double-row	 1.6 2
Four-point contact ball bearing	1.6
Self-aligning ball bearing	1.3 to 1.6
Deep groove thrust ball bearing	5 to 6
Angular contact thrust ball bearing double-row	 1.4
Cylinder roller bearing single-row double-row full-type	 3 to 3.5 3.5 25
Self-aligning roller bearing without flanges "E" type with center flange	 7 to 9 9 to 12
Needle bearing	3.5
Taper roller bearing	4
Spherical roller bearing	10
Cylinder roller thrust bearing	90

Other influencing factors 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
strong flow	$F_4 = 0.1$ to 0.5

5. Rotating outer ring

$F_5 = 0.6$

6. Vertical shaft arrangements

Depending on seal	$F_6 = 0.5$ to 0.7

For any influencing factor that does not apply, put in 1.

Formula to calculate the theoretical reduced grease service life:

$$F_{10q} = F_{10} \cdot K_n \cdot \frac{1}{K_f} \cdot F_1 \cdot F_2 \cdot F_3 \cdot F_4 \cdot F_5 \cdot F_6 \text{ [h]}$$

8.2 Rapidly biodegradable greases

Lubricants can only be considered environmentally acceptable if they are “rapidly biodegradable” whilst at the same time capable of providing long service life from initial, minimum quantity, lubrication. A standard biodegradable lubricant may be eco-friendly, as such, but only a high-performance lubricant actually prevents damage to the environment. Many rapidly biodegradable lubricants, based on vegetable oils, do not meet the high performance requirements of extreme applications. Klüber Lubrication manufacture rapidly biodegradable synthetic lubricants for extreme industrial demands.

At Klüber Lubrication, biodegradability is determined according to the special standard DIN 51 828-2 (= CEC-L-33-A-93 method). At present a lubricant is classified as rapidly biodegradable if it has been tested and approved according to the CEC-L-33-A-93 standard stating that more than 70% of its composition should biodegrade within 28 days.

Biodegradable lubricants should be selected for all applications where contamination of the soil or water cannot be excluded. Handling of such products requires the same care as with conventional oils and greases. For the manufacture of rapidly biodegradable lubricating greases only selected base oils, thickeners and additives are used:

ISOFLEX LDS 18 SPECIAL A

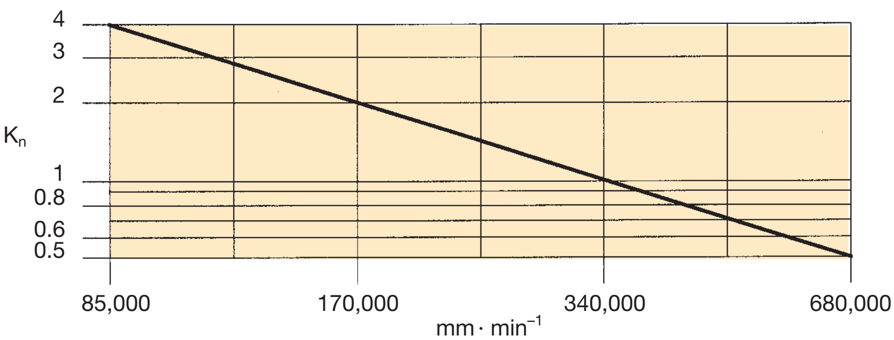
A dynamically light, noise-tested, long-term grease for rolling and plain bearings. Consisting of ester oil / mineral oil and special lithium soap, ISOFLEX LDS 18 SPECIAL A is suitable for bearings in high-speed applications such as grinding and work spindles, machine tools, spindle bearings, textile spindles and noise-tested bearings in precision and optical equipment.

Klüberbio M 72-82

A synthetic lubricating grease based on ester oil and polyurea. Klüberbio M 72-82 is mainly used for the lubrication of bearings in wood-processing and construction equipment, equipment for tunnel excavation as well as agricultural and forestry machinery.

Klüberbio BM 72-501

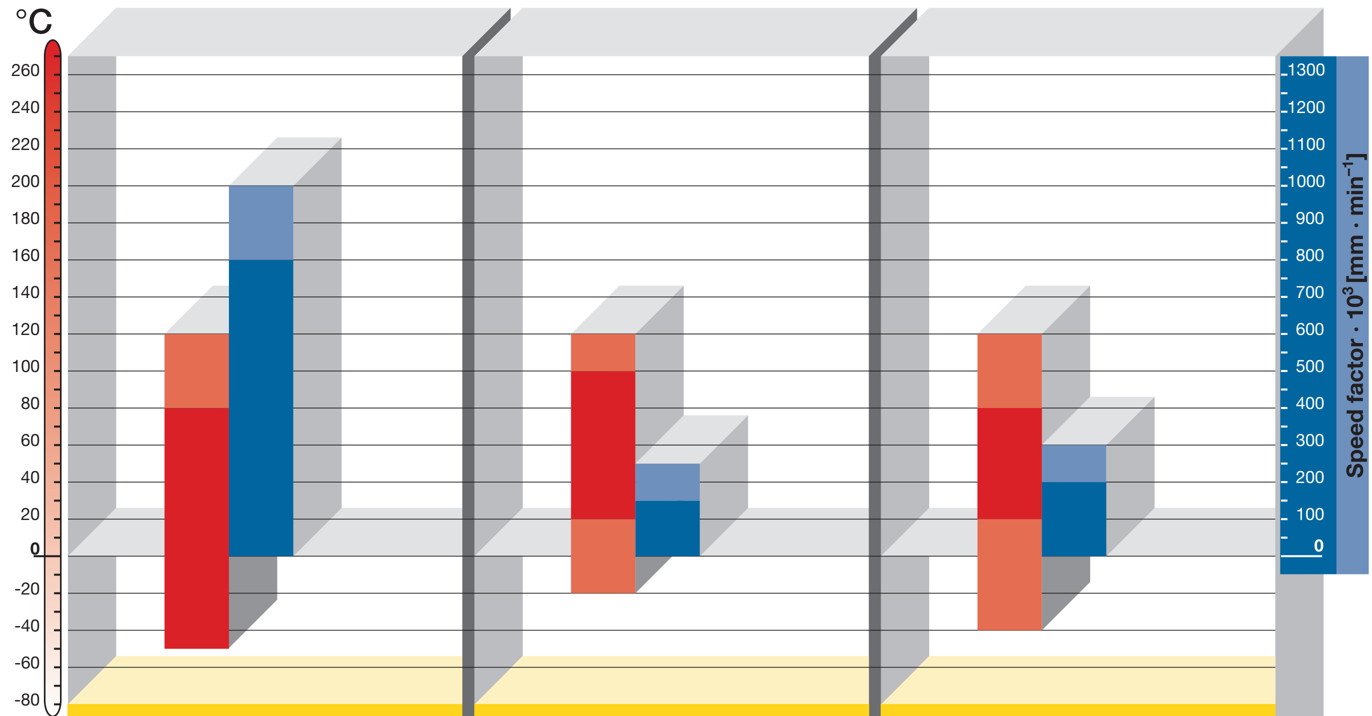
A lubricating grease containing ester oil and polyurea suitable for high load conditions at low to medium bearing speeds.



The diagram “Rapidly biodegradable greases” shows

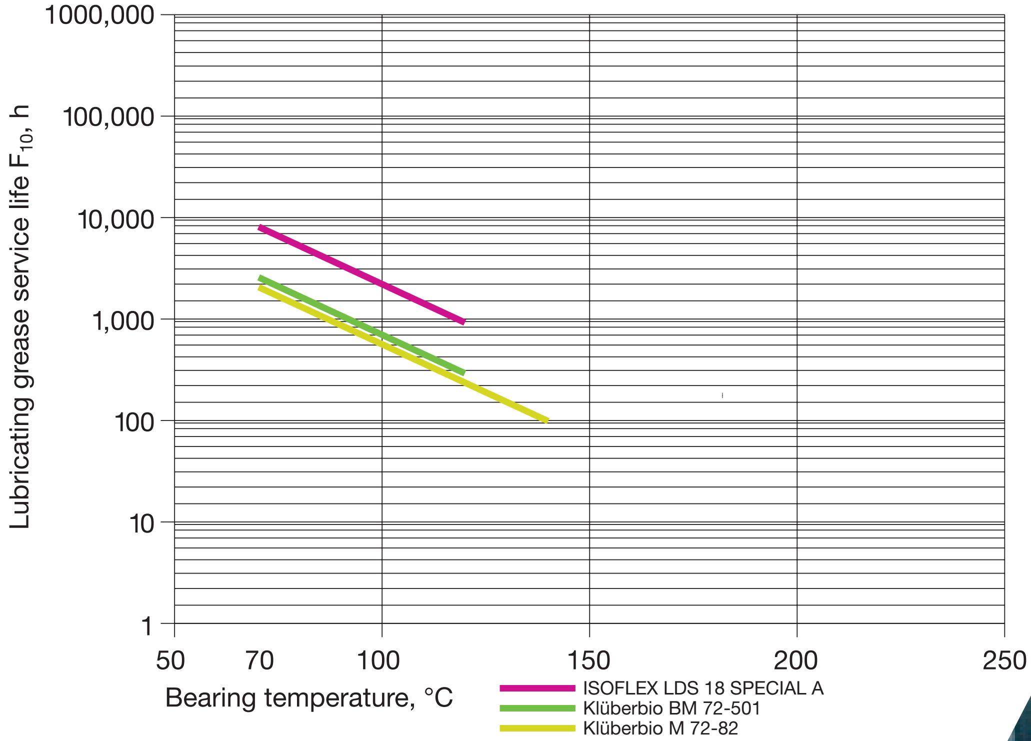
- ❑ Corrosion protection behavior according to the SKF-Emcor method (DIN 51 802)
- ❑ Water resistance (DIN 51 807, pt. 1)
- ❑ Desired C/P load ratio

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



	ISOFLEX LDS 18 SPECIAL A	Klüberbio BM 72-501	Klüberbio M 72-82
Emcor DIN 51 802	0/1	0/1	1
Water resistance DIN 51 807 T1, 3 h/90 °C	1-90	0-90	1-90
Estimated C/P ratio	> 30	> 5	> 20

Lubricating grease service life as a function of temperature



8.3 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 compared to the use of a standard industrial-grade grease.

Bearing specifics

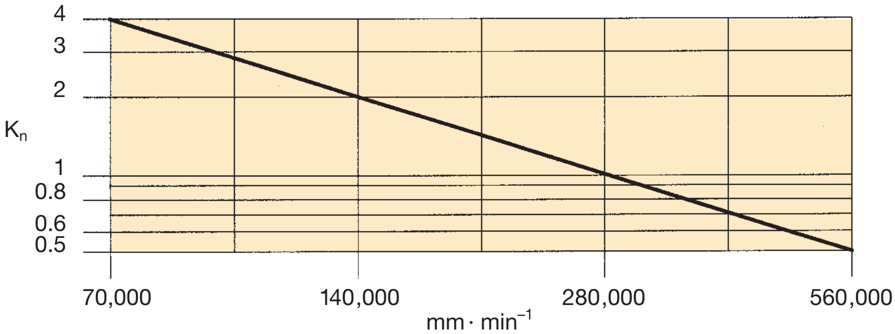
- Bearing surface (roughness, waviness)
- Contamination in the bearing
- Sealing material
- Bearing dimensions
- Cage type
- Seal type
- Vibration
- Osculation
- Bearing size
- Temperature
- Materials
- Load
- Internal clearance
- Precision
- Speed factor
- Cage type

Lubrication specifics

- Additives
- Grease volume
- Thickener
- Consistency
- Grease texture
- Grease distribution
- Grease application
- Base oil viscosity
- Manufacturing technology
- Contamination in the grease (purity)

Power generation at the test object “rolling bearing”

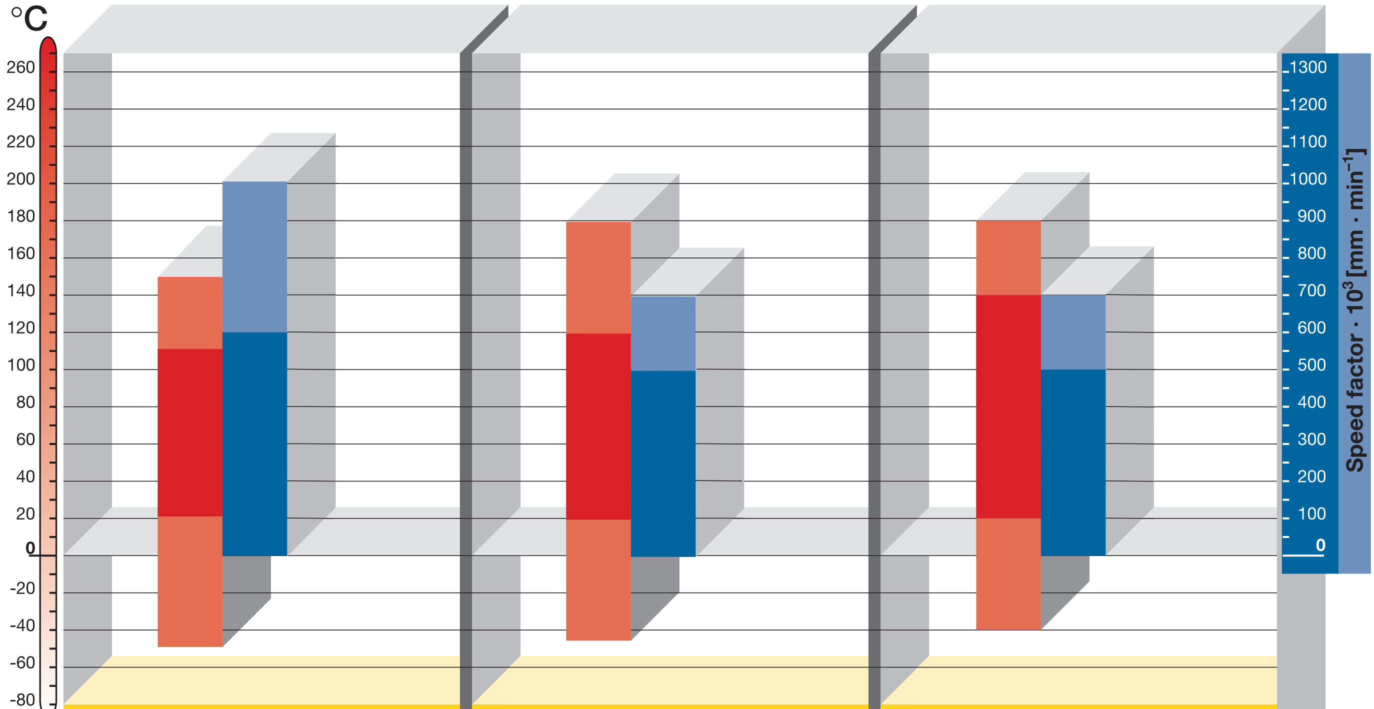
Both mechanical and lubrication-related factors can jointly influence the particular operating noise level of a rolling bearing. The combined noise behavior of the rolling bearing and lubricant is measured on special noise test equipment. It is often difficult to identify which influencing factors are responsible for generation of both solid and air-borne sound.



