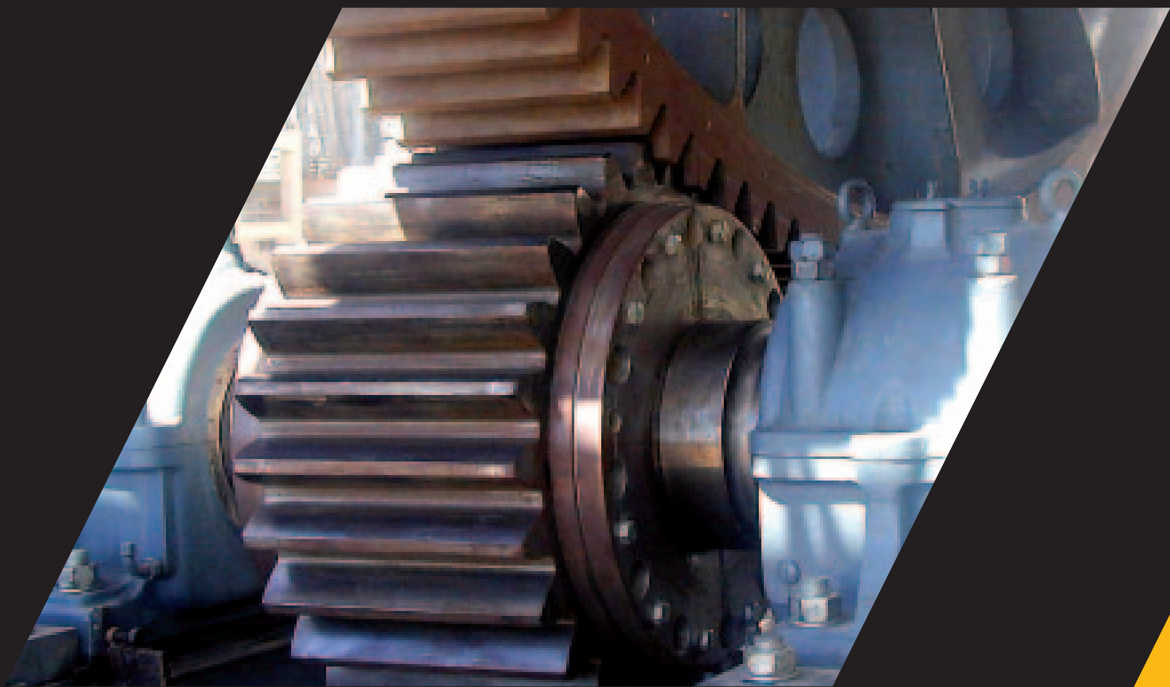
Lubrication of large gear drives



Systematic lubrication with
purpose-made adhesive lubricants
and lubrication systems

Lubrication is our World

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1.
Introduction

Large girth gear drives have proven effective in plant engineering for many decades and continue to be the type of drive unit most commonly found in tubular mills, drums and rotary kilns in the base material industry. In recent years, other types of drive units have also been increasingly used.

These other types are enclosed gears that are firmly attached to the drive cover, central gear drives, frictional drives or ring motors. Such gears are lubricated by high-quality mineral or synthetic oils. The gear rim/pinion drives, on the other hand, are counted among the so-called 'open gears' and are normally built in the form of either a single or double-pinion drive. Their advantage over other drive types is that they are normally less expensive to buy.

Large girth gear drives are used in the main cement production machines, for ore and raw materials processing machinery, in coal-fired power plants, fertilizer plants, chemical factories, waste incineration and composting plants. The reliability and operational safety of the drives, and in consequence their lubrication, is of utmost importance.

Lubricating the gear drives of the machines listed above is a very complex task. Not only do the design characteristics of the 'open gears' have to be taken into account, but also their highly varied operating and ambient conditions.

To ensure optimum lubrication of gear drives not only the types of lubricants used and their characteristics are important, but also the method of application to the tooth flanks. It is therefore indispensable to choose an application method that fits the lubricant used to ensure that the drive functions under the prevailing operating conditions.

At Klüber, lubricants are manufactured using the most advanced production techniques. Raw materials are selected according to a demanding set of criteria and their quality is checked when they reach our plant. The production process is meticulously monitored and the finished product subjected to regular inspection. These processes are certified according to the quality standards DIN EN ISO 9001:2000 and the environmental standard DIN EN ISO 14001.

Fig. 1: Tube mill with girth gear drive

Fig. 2: Rotary kiln with girth gear drive

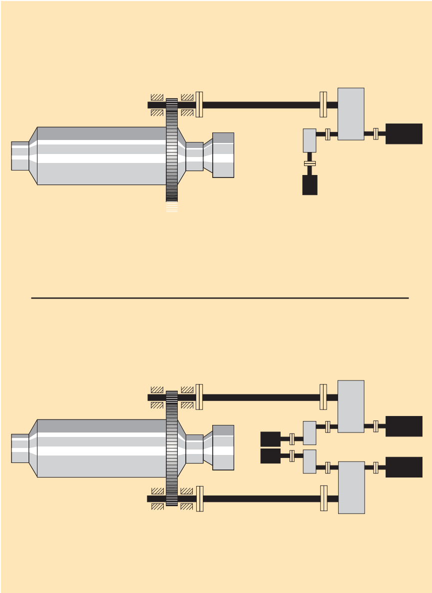


Fig. 3: Possible arrangement of drive elements in single and double-pinion drives

2.
Gear technology

General

The gear drives used in tube mills and rotary kilns are usually very sturdy in design and operate at low speeds. The peripheral speed in mills is normally 6 to 10 ms^{-1} and in kilns 0.3 to 3.0 ms^{-1}. The main drive characteristics are:

- high output torque
- large, sometimes variable centre distance
- medium to high modules
- tooth width up to approx. 1,200 mm, depending on the drive

Involute toothing with a corrected flank geometry is very common. The gear teeth quality of gear rims in kilns is 9 to 10 according to ISO 1328 (AGMA 2000 = 8 to 9), and 8 to 9 according to ISO in mills (AGMA 2000 = 9 to 10). The transmission ratio is often between 6 and 15.