High-purity and low-noise greases undergo a special manufacturing process. The diagram shows

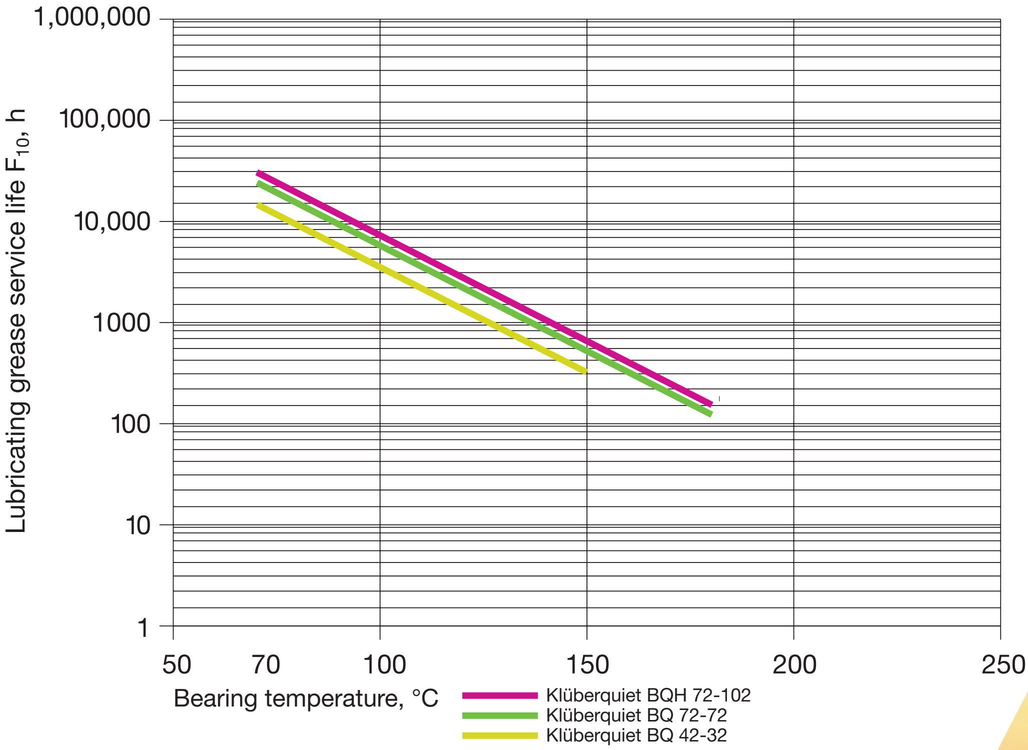
- ❑ Corrosion protection behavior according to the SKF-Emcor method (DIN 51 802)
- ❑ Water resistance (DIN 51 807, pt. 1)
- ❑ Desired C/P load ratio

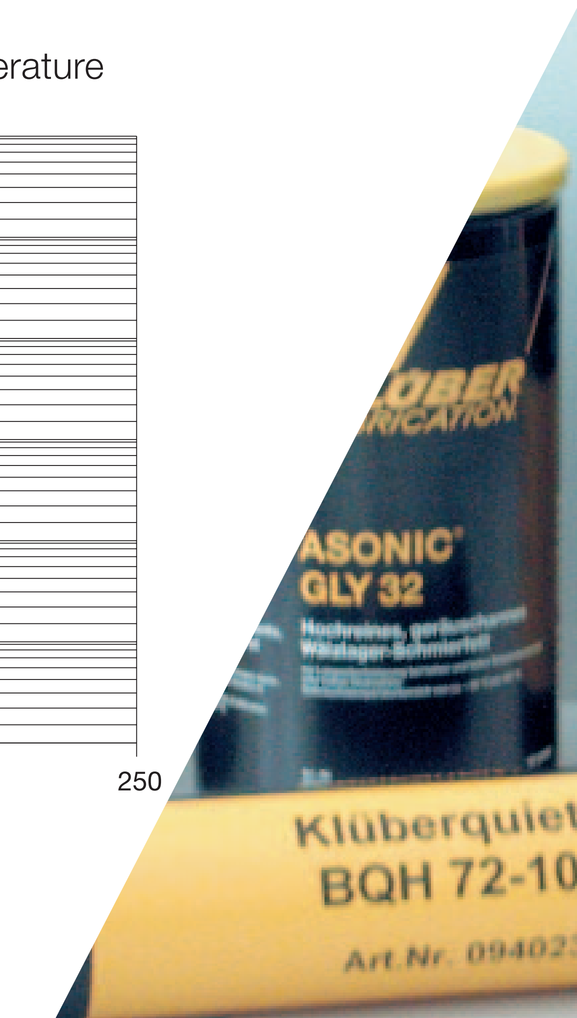
The operating temperature range and the maximum speed factor n · d_m can be read from the diagram. (The darker areas are target if lifetime lubrication is required.)



	Klüberquiet BQ 42-32	Klüberquiet BQ 72-72	Klüberquiet BQH 72-102
Emcor DIN 51 802	0/1	0/1	1
Water resistance DIN 51 807 T1, 3 h/90 °C	1-90	0/90	0/90
Estimated C/P ratio	> 20	> 10	> 10

Lubricating grease service life as a function of temperature





8.4 Low-temperature greases

Lubricating greases exhibiting minimal consistency increase at temperatures below zero. Such greases provide excellent low-temperature stability with the lowest starting and running torque. Suitable base oils for low-temperature duty are silicones, esters and polyalphaolefines. The general criterion defining low-temperature stability is the flow pressure test in accordance with DIN 51 805.

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 °C while the actual day to day operating temperature of the unit is for example + 100 °C.

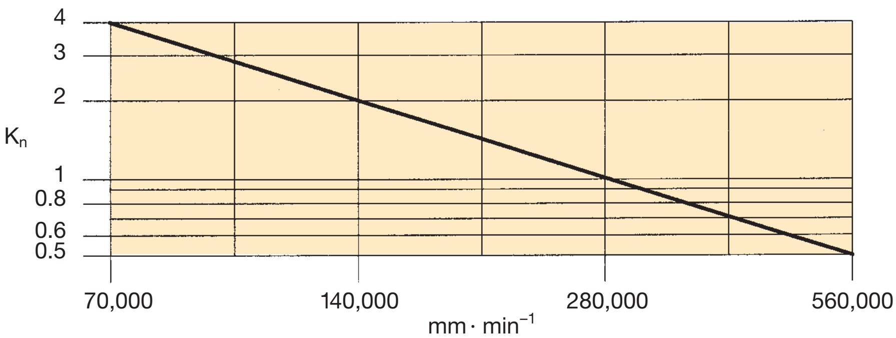
Three grease types are shown whose lower operating temperature range is clearly below minus 40 °C:

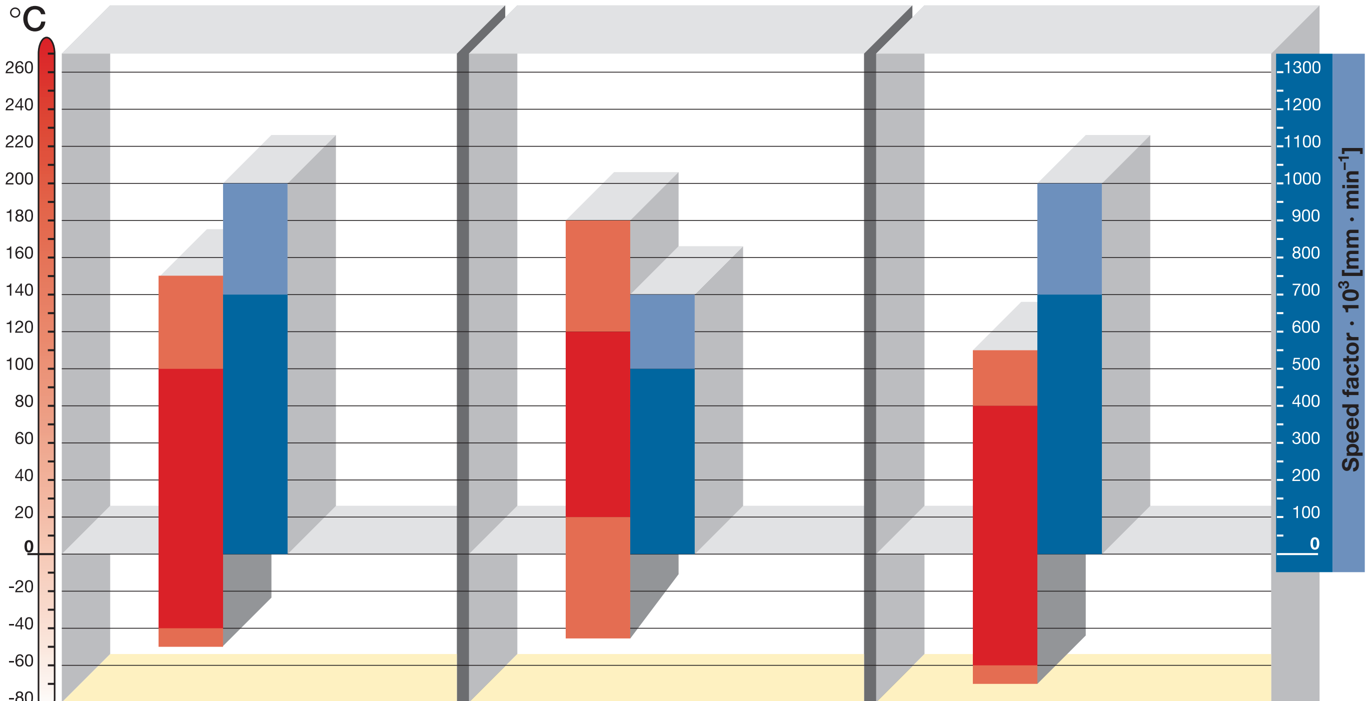
- **ISOFLEX PDL 300 A**
- **Klüberquiet BQ 42-32**
- **Klüberquiet BQ 72-72**

The diagram shows

- Corrosion protection behavior according to the SKF-Emcor method (DIN 51 802)
- Water resistance (DIN 51 807, pt. 1)
- Desired C/P load ratio

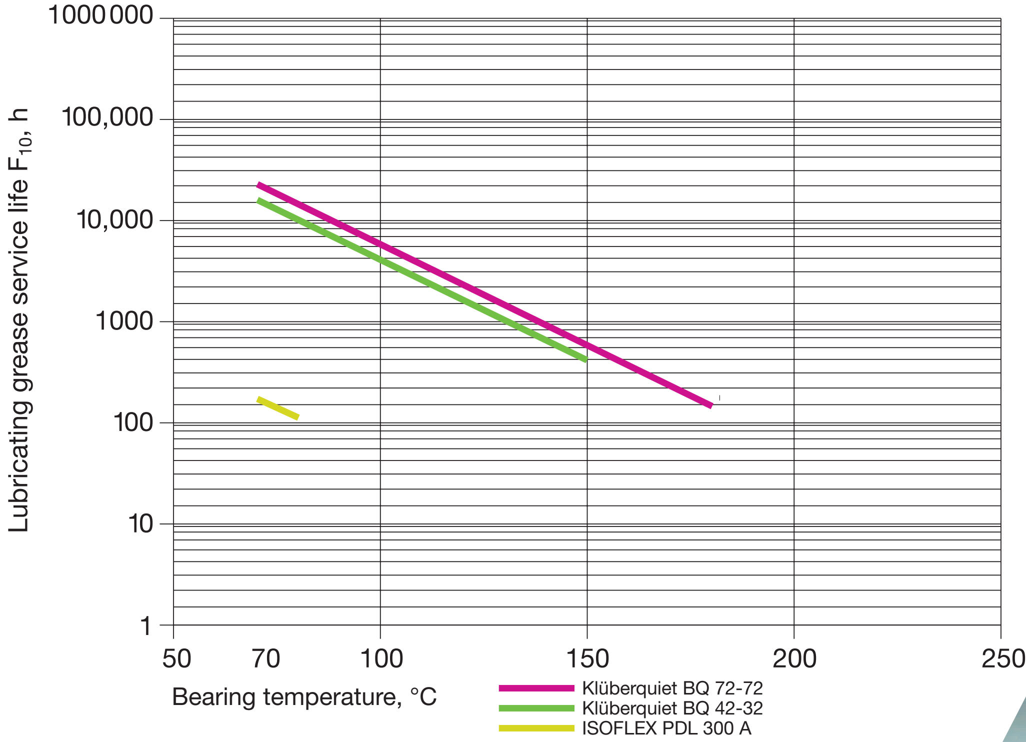
The operating temperature range and the maximum speed factors n · d_m can be read from the diagram. (The darker areas are target if lifetime lubrication is required.)

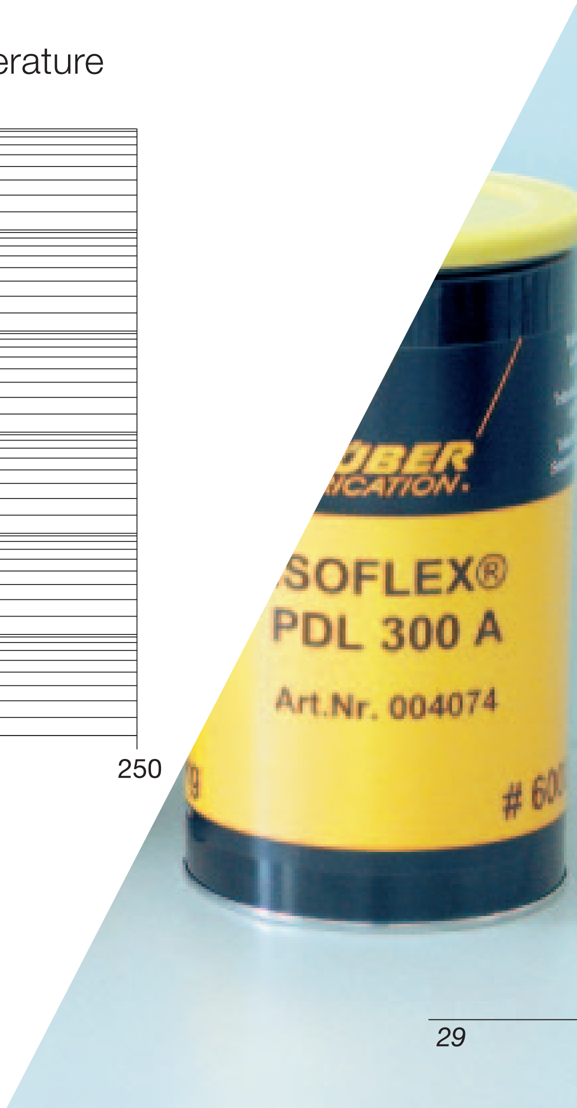




	Klüberquiet BQ 42-32	Klüberquiet BQ 72-72	ISOFLEX PDL 300 A
Emcor DIN 51 802	0/1	0/1	1
Water resistance DIN 51 807 T1, 3 h/90 °C	1-90	0/90	1-90
Estimated C/P ratio	> 20	> 10	> 30

Lubricating grease service life as a function of temperature





8.5 High-temperature greases

Greases consisting of synthetic, thermally stable, oxidation-resistant base oils incorporating organic or inorganic thickeners or temperature-resistant complex soaps. The maximum upper operating temperature limit for lubricating greases today is approximately 300 °C. For lifetime lubrication, however, the upper operating temperature has to be considerably lower than this maximum temperature in order to achieve acceptable running times.

BARRIERTA L 55/2
Lubricating grease based on perfluoropolyether and PTFE. For many years this grease has proven successful for high-temperature applications up to 260 °C. Before application of this special grease bearings require thorough cleaning to ensure maximum adhesion of the grease film.

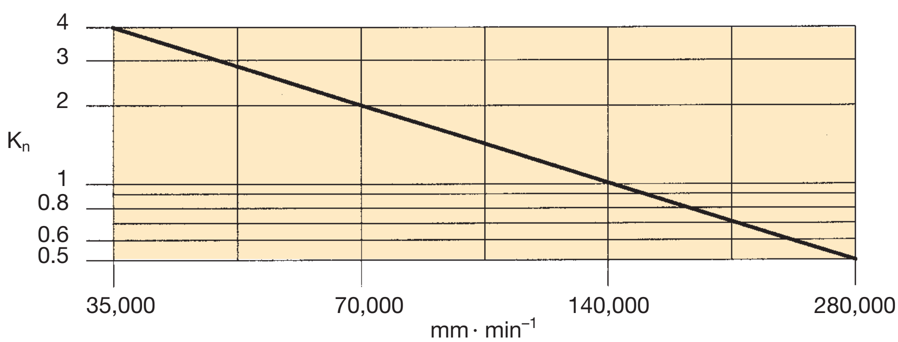
Klübersynth BH 72-422
Belongs to a new generation of so-called “wide range” lubricating greases suitable for both low and high temperatures. Resistant to chemicals, they are an excellent alternative to pure PFPE greases. Klübersynth BH 72-422 is based on ester oil, PFPE oil and polyurea as the thickening agent.

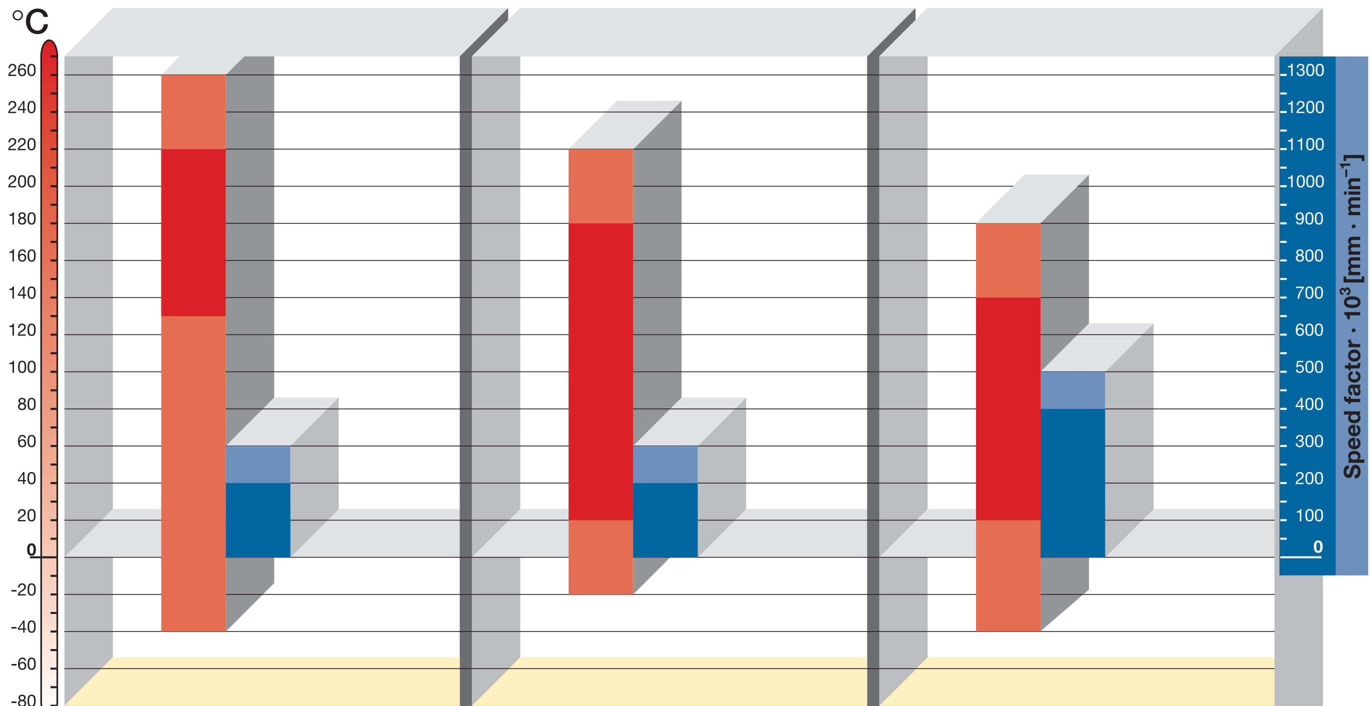
Klübersynth HB 72-102
Based on ester oil and polyurea as the thickening agent. Such greases have been successfully used for many years in the automotive industry for low- and high-temperature applications. A good economical, non-PFPE- based, alternative selection where lifetime lubrication at high operating temperature is required.

The diagram shows

- ❑ Corrosion protection behavior according to the SKF-Emcor method (DIN 51 802)
- ❑ Water resistance (DIN 51 807, pt. 1)
- ❑ Desired C/P load ratio

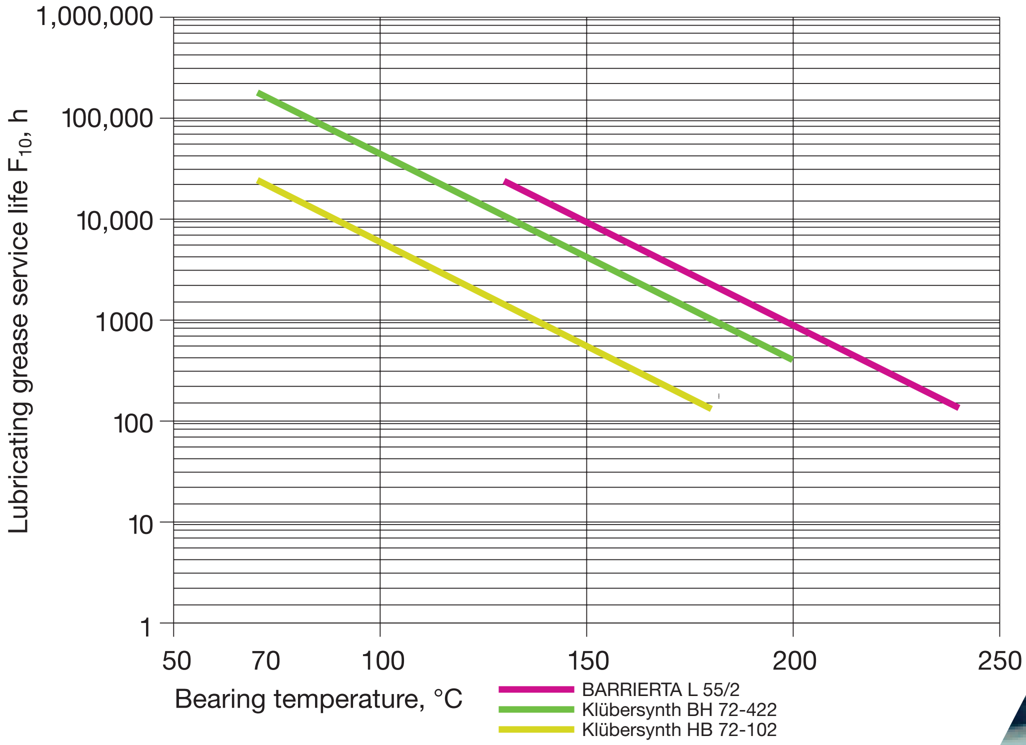
The operating temperature range and the maximum speed factors $n \cdot d_m$ can be read from the diagram. (The darker areas are target if lifetime lubrication is required.)

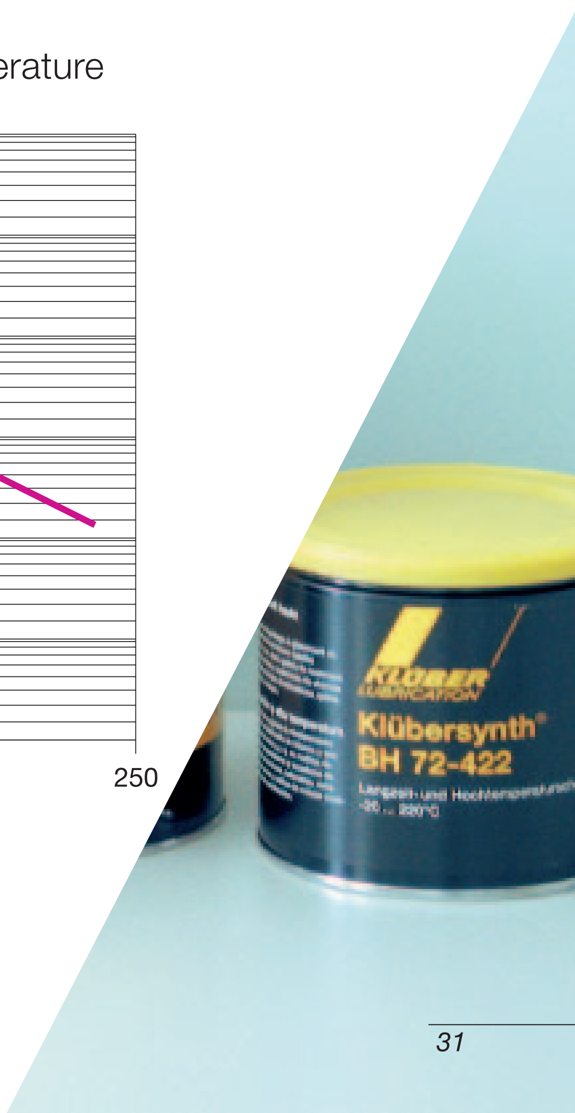




	BARRIERTA L 55/2	Klübersynth BH 72-422	Klübersynth HB 72-102
Emcor DIN 51 802	1	0/1	0/1
Water resistance DIN 51 807 T1, 3 h/90 °C	0-90	0/90	0-90
Estimated C/P ratio	> 5	> 10	> 10

Lubricating grease service life as a function of temperature





8.6 High-speed greases

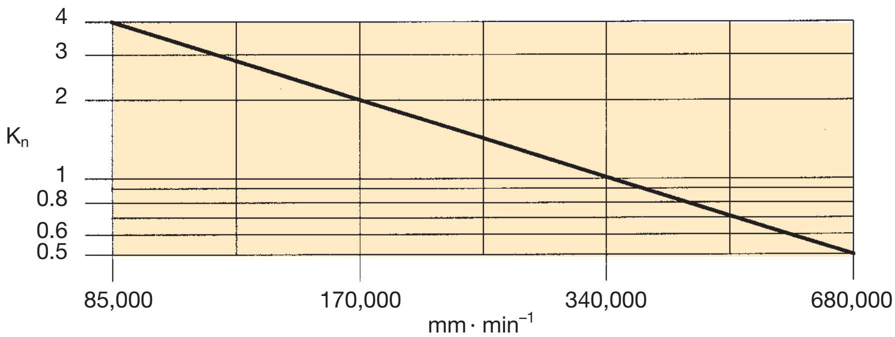
Modern high-speed lubricating greases easily cope today with speeds previously only possible through the use of lubricating oils. Their consistency corresponds to that of usual rolling bearing greases (e.g. NLGI grades 1 or 2). For speed factors below 1 million [mm · min^{-1}], high-speed rolling bearing greases have provided excellent operational performance for a great many years. More recently “new generation” extreme-speed greases have been developed enabling operational speed factors in excess of 2 million [mm · min^{-1}]! These greases fulfill lifetime lubrication conditions in machine tool spindles operating at low temperature.