Modules

In mill drives, modules of between 18 mm and 36 mm are frequently found, with the large ones of up to 36 mm being most common in the mining sector.

When lower modules and helical teeth are used, the same power can be transmitted at reduced gear width, which makes the drive less expensive.

Kiln drives have normally spur gears with modules between 25 mm and 60 mm.

Tooth traces

Gear drives can have helical or spur teeth. Helical gears have the advantage of gradual flank intermeshing, a higher contact ratio, softer teeth contact and lower running noise. However, they are more expensive and more difficult to align.

Materials

A transmission performance of 8,000 kW and more, which is common today, the wish for smaller component sizes and the increased specific loads on the tooth flanks call for special materials to be used for the gear rims and pinions. The older gear rim designs consisting of a cast iron body with a shrunk-on ‘tire’ are now widely out of use. Instead, we find more and more gear rims made of cast steel or nodular cast iron, and others where ‘tires’ of wrought steel S 235 JR (St 37-2 or 1.0037) or 42 Cr Mo 4 are welded onto steel bodies. Their tooth flank hardness is between 250 HB and 280 HB.

The alloy used for cast gear rims is often G 34 Cr Ni Mo 6 with a flank hardness of 280 HB to 310 HB, sometimes 340 HB. G 34 Cr Ni Mo 4 with a hardness of 230 HB maximum is also used. For nodular cast iron, GGG 70 or 80 with a hardness of up to 320 HB is used.

Tempered pinions consist normally of 30 Cr Ni Mo 8 with a tooth flank hardness of 280 to 310 HB, 350 HB maximum. Hardened and ground pinions are made of steel 17 Cr Ni Mo 6 with a flank hardness of 58 HRC. The surface quality of ground flanks is hrms 0.8 to 1.6 µm and that of unground flanks 3.2 to 4.0 µm. Material alloys vary with every manufacturer and may not correspond exactly with the values mentioned.

Loads on materials

Along the path of contact A–E, the sliding speed decreases and increases with the distance from the pitch point *(C)*, i.e. it is highest immediately after the impact of contact *(A)* and at the end of the contact *(E)*. Here we encounter also the highest friction forces.

At the pitch point *(C)*, the sliding speed is 0, i.e. we have only rolling friction. While between A and B, and between D and E, power is transmitted by two pairs of teeth, only one pair of teeth is contact between B and D, which means that the force acting on the teeth is here much higher. Please see diagram B for illustration.

Fig. 4: Intermeshing pinion and gear (Krupp-Polysius)

Sliding motion, alignment of gear rim and pinion

While the sliding speeds have opposing directions over the tooth height, the direction of motion of the contact area is continuous: from the tooth root of the driving wheel *(pinion)* to the tip, and from the tip of the driven wheel *(gear rim)* to the root *(see diagram A)*.

Gear alignment is the most important technical procedure for optimum operation of two gears in mesh. It is always a compromise; depending on the size and design of the components, gear manufacturers have developed their own alignment technologies for such gears. As a guideline for the alignment of large girth gear drives, the formulas shown in diagram C may be used.

However, the principle for the alignment of new drive units should always be: face backlash takes priority over root clearance, which comes as a result of face backlash. When re-aligning drive units in operation, the reverse applies: root clearance takes priority over face backlash, which comes as a result of root clearance.

Root clearance

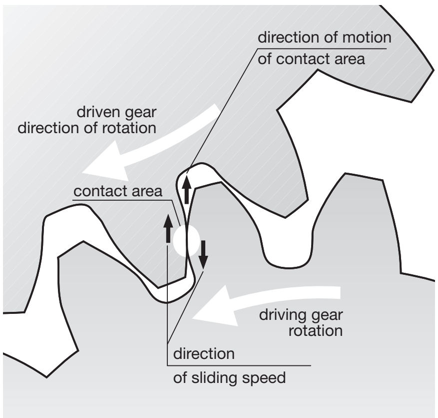
y = 0.1 … 0.3 x m *(frequently 0.167 x m)* [mm]

(Source: Tabellenbuch Metall)

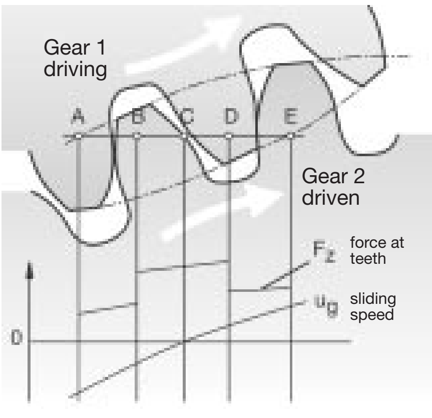
Face backlash

x = 0.05 + (0.025 … 0.1) x m [mm]

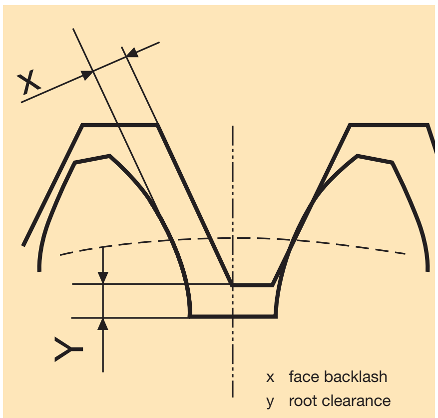
(Source: Rohloff/Matek)