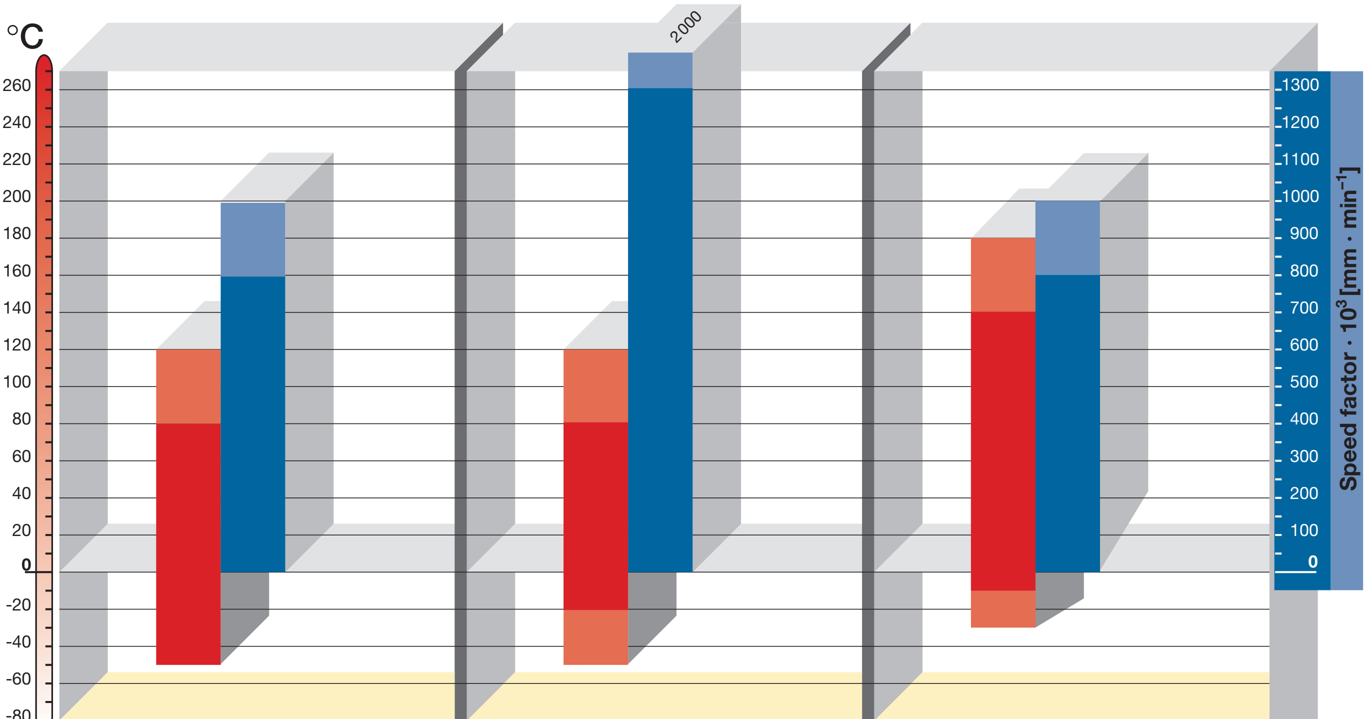
High-speed greases:
ISOFLEX LDS 18 SPECIAL A and ISOFLEX TOPAS L 152 have proven successful for many years.
Klüberspeed BF 42-12 and Klüberspeed BF 72-22 are the latest developments in high-speed bearing lubrication.
Klüberspeed BF 42-12 may be used at speed factors up to 1.6 million [mm · min^{-1}] and Klüberspeed BF 72-22 up to approximately 2 million [mm · min^{-1}].

The diagram shows

- ❑ Corrosion protection behavior according to the SKF-Emcor method (DIN 51 802)
- ❑ Water resistance (DIN 51807. pt. 1)
- ❑ Desired C/P load ratio

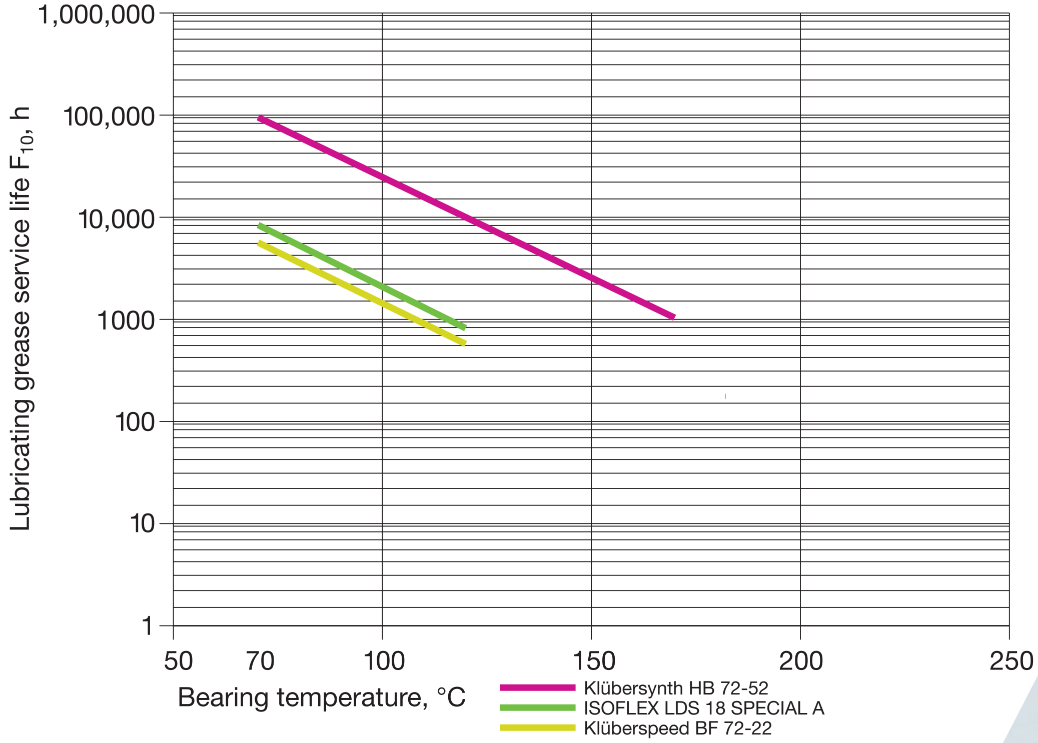
The operating temperature range and the maximum speed factors n · d_m can be read from the diagram. (The darker areas are target if lifetime lubrication is required.)

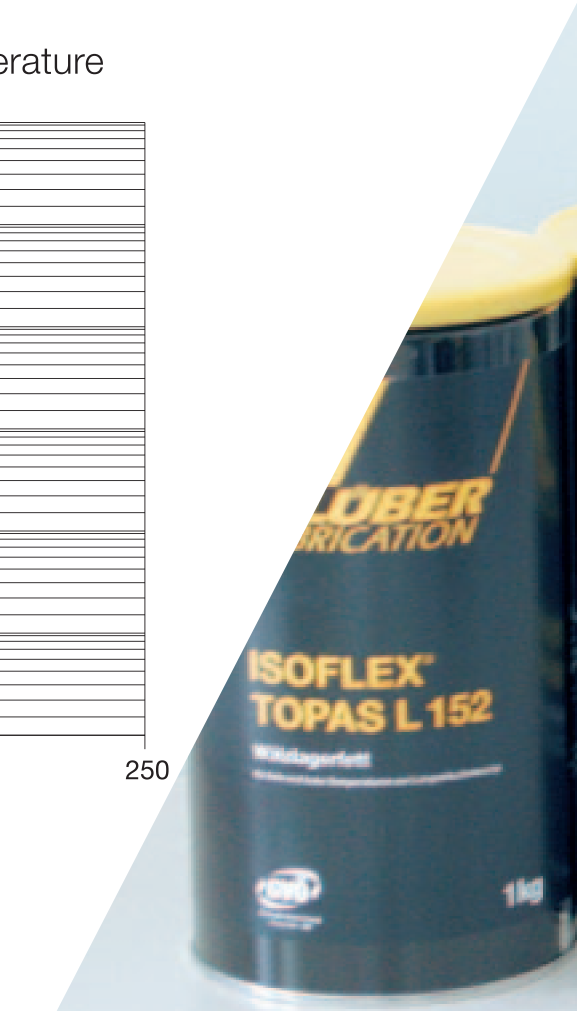


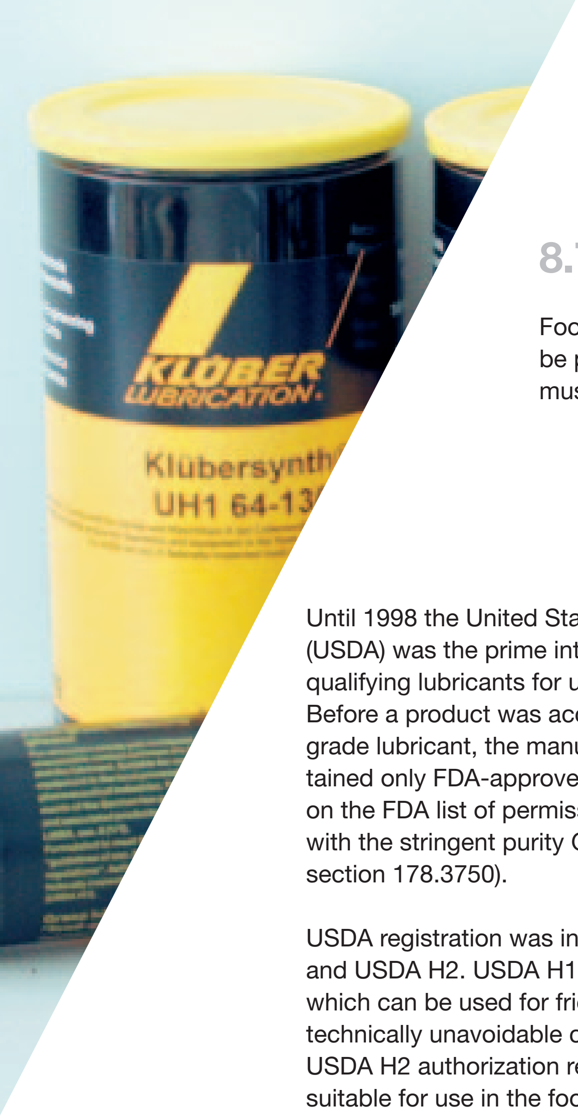


	ISOFLEX LDS 18 SPECIAL A	Klüberspeed BF 72-22	Klübersynth HB 72-52
Emcor DIN 51 802	0/1	1	1
Water resistance DIN 51 807 T1, 3 h/90 °C	1-90	1-90	0-90
Estimated C/P ratio	> 30	> 20	> 15

Lubricating grease service life as a function of temperature







8.7 Food-grade greases

Food-grade greases should be selected for applications where food contact may be possible. To meet international approval requirements, food-grade lubricants must be physiologically safe and neutral in terms of odor and taste.

Until 1998 the United States Department of Agriculture (USDA) was the prime internationally renowned authority qualifying lubricants for use in food-processing applications. Before a product was accepted by the USDA as a food-grade lubricant, the manufacturer had to prove that it contained only FDA-approved ingredients (ingredients that were on the FDA list of permissible substances in accordance with the stringent purity Guidelines of Security CFR 21 section 178.3750).

USDA registration was in two specific categories – USDA H1 and USDA H2. USDA H1 authorization refers to lubricants which can be used for friction points with incidental, technically unavoidable contact with the food product. USDA H2 authorization refers to lubricants which are suitable for use in the food-processing and pharmaceutical industries provided that contact with the food product is absolutely impossible.

For newly developed food-grade lubricants to be certified according to H1/H2, a DIN working group chaired by Klüber Lubrication München KG created the standard DIN V 0010517, definitions and requirements regarding food-grade lubricants. This standard has been approved by the DIN Food Hygiene Committee and was published in April 2001.

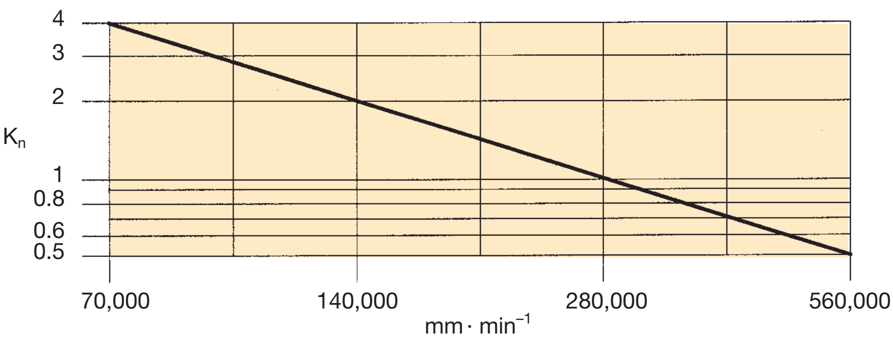
The global successor to the United States Department of Agriculture may in future be NSF (National Sanitation Foundation), which originated in the USA in 1944. NSF has since adopted the DIN standard V 0010517 as its own guideline for the registration of food-grade lubricants.

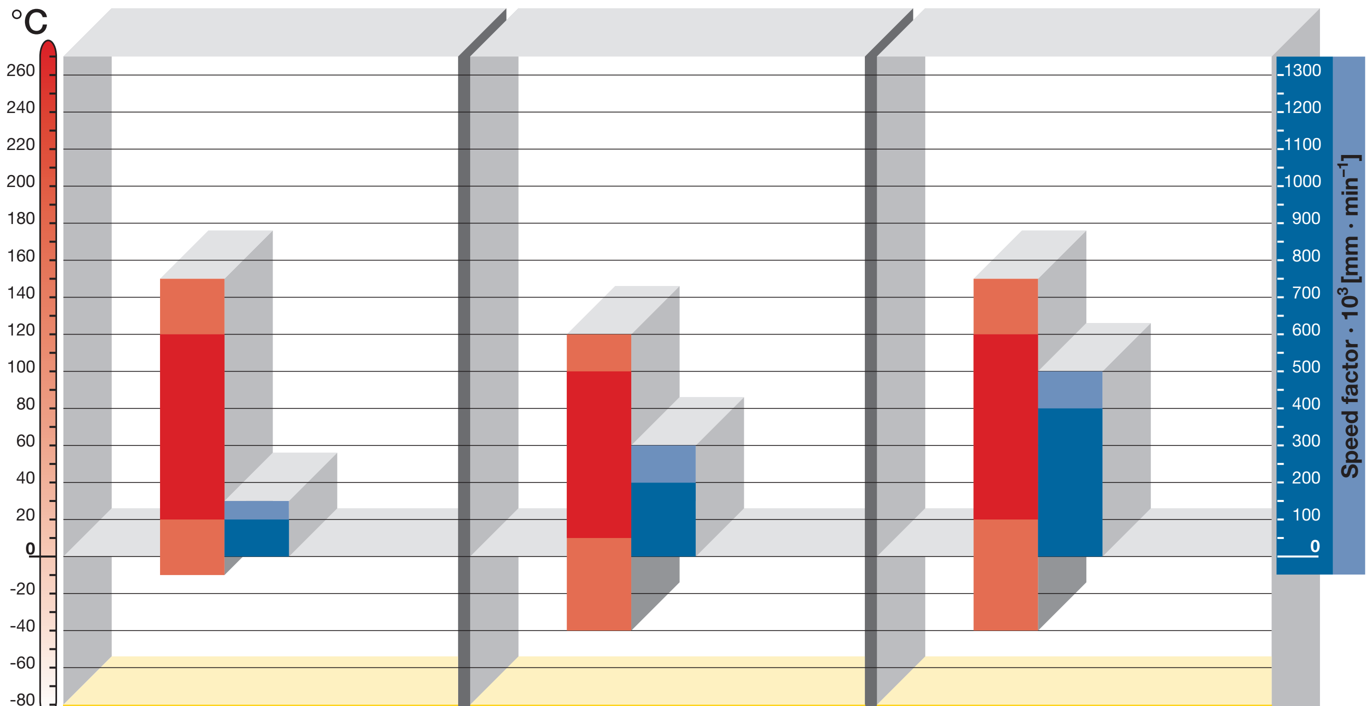
Greases for the food-processing industry:
The diagram shows three H1-certified lubricating greases suitable for a wide range of bearing applications. Klübersynth UH1 64-1302, incorporating a high base oil viscosity, is used mainly for bearings subject to high loads at low speed. Klübersynth UH1 14-151 and Klübersynth UH1 64-62 are selections for general-purpose use covering a wide range of applications. Klübersynth UH1 14-151 may be used at elevated operating temperatures up to 150 °C.

The diagram shows

- ❑ Corrosion protection behavior according to the SKF-Emcor method (DIN 51 802)
- ❑ Water resistance (DIN 51 807, pt. 1)
- ❑ Desired C/P load ratio

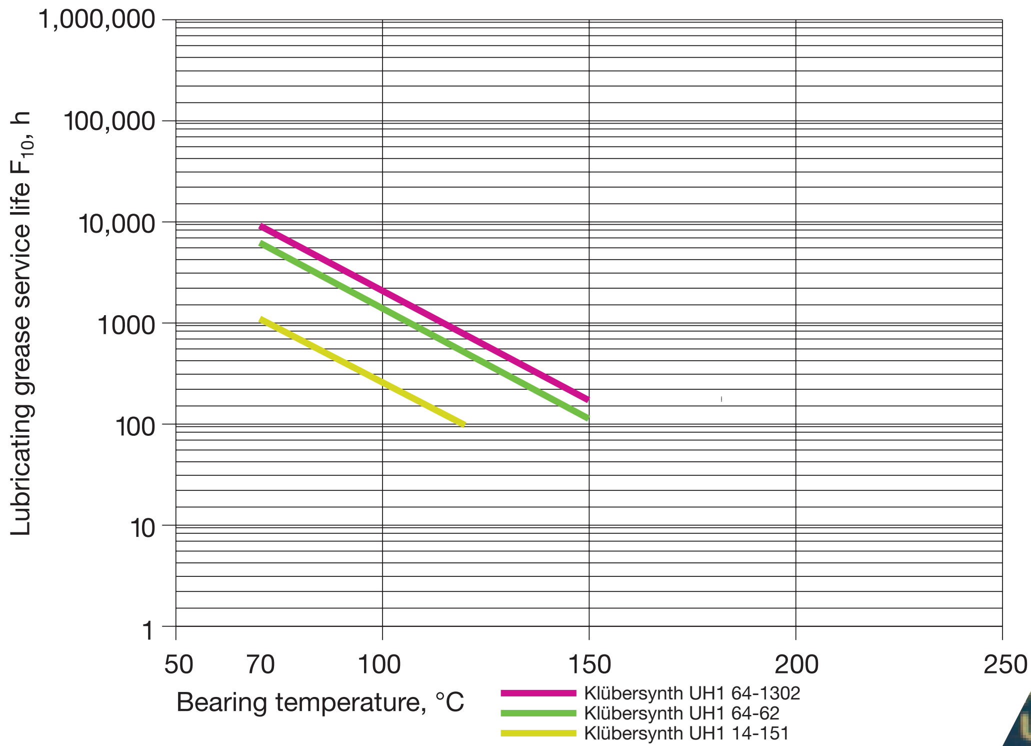
The operating temperature range and the maximum speed factors $n \cdot d_m$ can be read from the diagram. (The darker areas are target if lifetime lubrication is required.)





	Klübersynth UH1 64-1302	Klübersynth UH1 14-151	Klübersynth UH1 64-62
Emcor DIN 51 802	0/1	0/1	0/1
Water resistance DIN 51 807 T1, 3 h/90 °C	0-90	0-90	0-90
Estimated C/P ratio	> 5	> 10	> 10

Lubricating grease service life as a function of temperature



8.8 Extreme-pressure greases

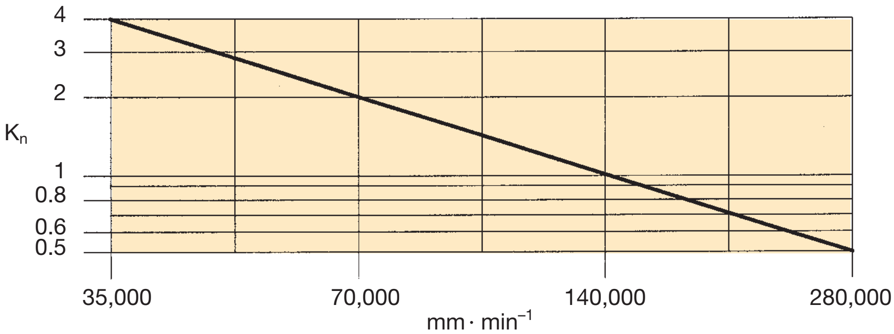
Such greases can often be identified by their suffix “EP” indicating the presence of EP (extreme pressure) additives, which together with special thickeners and base oils impart high load-carrying capacity. EP greases perform extremely well under boundary and mixed friction regimes. EP greases should be used for rolling bearings with a C/P load ratio of less than 10.

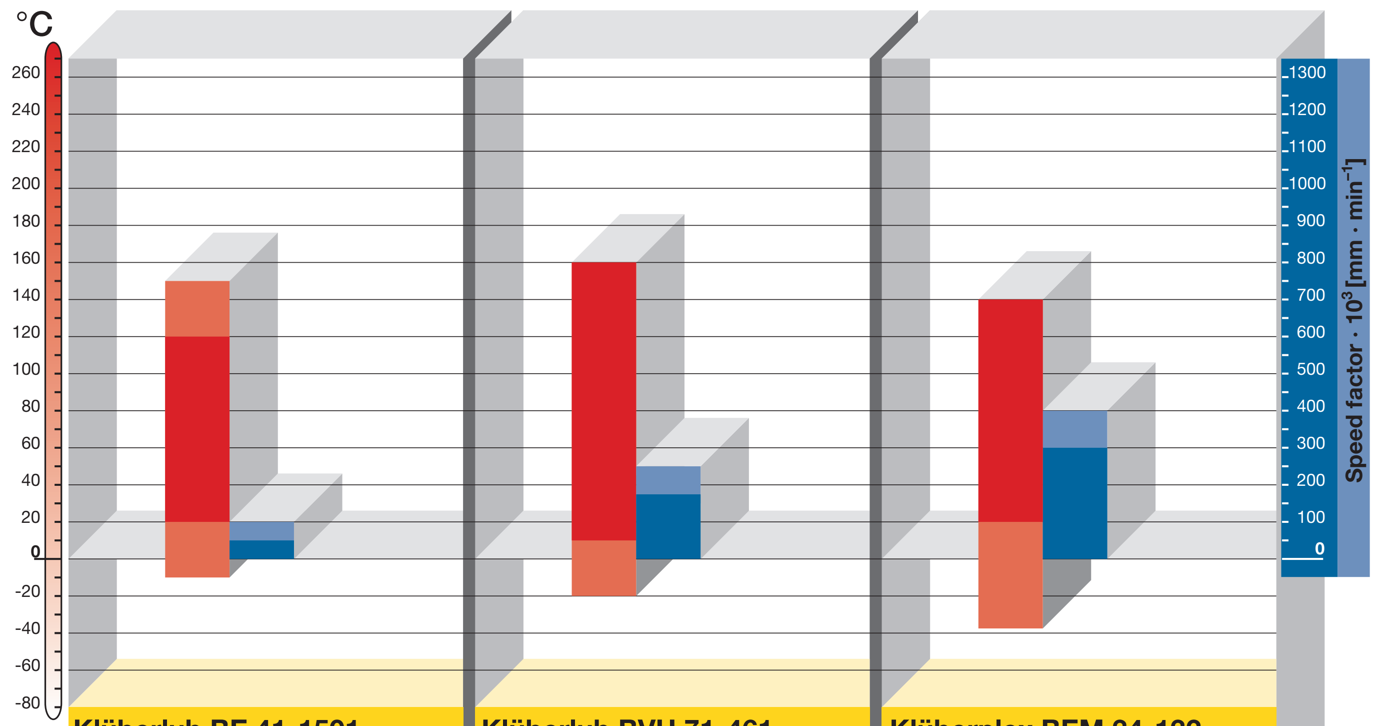
Extreme-pressure greases:
Those containing special additives to minimize wear under high load conditions. Klüberlub BE 41-1501 is an exceptional extreme-pressure grease containing molybdenum disulfide and graphite as solid lubricants. This composition enables its use under extreme load conditions, C/P ratio > 2.

The diagram shows

- Corrosion protection behavior according to the SKF-Emcor method (DIN 51 802)
- Water resistance (DIN 51 807, pt. 1)
- Desired C/P load ratio

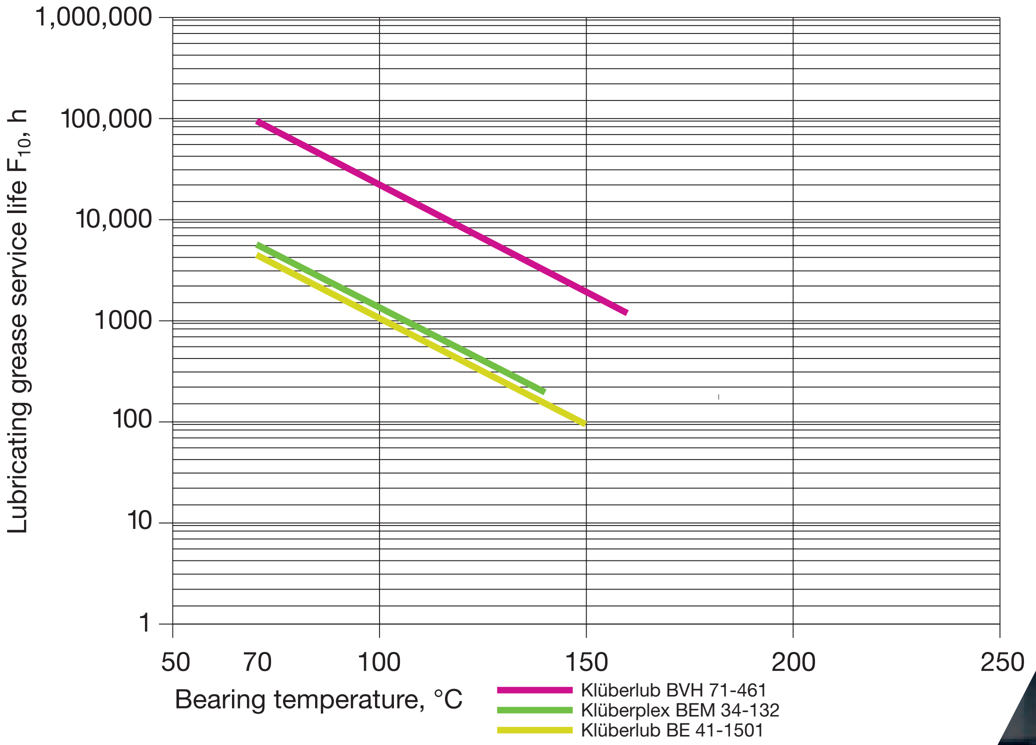
The operating temperature range and the maximum speed factors $n \cdot d_m$ can be read from the diagram. (The darker areas are target if lifetime lubrication is required.)

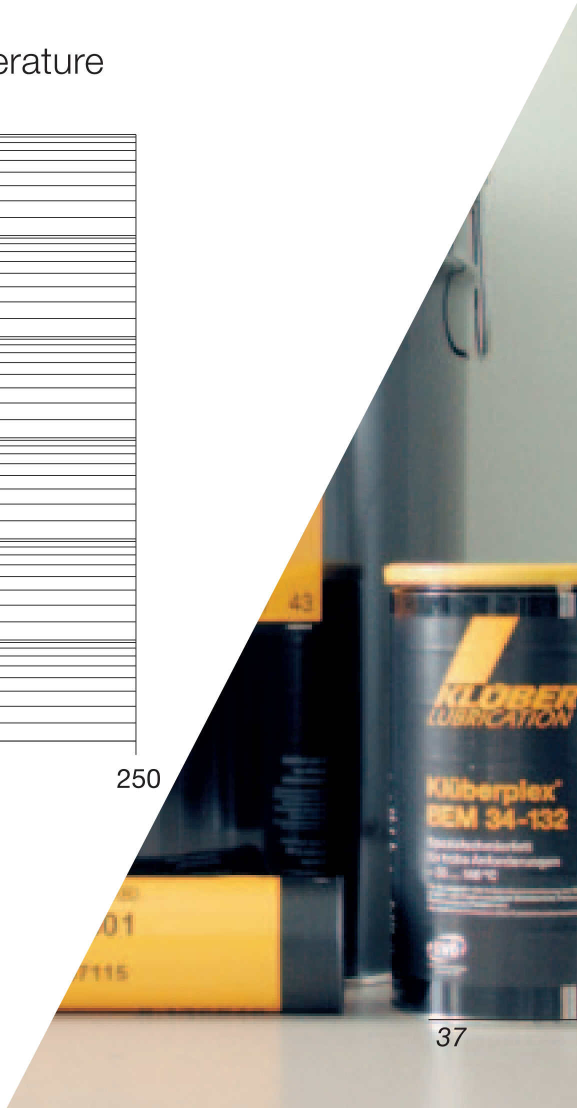




	Klüberlub BE 41-1501	**Klüberlub BVH 71-461**	**Klüberplex BEM 34-132**
Emcor DIN 51 802	0/1	0/1	0/1
Water resistance DIN 51 807 T1, 3 h/90 °C	1-90	0/1-90	0/1-90
Estimated C/P ratio	> 2	> 10	> 10

Lubricating grease service life as a function of temperature





9.0 Corrosion protection of rolling bearings

9.1 Why do rolling bearings require corrosion protection?

Most rolling bearing components are made of steel. When exposed to air humidity, the most commonly used steel, CrM6, has no long-term resistance to corrosion. Corrosion particles formed on an unprotected bearing surface may gradually find their way into the bearing and lead to increased running noise and premature bearing failure.