Graphics A: Direction of sliding speed and of contact area of two meshing gear wheels (acc. to Dudley / Winter 2)



Graphics B: Sliding speed and force at teeth over the path of contact



Graphics C: Guideline for the alignment of large gear drives

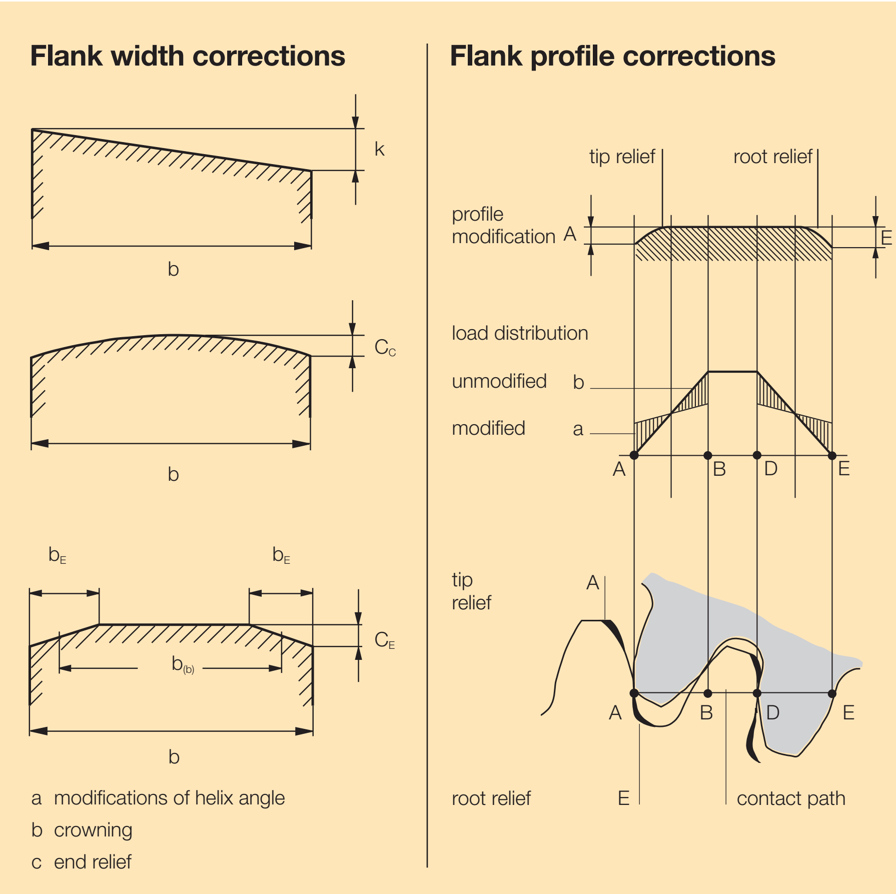


Fig. 7: Flank width and profile modifications

Fig. 5: Gear drive with tiltable pinions during assembly (Krupp-Polysius)

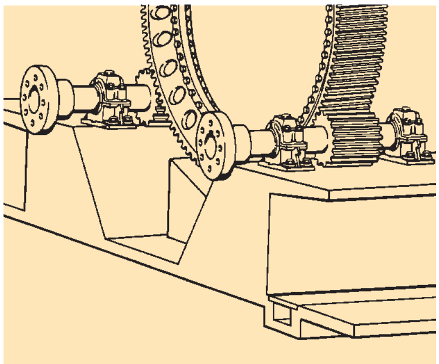


Fig. 6: Separate support of gear and pinions

Pinion and gear rim

Pinions are manufactured as a single part with an integrated shaft, e.g. from a forging blank, or as two individual parts, i.e. a pinion and a separate shaft. These pinions are then mounted on the shaft by means of feather keys or tensioning elements. Most gear rims, on the other hand, are made of two or more parts for easier transportation and assembly, due to their size. These segments are mounted on the machine frame and are held in place by suitable connections. The torque is transmitted to the rotary tube by way of friction (flanged connections) or positive locking via intermediate elements (bridge plates, spring elements).

Load-carrying behavior – load distribution across the face width

A main disadvantage of girth gear drives as compared to enclosed gears is the fact that the gear rim and the

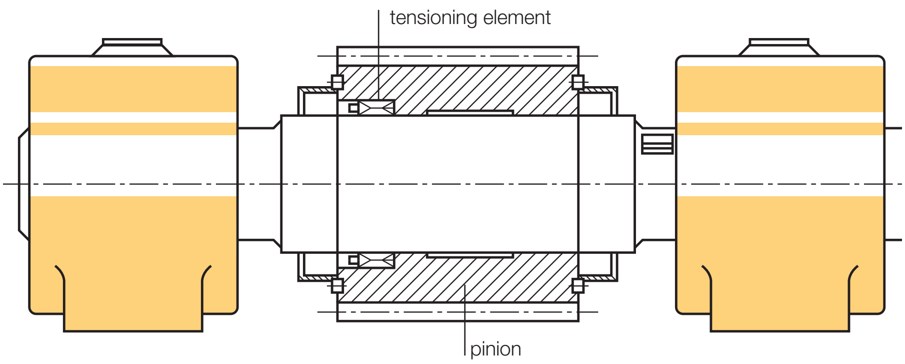


Fig. 8: Pinion mounting with tensioning element

pinion(s) are supported by separate bearings, which results in difficulties when mounting and aligning the drive components. Load-dependent deformations, manufacturing and assembling tolerances as well as kiln displacement due to thermal effects often make it impossible to avoid alignment errors. This, in turn, increases the problems of a uniform load distribution across the entire flank width and height.