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

Compatibility with the bearing lubricant

- Incompatibility of the grease with the corrosion protection agent may result in insufficient adhesion of the grease to the bearing surface. The grease floats on top of the oil film and cannot establish a firm connection with the bearing material, which may eventually lead to the loss of lubricant 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 a bearing during its first operational rotations may cause initial damage, which could shorten the expected life of the bearing. This can be prevented by using a high-performance corrosion protection oil, such as Klübersynth MZ 4-17.

False Brinelling

- So-called False Brinelling is the formation of undesirable wear on the bearing raceways. This phenomenon is mainly due to minute oscillating movements in the contact areas of bearings which are not actually rotating, for example in automotive wheel bearings during transport of cars or standby (off-line) compressors.
- False Brinelling may be prevented by replacing the standard conventional anti-corrosion oil by a corrosion protection oil containing special additives, such as Klübersynth BZ 44-4000.

Wear 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 a corrosion protection oil which does not offer sufficient purity or is incompatible with the grease. This may lead to the bearing no longer being able to meet its low-noise requirements. Klübersynth MZ 4-17 was developed to complement our low-noise greases ISOFLEX and Klüberquiet 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. We are glad to provide advice on issues of material compatibility.

Use of a high-performance anti-corrosion agent leads to improved and extended bearing functionality and, thus, to cost savings for the user. As a corrosion protection agent is virtually indispensable, it is extremely worthwhile examining its performance more closely, especially in the case of bearings lubricated for life with high-performance greases.

Anti-corrosion agents for rolling bearings

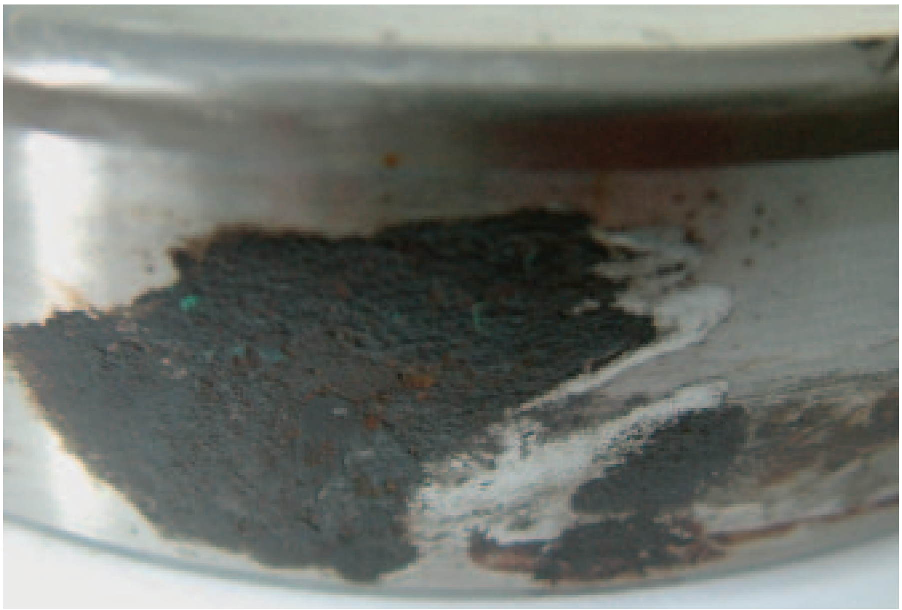
		Klübersynth MZ 4 - 17	**Klübersynth BZ 44-4000**
Base oil		ester oil / synthetic hydrocarbon	synthetic hydrocarbon
Thickener		n.a.	lithium soap
Viscosity	DIN 51561 [mm^2/s]		
	at 40 °C approx.	22	40
	at 100 °C approx.	5	–
Color		brown	beige
Aspect/Texture		liquid	milky / liquid
Service temperature range[1]	in [°C] approx.	– 54 to 150	– 40 to 140
Application notes		Synthetic lubricating and anti-corrosion oil for rolling bearings	Synthetic lubricating and anti-corrosion fluid with additives protecting against False Brinelling

[1] *see page 63*

10.0 Bearing assembly using suitable pastes

10.1 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 often in components which are subject to high loads and vibration (e.g. in plummer 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

10.2 Preventing fretting corrosion

10.2.1 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.

Various assembly pastes

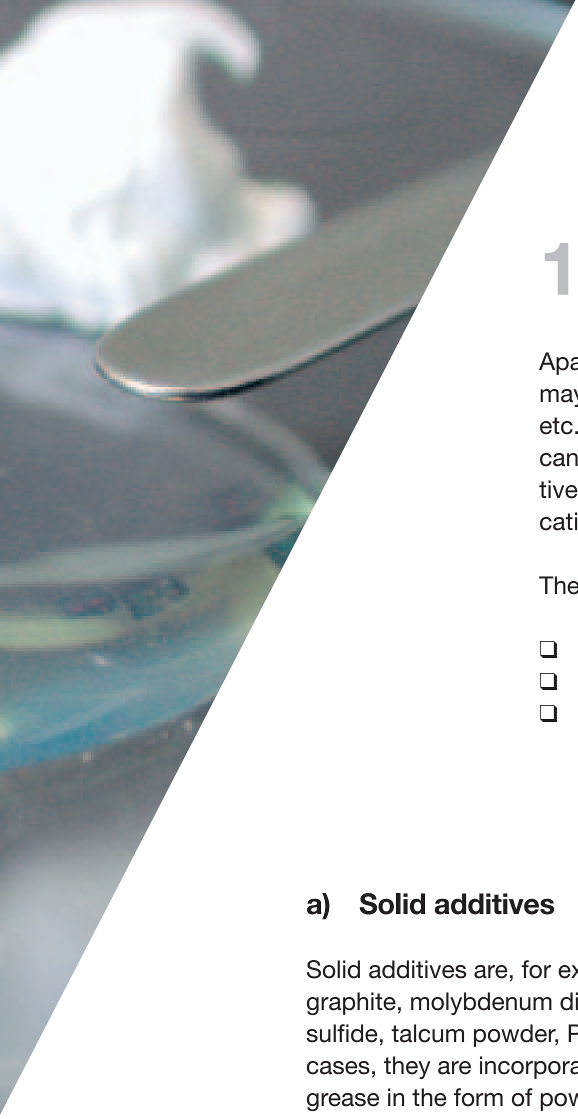
	Klüberpaste ME 31-52	Klüberpaste HEL 46 - 450
Base oil	mineral oil	ester oil /PAG
Thickener/ solid lubricant	calcium complex soap / inorganic solid lubricants	solid lubricant
Color	white to beige	black
Aspect/texture	homogeneous / short-fibred	homogeneous / short-fibred
Service temperature range[1], [°C], approx.	– 15 to 150	– 40 to 1000
Notes	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 dry lubrication.

[1] *see page 63*

10.2.2 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 (seals, bearing shields, special designs).
- ❑ Reduction of load may also lead to reduced wear.

Klüberbio EM 72 - 81	Klüberpaste UH 1 84 - 201
ester oil	synth. hydrocarbon
polyurea / solid lubricant	PTFE / solid lubricant
whitish	white
homogeneous / short-fibred	homogeneous / short-fibred
– 30 to 120	– 45 to 120
Rapidly biodegradable assembly paste for use in combination with the rapidly biodegradable lubricating greases mentioned in chapter 8.2	For use in the food-processing and pharmaceutical industries. Recommended for use in combination with the food-grade greases mentioned in chapter 8.7



11.0 Additives

Apart from the base oil and thickener, lubricating greases may also contain additives to counteract wear, corrosion etc. Some additives provide a friction-reducing effect, others can improve adhesion of the grease. In general terms additives can considerably increase the performance of a lubricating grease.

There are three different types of additives:

- ❑ Solid additives
- ❑ Polar additives
- ❑ Polymer additives

a) Solid additives

Solid additives are, for example, graphite, molybdenum disulfide, zinc sulfide, talcum powder, PTFE. In most cases, they are incorporated into the grease in the form of powder and are effective in the boundary and mixed friction regime. Solid lubricants may considerably improve the running-in process and the emergency running properties of the bearing.

b) Polar additives

Polar additives are hydrocarbon molecules which produce polarity by taking up other elements, such as oxygen, sulfur or chlorine. On metal surfaces they form physical bonds which increase adhesion of the lubricating film. Pure hydrocarbon atoms are non-polar.

c) Polymer additives

Polymer additives consist of organic polymers having a molecular weight of 10,000 to 200,000. At moderate temperatures the chain-like molecules form coils, which turn into straight filaments at high temperatures.

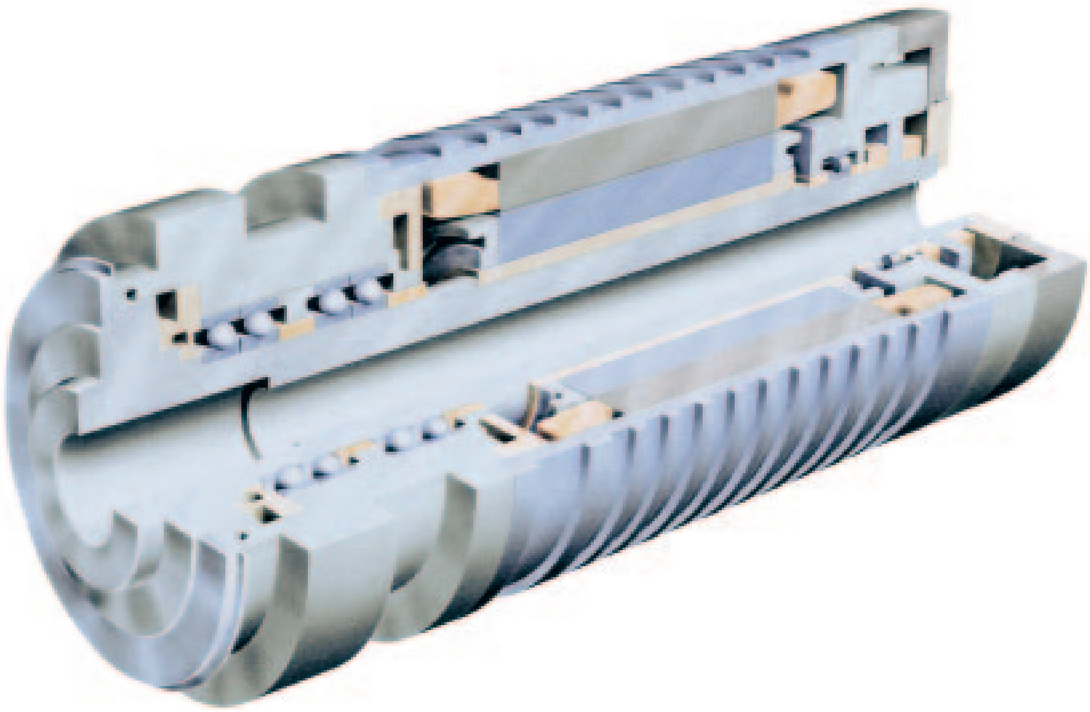
Polymer additives in the base oil increase the viscosity index VI and flatten the viscosity-temperature curve, which makes for a wider service temperature range. Furthermore, they improve the adhesion of the grease to the surface and also increase wear protection.

Additives for lubricating greases

Additive	Characteristic compounds	Task
EP additives	Organic sulfur, phosphorus and nitrogen compounds	Increase load-carrying capacity by forming tribochemical reaction layers and protect against microwelding
Antiwear additives	Organic phosphorus/nitrogen/sulfur-compounds, zinc dialkyldithiophosphate	Reduce wear in the mixed friction regime by forming reaction layers
Friction modifiers	Fatty oils, phosphorous compounds, PTFE	Reduce friction losses, impede stick-slip and noise by adsorption of polar additives at the metal surface
Corrosion inhibitors	Metal sulfonates, amine oleates, carboxylic acids, zinc dialkyldithiophosphate	Protect against corrosive attack on metals, even when exposed to water; neutralize acidic ageing products
Antioxidants	Sterically hindered phenols, alkylated aromatic amines, zinc dialkyldithiophosphate	Retard oxidative decomposition; reduce sludge formation and varnish build-ups
Solid lubricants	Graphite, MoS_2, PTFE, oxides and phosphates, talcum	Improve load-carrying capacity; reduce tribocorrosion and stick-slip tendency
Adhesion improvers	Polyisobutylene, olefine polymers, latex	Improve adhesion of the lubricant

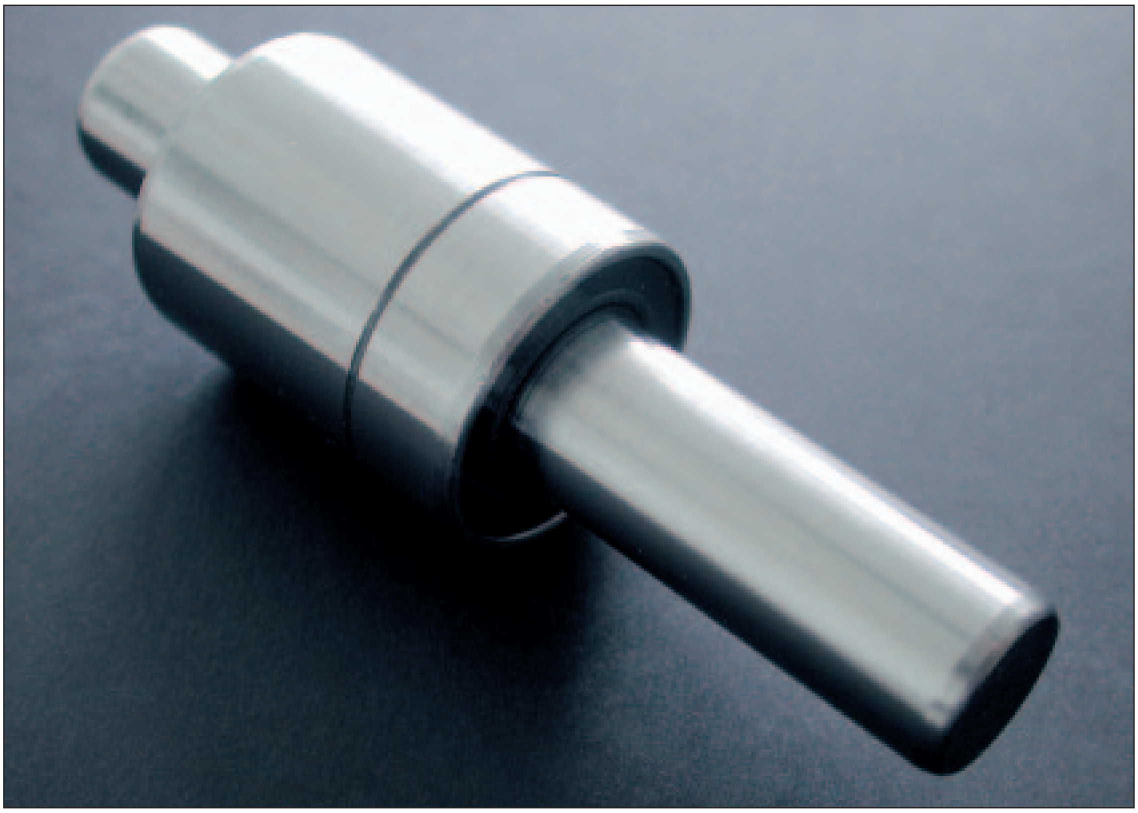
12.0 Application examples

Spindle bearings



Weiss GmbH Spindle Technology

Grease-lubricated spindle head. Speed factor n · d_m for maximum spindle rigidity is approximately 725,000 [min · min^{-1}]. Bearings lubricated with Klüber high-speed spindle greases operate at a temperature of approximately 35 °C.



The bearings are at the core of the water pump. A bearing failure can incur huge motor damage. Roughly 80% of cars have their water pumps exchanged at least once during the lifetime of the vehicle!

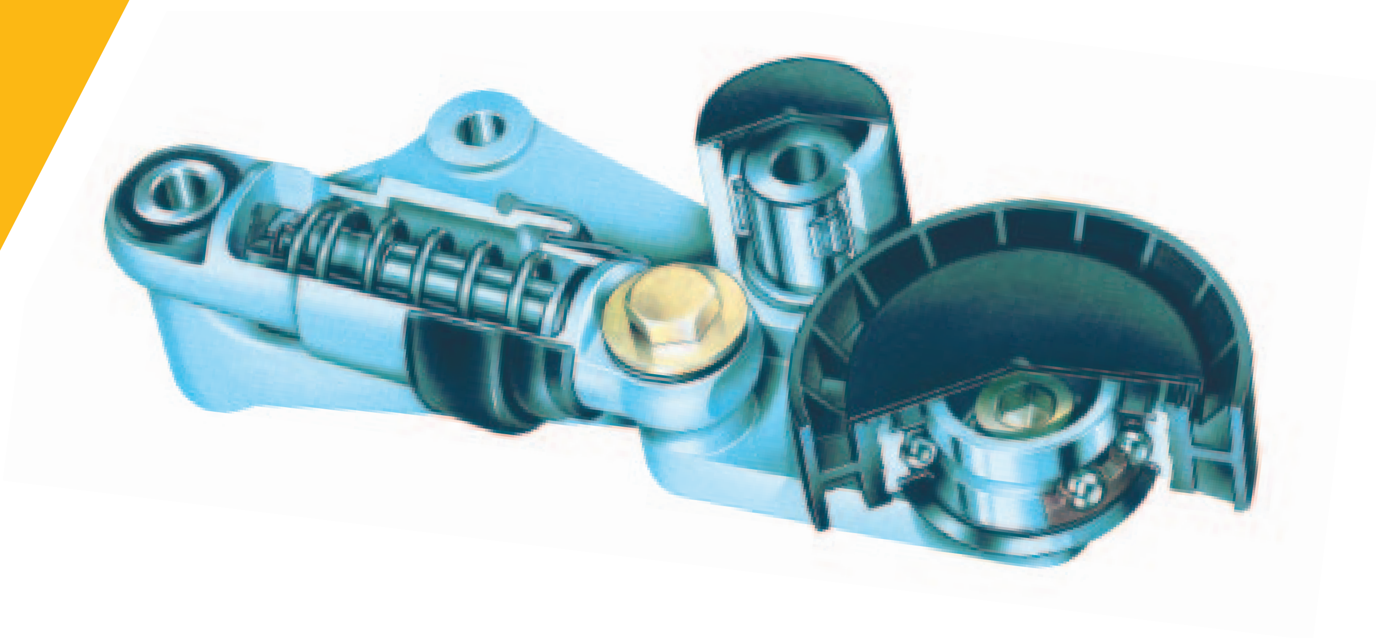
A tailor-made specialized lubricating grease may contribute considerably to increase of lifetime and reliability of the water pump bearing arrangement. Typical requirements are:

- Temperature range – 40 to 130 °C
- Lifetime lubrication > 2,000 h
- Compatibility with elastomers and plastics (seal and cage material)
- Good corrosion protection
- Water resistance
- Resistance to anti-freeze mixtures
- Low starting and running torque at low temperatures

A number of Klüber special lubricants have proven successful for this application; e.g.

- **ISOFLEX TOPAS NB 52**
- **ISOFLEX TOPAS NB 152**
- **PETAMO GHY 133 N**
- **Klüberplex BEM 34-132**

Automotive belt tensioners



Belt tensioner: INA rolling bearings SCHAEFFLER KG

This component ensures uniform tension of the driving belt, a parameter of utmost importance because, for example, the camshaft is driven by a toothed belt to control operation of the engine valves.
“Jumping” of the toothed belt at its worst causes the engine to break down. Less catastrophic is whistling of the belt tensioner at low temperatures, the critical point here being rotation of the bearing’s outer ring. The following products are based on Klüber’s long-standing experience in this field and have proven successful for many years:

- ❑ **ASONIC HQ 72-102 or Klüberquiet BQH 72-102**
- ❑ **PETAMO GHY 133 N for ball bearings**
- ❑ **Klüberplex BEM 34-132 for needle bearings**

ABB Motors, Finland

Example 1:

Electric motor, regreasable

Requirements: Extend relubrication intervals and reduce grease quantities at high temperatures.

Solution: With ASONIC GHY 72 and Klüberquiet BQH 72-102 relubrication intervals can be extended several-fold and grease quantities reduced.

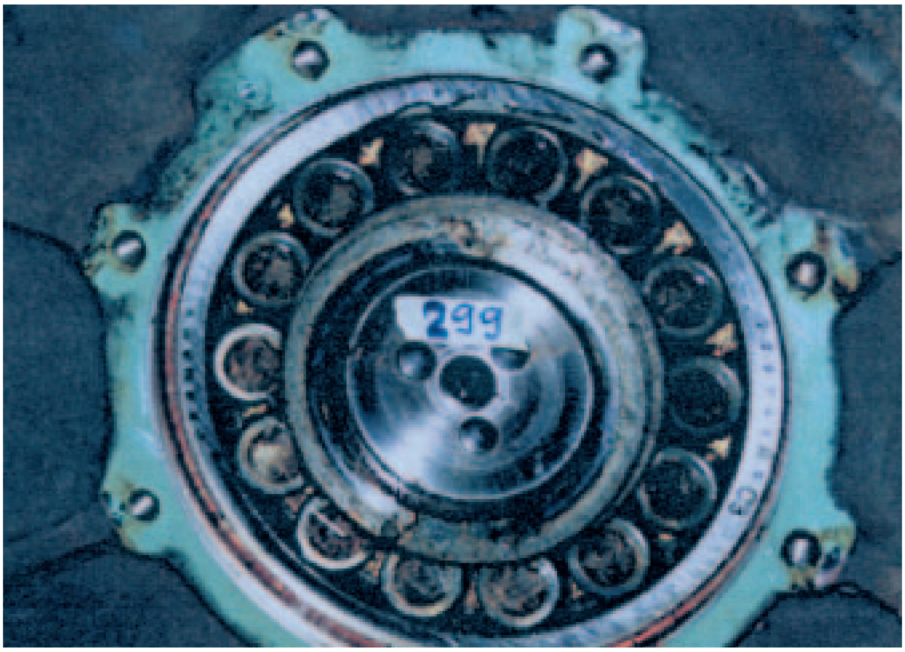
Example 2:

ABB traction motor type GRLM 763 ST for locomotive Re 4/4 of BLS-Lötschberg-Bahn (railway)

Requirements: Prevent rolling bearing failure occurring after only a few thousand hours at v = 140 km/h (mountain tracks), n = 2,000 min^{-1}.

Solution: With ISOFLEX TOPAS L 152 relubrication intervals were extended to 900,000 km at 140 km/h
Bearing 22324 EAS C3.

See positive results of bearing analysis after 630,000 km on the next page.



Bearing 22324 EAS C3

Lubricant condition after 630,000 km:

Sample taken opposite motor:

- ❑ texture slightly heterogeneous
- ❑ good lubricity
- ❑ penetration 260 – 275
- ❑ free from foreign particles

Sample taken from cage center:

- ❑ texture slightly heterogeneous
- ❑ good lubricity
- ❑ penetration 247 – 255
- ❑ free from foreign particles
- ❑ slight traces of use

Sample taken at rotor side:

- ❑ no traces of use
- ❑ like fresh grease
- ❑ texture heterogeneous
- ❑ good lubricity
- ❑ penetration approx. 275

Drive shaft support – Messrs. Vibracoustic

Example 3:

Drive shaft support for multi-part automotive drive shafts

Requirements: A drive shaft support consists of a rolling bearing (most commonly a sealed deep groove ball bearing), a vibration dampening element (elastomer) and a frame. The lubricating grease used in a drive shaft support must meet all the requirements set out by the expected operating conditions, such as water resistance, corrosion protection and, as off road vehicles may need the ability to actually drive through water, splash resistance. The grease must also be able to cope with the high temperatures it is exposed to when assembled next to the exhaust system and with low temperatures in winter, preventing any low temperature-related noise generation.

Solution: Klüberquiet BQ 72-72 fulfils all the requirements regarding grease service life, low-temperature behaviour, corrosion protection and water resistance. Klüberquiet BQ 72-72 is used successfully in Vibracoustic drive shaft supports.

For further information please visit us at

www.klueber.com

13.0 Product survey

Klüber product	Base oil	Thickener	Viscosity DIN 51561 [mm²/s] at 40 °C approx.	Viscosity DIN 51561 [mm²/s] at 100 °C approx.	Color
ASONIC GLY 32	Ester oil, synth. hydro-carbon oil	Lithium soap	25	5	beige, light yellow
BARRIERTA L 55/2	PFPE	PTFE	420	40	white
ISOFLEX LDS 18 Special A	Mineral oil, ester oil	Lithium soap	15	3.7	yellow
ISOFLEX NBU 15	Mineral oil + ester oil + synth. hydrocarbon oil	Barium complex soap	21	4.7	beige
ISOFLEX NCA 15	Mineral oil + ester oil	Special-calcium soap	25	4.7	beige
ISOFLEX PDL 300A	Ester oil	Lithium soap	9	2.6	white
ISOFLEX TOPAS L 152	Synth. hydro-carbon oil	Lithium soap	100	15	white
ISOFLEX TOPAS NB 52	Synth. hydro-carbon oil	Barium com-plex soap	30	5.5	beige
ISOFLEX TOPAS NB 152	Synth. hydro-carbon oil	Barium com-plex soap	100	14.5	light beige
Klüberbio EM 72-81	Ester oil	Polyurea/ solid lubricants	100	28	whitish
Klüberbio M 72-82	Ester oil	Polyurea	100	28	brown
Klüberbio BM 72-501	Esteröl	Polyurea	590	70	brown
Klüberlectric B 42-72	Ester oil, synth. hydro-carbon oil	Special-lithium soap, solid-lubricants	70	25	black

Operating temperature range[1)] [°C] approx.	Worked penetration DIN ISO 2137 [0.1 mm] approx.	Speed factor[2)] $n \cdot d_m$ $[min^{-1} \cdot mm]$ approx.	Application notes
– 50 to 140	265 to 295	1,000,000	Low-noise ball bearings, miniature and instrument bearings; lifetime lubrication of ball bearings sealed on both sides
– 40 to 260	265 to 295	300,000	High-temperature and long-term lubricant
– 50 to 120	265 to 295	1,000,000	Dynamically light rolling bearing grease for low temperatures and/or high speeds. Suitable for grinding and work spindles, textile spindles, noise-tested bearings in precision equipment and optical appliances
– 40 to 130	265 to 295	1,000,000	High-speed and low-temperature grease
– 40 to 130	265 to 295	1,300,000	High-speed grease
– 70 to 110	280 to 320	1,000,000	High-performance grease for rolling bearings subject to low temperatures
– 50 to 150	265 to 295	600,000	Low-noise bearings subject to high operating temperatures
– 50 to 120	250 to 280	1,000,000	High-speed and low-temperature grease
– 40 to 150	265 to 295	600,000	EP grease for high speeds or high temperatures
– 30 to 120	290 to 330	–	Rapidly biodegradable assembly paste for use with the rapidly biodegradable greases mentioned in chapter 8.2
– 40 to 120	265 to 295	300,000	Suitable for machines in forestry and agriculture, construction machines as well as heading and cutting machines for tunnels
– 20 to 120	310 to 340	250,000	Rapidly biodegradable rolling bearing grease; also suitable for lubricant dispensers
– 40 to 140	265 to 295	350,000	Electrically conductive long-term grease