If there is a directional deviation in the area of contact of the pinion's and the gear rim's tooth flanks, there is no continuous line of contact in unloaded condition. Only when load is applied, for example when a mill is filled, the elastic deformation at the intermeshing teeth results in a line of contact; its length depends on the load, the teeth's resilience, the type of gear rim fastening and the magnitude of the directional deviation between the tooth flanks. An insufficient load-carrying capacity of the gear rim and the pinion, i.e. an unsuitable load distribution across the face width and height results in an increased load on the areas which actually carry the load. This insufficient distribution of loads is taken into consideration when designing the gear drive. If the contact ratio is too low, however, partial overloading may result in drive damage, manifesting itself in the formation of scuffings and local pittings.

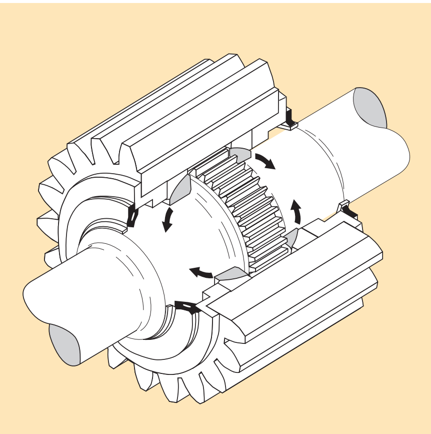


Fig. 9: Tiltable pinion, Krupp-Polysius

Hardened pinions

Today, more and more case-hardened and ground pinions are used. Besides a substantially improved scuffing strength, such pinions show higher tooth accuracy and a better surface quality of the tooth flanks, which leads to higher operational reliability. Such pinions can be made less wide without reduction of the power rating, which in turn improves the load distribution across the face width. This type of pinion design requires the flanks to be modified by tip, root and end relief. This is necessary to compensate for the disadvantage of not being able to run the hardened tooth flanks in through initial wear.

As these corrections have proven highly successful, they are today also often carried out on non-hardened pinions.

Tiltable pinions

Again and again, efforts have been made to solve the problem of insufficient load distribution across the face width. The idea behind many designs is that the pinion should adapt to the tumbling motion of the gear rim, for example by making the pinion tiltable as illustrated in Fig. 9. In this design, the pinion runs on a universal ball joint and can therefore follow any tilting motion of the gear rim. The torque is transmitted by a toothed coupling located between the pinion and the pinion shaft.

The universal ball joint and the toothed coupling are lubricated with a fluid grease; both regular relubrication and lifetime lubrication is possible. Advantages of tiltable pinions:

- ❑ compensation of alignment errors
- ❑ optimum load distribution under any conditions of operation
- ❑ very favorable dynamic load ratios

3.
Lubrication technology

Excessive wear and flank damage can be avoided if the intermeshing tooth surfaces are completely separated by a lubricant film. This, however, is almost impossible in large gear drives due to the low peripheral speed, the very high flank pressure and the relatively high flank roughness and temperatures. Furthermore, since pinion and gear rim are supported separately and are aligned during assembly, their axes are often not 100 % parallel, which makes the operating conditions even more difficult. This may lead to partial overloading and detrimental friction forces on the intermeshing tooth flanks carrying the load.

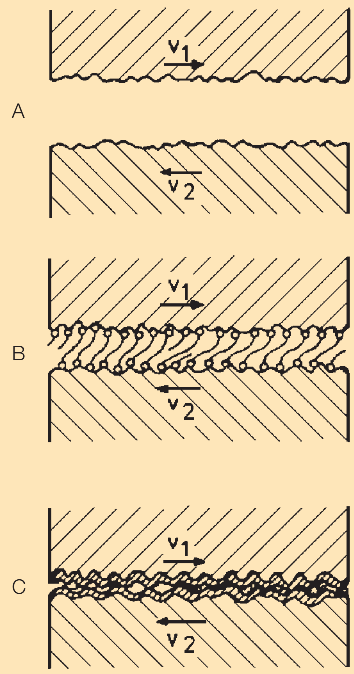
As a consequence, large gear drives operate mostly under mixed friction conditions, which makes boundary lubrication so important in these applications. To lubricate large gear drives reliably and protect them against damage, the lubricants applied must be highly adhesive, and their physical and chemical properties must be such that they form protective layers *(so-called reaction layers)* on the tooth flanks under the prevailing operating conditions. These protective layers largely prevent direct metal/metal contact and hence minimize boundary friction.

To create lubricants that have this effect, special types of base oil are selected that have the right viscosity, contain EP *(extreme pressure)* additives and sometimes also the right amount and type of solid lubricants with a lattice layer structure. In the past few years, new lubricants were developed that offer the same or even better tooth flank protection without containing solid lubricants. Instead, these lubricants are made of innovative special mineral and/or synthetic oils and contain adhesion improvers and even better EP additives; they have a very high viscosity, and backflow from the root depot ensures a longer-lasting lubricant film.

However, even the best of lubricants will compensate for partial overloading of the tooth flanks to a limited extent only. In new gear drives with their production-related flank roughness and/or waviness, scuffings may therefore occur and cause severe damage within a short period of time.

The surface quality is of utmost importance for reliable lubrication and trouble-free operation. Only smooth tooth flanks will remain undamaged when exposed to peak loads, provided the longitudinal and transverse load distribution is even. New or turned gear drives should therefore undergo a running-in procedure with special lubricants developed for this purpose. This ensures that the tooth flanks are smoothed and the contact ratio is increased.

For large gear drives, the use of running-in lubricants is critical to allow subsequently continuous operation with very low wear rates and minimum lubricant consumption *(in applications with spray lubrication)*. As these lubricants are expected to smooth the surfaces relatively quickly and a stepwise increase of tooth flank loads to full is not always possible during



A hydrodynamic lubrication
B lubrication by physically adsorbed layers
C lubrication by chemical reaction layers

Fig. 10: Lubrication mechanism: oils with additives

running-in, the contained additives should have a very rapid and controlled micro-wear effect.

Therefore they are only applied for a certain period of time and should be replaced by an operational lubricant as soon as the running-in process is completed. Today, the drives no longer require cleaning after the running-in process.

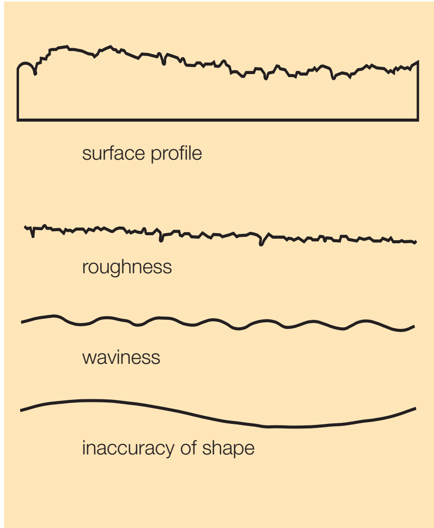


Fig. 11: The surface profile – a combination of roughness, waviness and inaccuracy of shape

4.

Lubrication and application methods

The decisions which type of lubrication and which method of lubricant application to the tooth flanks are used are of major importance for successful lubrication and maintenance. When selecting a type of lubrication and an application method it is important to check whether it will supply sufficient lubricant to the load-carrying tooth flanks so as to avoid deficient lubrication, damage to the gears and operational malfunctions.

Of course, the type of lubricant used must be taken into account in this context. It may be fluid or consistent, which makes it suitable for different types of feeding equipment. Which types of lubrication are appropriate for which application methods is shown in Fig. 12.

There are two basic types of lubrication:

- ❑ **continuous lubrication**
  (long-term lubrication)

and

- ❑ **intermittent lubrication**
  (total loss lubrication)

Both types of lubrication allow several application methods.

The types of lubrication and application methods for Klüber adhesive lubricants are listed in Table 1.

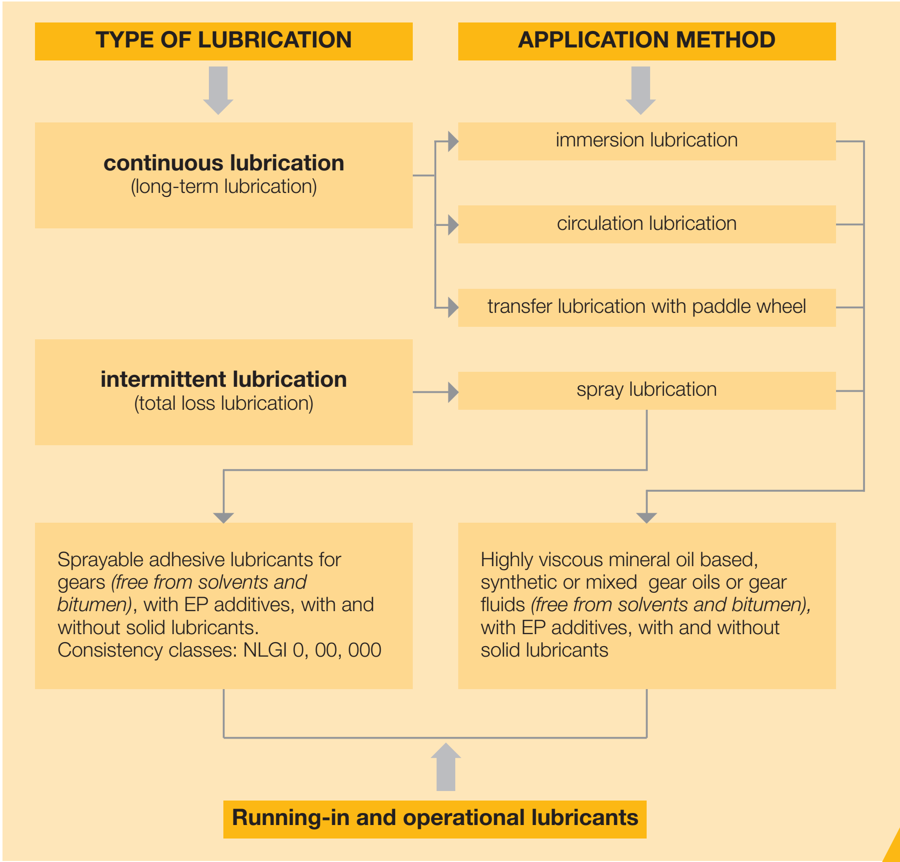


Fig. 12: Common types of lubrication and application methods for large gear drives

Fig. 13: Rotary mill in operation

Lubricant application methods suitable for Klüber adhesive lubricants

(the shadowed lubricants are black products)