[1)] and [2)] see page 63

Klüber product	Base oil	Thickener	Viscosity DIN 51561 [mm²/s] at 40 °C approx.	Viscosity DIN 51561 [mm²/s] at 100 °C approx.	Color
Klüberlub BE 41-1501	Mineral oil	Lithium soap, solid lubricants	1500	60	greyish black
Klüberlub BVH 71-461	Mineral oil, synth. hydro-carbon oil	Polyurea	490	34.5	light brown
Klüberpaste HEL 46-450	Ester oil/PAG	Solid lubricants	–	–	black
Klüberpaste ME 31-52	Mineral oil	Calcium complex soap	50	5	white to beige
Klüberpaste UH1 84-201	Synth. hydrocarbon	PTFE/solid lubricants	200	–	white
Klüberplex BE 11-462	Mineral oil	Aluminium complex soap	500	30	brown
Klüberplex BE 31-102	Mineral oil	Special calcium sop	100	12	light brown
Klüberplex BE 31-222	Mineral oil	Special calcium soap	220	19	light brown
Klüberplex BE 31-502	Mineral oil	Special calcium soap	500	31	light brown
Klüberplex BEM 34-132	Synth. hydro-carbon oil	Special calcium soap polyurea	130	15.5	light brown
Klüberplex BEM 41-132	Mineral oil, synthetic hydrocarbon oil	Special lithium soap	120	14	yellow
NEW **Klüberquiet BQ 42-32**	Ester oil	Lithium soap	25	5	beige – light yellow
Klüberquiet BQ 72-72	Ester oil	Polyurea	70	9	beige
Klüberquiet BQH 72-102	Ester oil	Polyurea	100	11	beige

Operating temperature range[1] [°C] approx.	Worked penetration DIN ISO 2137 [0.1 mm] approx.	Speed factor[2] $n \cdot d_m$ [min^{-1} · mm] approx.	Application notes
– 10 to 150	310 to 340	100,000	Lead-free heavy-duty grease for low speeds
– 20 to 160	340 to 370	200,000	High-performance grease for high temperatures, vibration and shock loads; suitable for bearings in steel mills, construction and base materials industries
– 40 to 1000	325 to 340	–	High-temperature paste for mounting rolling bearings and for positive connections. Above 200 °C dry lubrication
– 15 to 150	250 to 280	–	Tried-and-tested paste with solid lubricants protecting against fretting corrosion for mounting rolling bearings
– 45 to 120	310 to 340	–	For use in the food-processing and pharmaceutical industries. Recommended in combination with the food-grade greases mentioned in chapter 8.7
– 15 to 150	265 to 295	200,000	Adhesive, water-resistant rolling bearing grease
– 20 to 120	265 to 295	500,000	For ball bearings subject to high loads and speeds as well as moisture
– 15 to 140	245 to 275	300,000	For ball bearings subject to high loads and moisture operating at medium speeds
– 10 to 140	245 to 275	100,000	For ball bearings subject to high loads, low speeds and moisture
– 35 to 140	265 to 295	400,000	Long-term and lifetime lubrication, excellent lubricating effect when subjected to minute movements
– 30 to 150	265 to 295	600,000	Lubricating grease for long-term and lifetime lubrication of rolling bearings in the wet processing zone, automotive hub units, water pumps, electric motors and fans
– 50 to 150	245 to 275	1,000,000	Low-noise ball bearings, miniature and instrument bearings, for-life lubrication of ball bearings sealed on both sides
– 45 to 180	265 to 295	700,000	Low-noise rolling bearing grease for long-term and lifetime lubrication at low and high temperatures. Suitable for electric motors, fans, air conditioning systems, hard disk drives
– 40 to 180	265 to 295	700,000	Low-noise rolling bearing grease for long-term and lifetime lubrication at high temperatures

[1] and [2] see page 63

Klüber product	Base oil	Thickener	Viscosity DIN 51561 [mm²/s] at 40 °C approx.	Viscosity DIN 51561 [mm²/s] at 100 °C approx.	Color
Klüberspeed BF 42-12	Ester oil, synth. hydrocarbon oil	Special lithium soap	24	5	beige
Klüberspeed BF 72-22	Ester oil, synth. hydrocarbon oil	Polyurea	22	5	beige
NEW **Klüberspeed BF 72-23**	Synth. hydro-carbon+ester oil	Polyurea	22	5	beige
Klübersynth BEL 34-52	Synth. hydro-carbon oil	Calcium soap	46	–	light beige
Klübersynth BH 72-422	Ester oil, PFPE	Polyurea, solid lubricant	420	34	white
Klübersynth BMQ 72-162	Ester oil, PFPE	Polyurea	160	27	beige
NEW **Klübersynth BZ 44-4000**	Synth. hydro-carbon oil	Lithium soap	40	–	beige
Klübersynth HB 72-52	Ester oil	Polyurea	53	9	beige
Klübersynth HB 72-102	Ester oil	Polyurea	95	14	beige
Klübersynth MZ 4-17	Ester oil, synth. hydrocarbon oil	Polyurea	18	–	brown
Klübersynth UH1 14-151	Synthetic hy-drocarbon oil	Aluminium-komplexseife	150	22	beige
Klübersynth UH1 64-62	Ester oil, synth. hydro-carbon oil	Silicate	65	10	beige
Klübersynth UH1 64-1302	Synthetic hydrocarbon oil	Silicate	1300	100	beige
PETAMO GHY 133N	Mineral oil, synth. hydro-carbon oil	Polyurea	150	18	beige

Operating temperature range[1)] [°C] approx.	**Worked penetration** DIN ISO 2137 [0.1 mm] approx,	**Speed factor**[2)] $n \cdot d_m$ [$min^{-1} \cdot mm$] approx.	**Application notes**
– 50 to 120	265 to 295	1,600,000	Special lubricating grease for high-speed spindle bearings in machine tools
– 50 to 120	250 to 280	2,000,000	Special lubricating grease for high-speed spindle bearings in machine tools, horizontal shaft
– 50 to 120	220 to 250	2,000,000	Special grease for high-speed spindle bearings in machine tools
– 40 to 120	265 to 295	–	Grease for blade bearings in wind power stations – low temperatures, good corrosion protection – seawater, for high static loads and vibrations
– 20 to 220	265 to 295	300,000	Long-term and high-temperature grease, direct application onto thin anticorrosion film is possible
– 40 to 200	240 to 270	500,000	Long-term and high-temperature grease; direct application onto thin anticorrosion films is possible
– 40 to 140	–	–	Lubricating and anti-corrosion fluid for rolling bearings; good wear protection, for bearings subject to micromotions
– 30 to 180	265 to 295	1,000,000	High-temperature and long-term lubricating grease for EPDM materials
– 40 to 180	265 to 295	500,000	High-temperature and long-term lubricating grease offering particular corrosion protection
– 54 to 150	–	–	Synthetic lubricating and anticorrosion oil
– 40 to 120	310 to 340	300,000	Lubricant for the food-processing and pharmaceutical industries
– 40 to 150	265 to 295	500,000	Lubricant for the food-processing and pharmaceutical industries; wide service temperature range
– 10 to 150	265 to 295	150,000	Lubricant for the food-processing and pharmaceutical industries; for bearings subject to low speeds and high loads
– 30 to 160	265 to 295	500,000	High-temperature and long-term lubricant

[1)] and [2)] see page 63

Questionnaire Rolling Bearings

Sender:

Company ____________________

____

Name ____________________

Function ____________________

Street ____________________

Place ____________________

Phone ____________________

Fax ____________________

E-mail ____________________

1. Application

Machine/Equipment:

Manufacturer:

2. Bearing details

Type of bearing:*

Designation/suffix

Mounting pos.:* ❑ Vertical
❑ Horizontal
❑ Tilted

Seal: *(Type)**

Material

❑ Rubbing ❑ Non-rubbing

3. Operating conditions*

n = ____________ min^{-1}

Equivalent dynamic bearing load rating, P[N]

❑ Rotating inner ring
❑ Rotating outer ring
❑ Oscillating
❑ Intermittent
❑ Vibrating
Frequency ____________ [Hz]
Path ____________ [° or mm]
or speed-time diagram in sketch form

❑ Shock load [N] ____________
or speed-time diagram in sketch form

Temper-ature, °C	estimated		measured	
	min.	max.	min.	max.
Bearing temperature				
Ambient temperature				

AMBIENT INFLUENCES:

Type, concentration, temperature, pressure)
❑ Liquid ____________
❑ Vapour ____________
❑ Gas ____________
❑ Dust ____________
❑ Other media ____________
❑ Daily service time ____________ [h]
❑ Other factors ____________

4. Additional lubricant requirements

❑ Low-noise operation
❑ High degree of purity
❑ Very low friction torque
❑ Customer specification
❑ Compliance with lubricant chart (encl.)

Food-grade registration:
❑ NSF H1**
Others: ____________

5. Lubrication details

Lubricant currently used:

Type of lubrication:
❑ Lifetime lubrication [h]
Actual ____________
Desired ____________
❑ Lubrication interval [h]:
Actual ____________
Desired ____________
❑ Relubrication quantity [g/h]
Actual ____________
Desired ____________
❑ Manual ❑ Automatic

Lubricating equipment

Lubricant lines
(dimensions, pressure, material, type of distributor)

Annual lubricant consumption [kg/year]

Other factors ____________

* ***Minimum information required for consulting***
** ***National Sanitation Foundation***

Questionnaire Rolling Bearings

14.0 Conversion table

conversion → in → multiply by

in ← conversion ← divide by

Physical quantity	Unit	Abbre-viation	Unit	Abbre-viation	Factor
Force	Kilogram force	kgf	Newton	N	9.80665
Force	Kilopond	kp	Newton	N	9.80665
Force	Pound force	lbf	Newton	N	4.44822
Work, energy	Foot pound	ft lbf	Joule	J	1.35582
Power	Horsepower	hp	Kilowatt	kW	0.7457
Power	Metric horsepower	PS	Kilowatt	kW	0.735499
Power	Foot pound/minute	fit lbf/min	Watt	W	81.3492
Torque	Kilogram f. meter	kgf m	Newton meter	Nm	9.80665
Torque	Kilopond meter	kp m	Newton meter	Nm	9.80665
Torque	Pound f. foot	lbf ft	Newton meter	Nm	1.35582
Torque	Pound f. inch	lbf In	Newton meter	Nm	0.112985
Pressure	Atmosphere	Atm	Bar	bar	1.013250
Pressure	Kilogram f./sq centimeter	kgl/cm^2	Bar	bar	0.980665
Pressure	Kilopascal	kPa	Bar	bar	0.01
Pressure	Kilopond/square centimeter	kp/cm^3	Bar	bar	0.980665
Pressure	Newton/square centimeter	N/cm^2	Bar	bar	0.1
Pressure	Newton/square meter	N/m^2	Bar	bar	10^{-3}
Pressure	Pascal (newton/sq meter)	Pa	Bar	bar	10^{-3}
Pressure	Pound f./square inch	lbf/in^3	Bar	bar	0.06894
Pressure (water column	Inch of water	in H_2O	Millibar	mbar	2.49089
Pressure (water column	Foot of water	ft H_2O	Bar	bar	0.0298907
Pressure (water column	Millimeter of water	mm H_2O	Millibar	mbar	0.09806
Pressure (mercury col.)	Inch of mercury	in Hg	Millibar	mbar	33.8639
Pressure (mercury col.)	Millimeter of mercury	mm Hg	Millibar	mbar	1.33322
Degree of angle	Degree (angle)	°	Radian	rad	0.0174533
Length	Foot	ft	Meter	m	0.3048
Length	Inch	in	Centimeter	cm	2.54
Length	Inch	in	Millimeter	mm	25.4
Length	Microinch	in	Micrometer	m	0.0254
Area	Square foot	ft^2	Square meter	m^2	0.092903
Area	Square inch	in^2	Square meter	m^2	6.4516 x 10^{-4}
Area	Square inch	in^2	Square centimeter	cm^2	6.4516
Volume	Cubic centimeter	cm^3	Liter	l	0.001
Volume	Cubic centimeter	cm^3	Milliliter	ml	1.0
Volume	Cubic foot	ft^3	Cubic meter	m^3	0.0283168
Volume	Cubic foot	ft^3	Liter	l	28.3161
Volume	Cubic inch	in^3	Cubic centimeter	cm^3	16.3871
Volume	Cubic inch	in^3	Liter	l	0.0163866
Volume	Fluid ounce, UK	UK fit oz	Cubic centimeter	cm^3	28.413
Volume	Fluid ounce, US	US fl oz	Cubic centimeter	cm^3	29.5735
Volume	Gallon, UK	UK gal	Liter	l	4.54596
Volume	Gallon, US	US gal	Liter	l	3.78531
Volume	Pint, UK	UK Pl	Liter	l	0.568245
Volume	Pint, US	US liq pt	Liter	l	0.473163
Mass	Pound (mass)	lb	Kilogram	kg	0.4535
Density	Pound/cubic inch	lb/in^3	Kilogr./cubic centimeter	kg/cm^3	0.0276799
Density	Pound/cubic foot	lb/ft^3	Kilogr./cubic meter	kg/m^3	16.0185
Temperature	Fahrenheit	°F	Degree Celsius	°C	#
Quantity of heat	BTU/hour	Btu/h	Kilowatt	kW	0.293071 x 10^{-1}
Rotational frequency	Revolution/minute	r/min	Revolution/second	rad/s	0.10472O

#°C = 5(°F – 32)/9

Notes

1) *Service temperatures are guide values which depend on the lubricant's composition, the intended use and the application method. Lubricants change their consistency, apparent dynamic viscosity or viscosity depending on the mechano-dynamical loads, time, pressure and temperature. These changes in product characteristics may affect the function of a component.*

2) *Speed factors are guide values which depend on the type and size of the rolling bearing type and the local operating conditions, which is why they have to be confirmed in tests carried out by the user in each individual case.*

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Klüber products are continually improved. Therefore, Klüber Lubrication reserves the right to change all the technical data in this technical brochure at any time without notice.