		Klüber lubricant type																		
		A	A	B	B	B	C	C	C	C	C	C	C	C	C	C	C	C	D	D
Type of lubrication	**Application methods**	Klüberplex AG 11- 462	GRAFLOSCON A-G 1 Ultra	Klüberfluid B-F 2 Ultra	GRAFLOSCON B-SG 00 Ultra	Klüberfluid B-F 1 Ultra	Klüberfluid C-F 3 Ultra	Klüberfluid C-F 3 S Ultra	Klüberfluid C-F 3 M Ultra	Klüberfluid C-F 4 Ultra	Klüberfluid C-F 5 Ultra	Klüberfluid C-F 7 Ultra	Klüberfluid C-F 8 Ultra	GRAFLOSCON C-SG 0 Ultra	GRAFLOSCON C-SG 1000 Ultra	GRAFLOSCON C-SG 2000 Ultra	Klüberfluid C-F 1 Ultra	Klüberfluid C-F 2 Ultra	Klüberfluid D-F 1 Ultra	GRAFLOSCON D-SG 00 Ultra
Continuous lubrication = long-term lubrication	**Immersion lubrication** *(pinion or gear rim immersing in lubricant)*			x		x	x		x	x	x	x	x				x	x		
	Circulation lubrication with the Klübermatic PA system			x		x	x			x	x	x	x				x	x		
	Transfer lubrication with paddle wheel			x		x	x		x	x	x	x	x				x	x		
Intermittent lubrication = total loss lubrication	**Manual lubrication** by brush, spatula or compressed-air spray gun	x	x	o x	o x	o x	x x	o x	x x	x x	x x	x x	x x	o x	o x	o x	o x	o x	x x	x x
	Automatic spray lubrication			x	x	o	x	x	x	x	x	x	x	x	x	x	o	o		
	Transfer pinion lubrication *(lubricant is supplied to the transfer pinion by means of a pump)*	x		o	x	o	x		x	x	x	x	x	x	x	x	o	o		

Note: The application method depends on the lubricant temperature.

x = lubricant preferred for this application method

o = possible lubricant

A = priming lubricants

B = running-in lubricants

C = operational lubricants

D = repair lubricant *(not suitable for automatic spraying systems)*

For selection criteria of the a.m. lubricants please see **www.klueber.com**
or consult with Klüber Lubrication *(addresses on last page)*.

Table 1

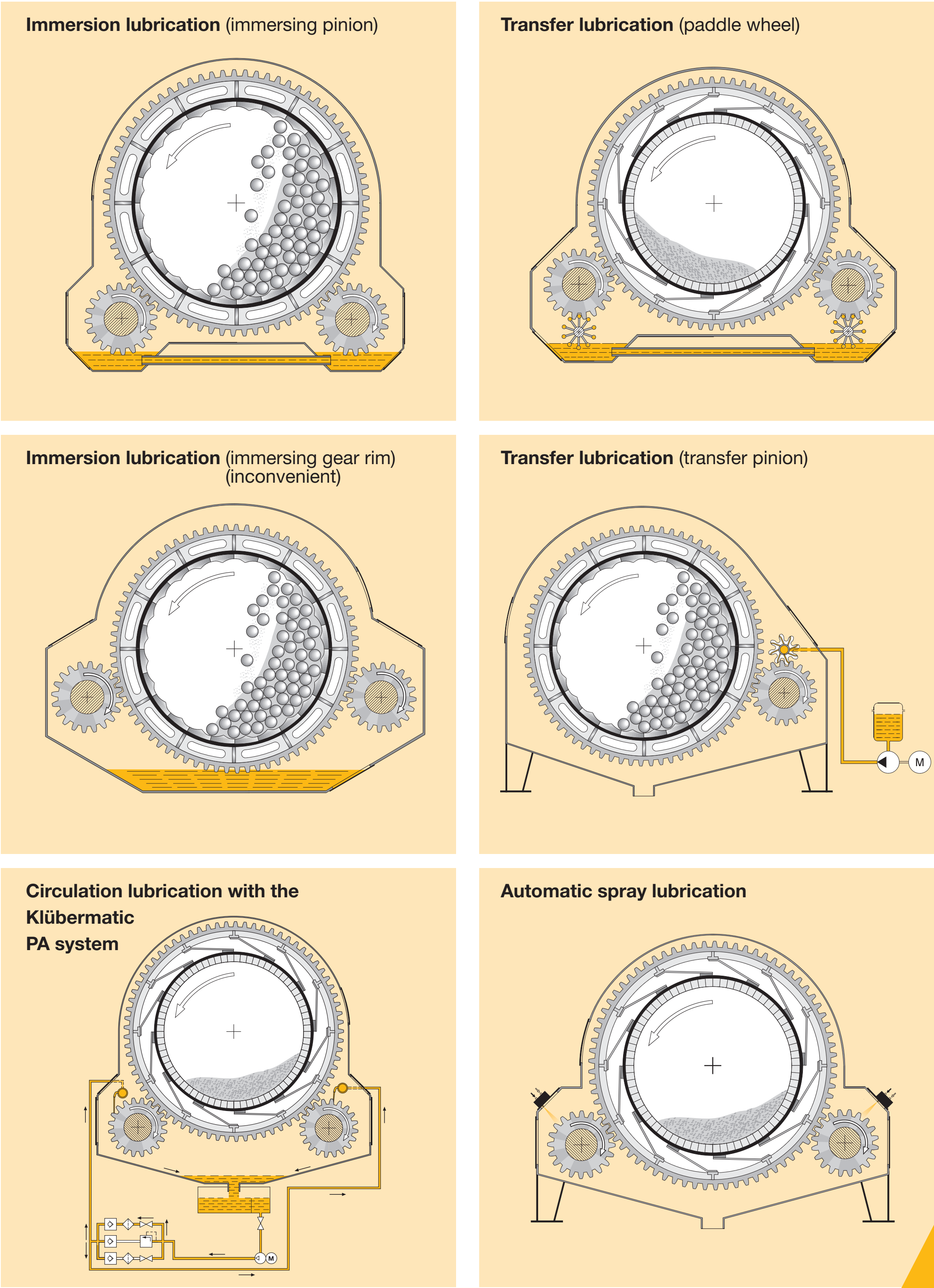


Fig. 14: Common lubricant application methods for gear drives

4.1. Continuous lubrication

Continuous lubrication means that the lubricant is fed to the friction point *(the meshing zone)* without interruption. The lubricant quantity at the load-carrying tooth flanks can vary between an extremely high and a minimal amount.

Continuous lubrication may be 'forced', as in the cases of immersion lubrication or transfer lubrication with a paddle wheel. If auxiliary equipment is used, as in the case of circulation lubrication, one speaks of 'non-forced' lubrication.

4.1.1. Immersion lubrication

Generally, immersion lubrication is one of the safest methods of applying a lubricant to a gear rim drive.

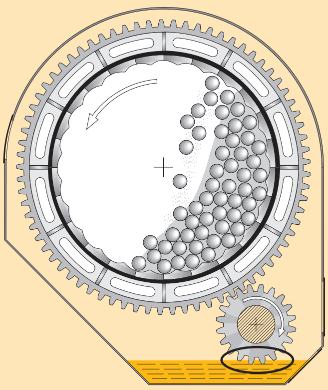
This is however conditional on the fact that the lubricant bath remains adequately filled and the drive cover is sealed properly to avoid lubricant losses. If possible, modern lubricants should be used, which are superior to the older bituminous ones in terms of efficiency and operational limits. They may or may not contain solid lubricants and have been specifically developed for a particular application, with optimized consistency and flow behavior. This ensures that immersion lubrication becomes highly effective.

However, it is just as important to know the operational limits of these modern fluids to be able to avoid critical situations as may arise, for example, due to very low or high ambient or drive temperatures.

The safety of immersion lubrication is based on the forced lubricant take-up by the pinion or the gear rim – the latter design is however not recommended. To ensure reliability and prevent deficient lubrication it is important to regularly compensate for lubricant losses, which may come as a result of leakage, lubricant discharge through the gear rim seals or evaporation.

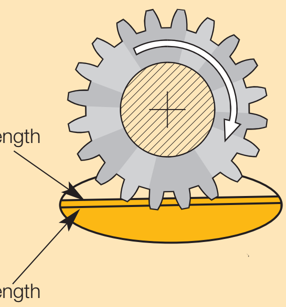
If sealing between the cover and the gear rim is insufficient, dust, sand, clinker, water, etc. will contaminate the immersion bath. As the lubricant is applied, contaminating particles will reach the friction point *(the intermeshing zone)*, which leads to increased abrasive wear of the tooth flanks. For this reason good sealing is a necessity.

Single-pinion drive (immersing pinion)



Depth of pinion teeth immersion in oil bath

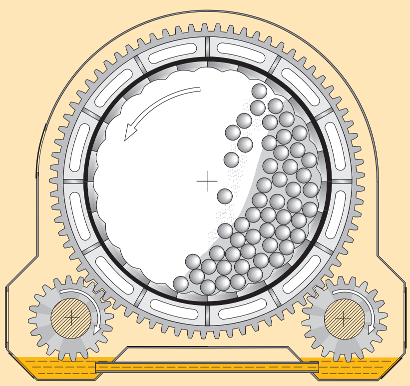
Detailed view: The right immersion depth is 1/3 of the vertical tooth in operation, and 1/2 of it when the drive is not moving.
Deeper immersion will lead to overlubrication and contamination by lubricant dripping off.



Maximum:
1/2 of tooth length

Nominal:
1/3 of tooth length

Double-pinion drive (immersing pinions)



Single-pinion drive (immersing gear rim not rrecommended)

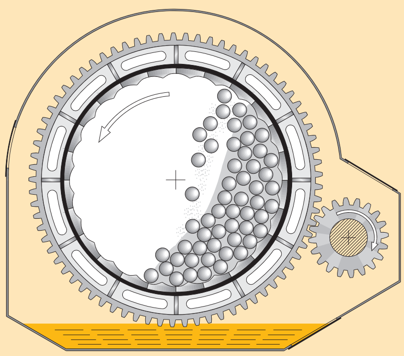
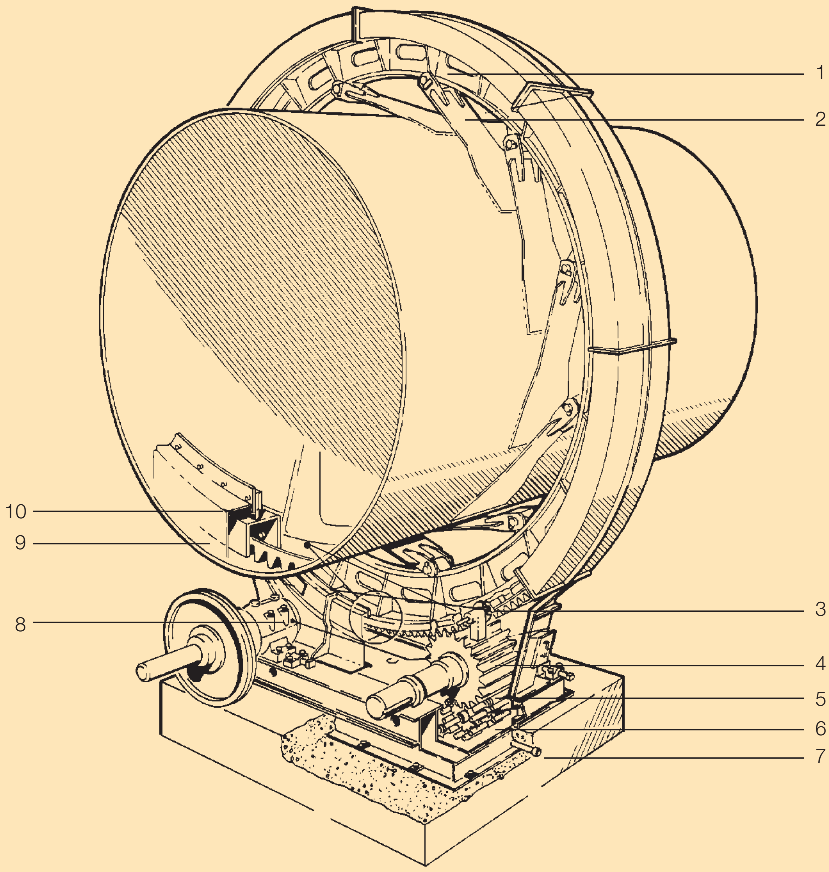


Fig. 15: Types of immersion lubrication

To prevent major damage to the tooth flanks, the immersion bath should be regularly checked and refilled or exchanged when necessary. When exchanging the bath, its reservoir should be cleaned to remove all contaminants. The applied lubricant must meet the following requirements to ensure reliable and safe operation of the gear drives over a long period of time:

- ❑ solvent-free
- ❑ good backflow behavior; no channeling at operating temperatures, especially in drives with gear rim immersion
- ❑ suitable viscosity-temperature behavior such that the bath must neither be heated nor cooled
- ❑ low evaporation losses
- ❑ easy replacement and disposal
- ❑ the load-carrying capacity and the antiwear behavior should have been tested on an FZG gear testing rig *(FZG = Forschungsanstalt für Zahnräder und Getriebe, Gear Wheel and Drive Testing Institute)*; the lubricant should meet today's gear lubricant requirements, i.e. have a load stage of at least 12 ($\triangleq$ 1841 N/mm^2) at a specific weight loss of < 0.2 mg/kWh.

All fluids developed by Klüber for immersion and circulation lubrication meet these requirements. They were adapted to suit the specific operating conditions of large gear drives, e.g. in ball mills and rotary kilns, and comply fully with the requirements to be met by extreme pressure lubricants.



1 Gear rim	6 Immersion bath
2 Gear rim fixture	7 Lubricant drain
3 Scraper	8 Pinion bearing
4 Pinion	9 Gear rim cover
5 Paddle wheel	10 Felt ring

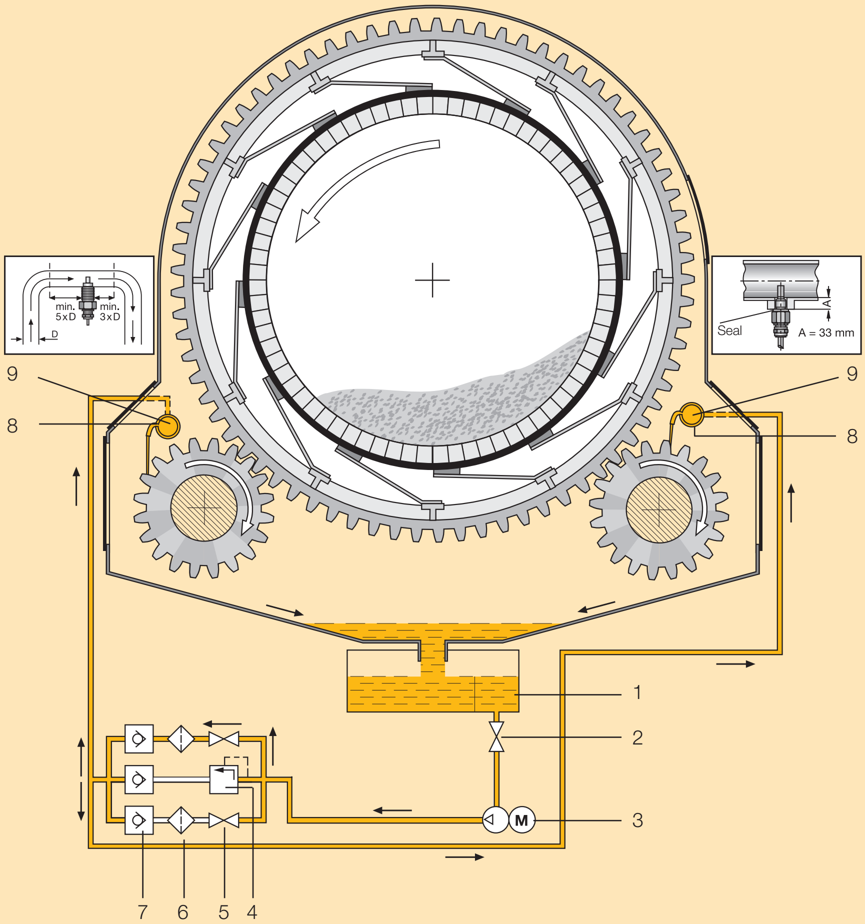
Fig. 16: Paddle wheel lubrication, double-pinion kiln drive by FLS

4.1.2. Transfer lubrication

Transfer lubrication by means of a paddle wheel is a special variant of immersion lubrication. In contrast to the type of immersion lubrication described above, i.e. where the teeth of the pinion or the gear rim take the lubricant up from the bath, this type of lubrication uses paddle wheels to transfer the lubricant to the pinions or the gear rim. This method of application has the advantage that smaller quantities of lubricant are transferred onto the tooth flanks and a smaller amount of excess lubricant is circulated with the drive.

Fig. 16 shows an example of paddle wheel lubrication in a rotary kiln with a double-pinion drive. The paddle wheels are located directly below the pinions and are driven by them. Transfer lubrication by means of paddle wheels is mainly found in slowly operating kiln drives.

In both immersion and transfer lubrication, the lubricant should be applied to the pinions rather than to the gear rim. If it is the gear rim that takes up lubricant from the bath, or receives it from the paddle wheel, the supply of lubricant to the load-carrying tooth flanks may be insufficient, particularly at low lubricant temperatures, when the immersing gear rim forms a channel in the lubricant, which may be highly viscous when cold. Another type of transfer lubrication is by means of a transfer pinion: the lubricant is pumped through the hub of the transfer pinion and reaches the drive pinion through bore holes. This application method can be used for both fluids and greases. *(See fig. 14)*



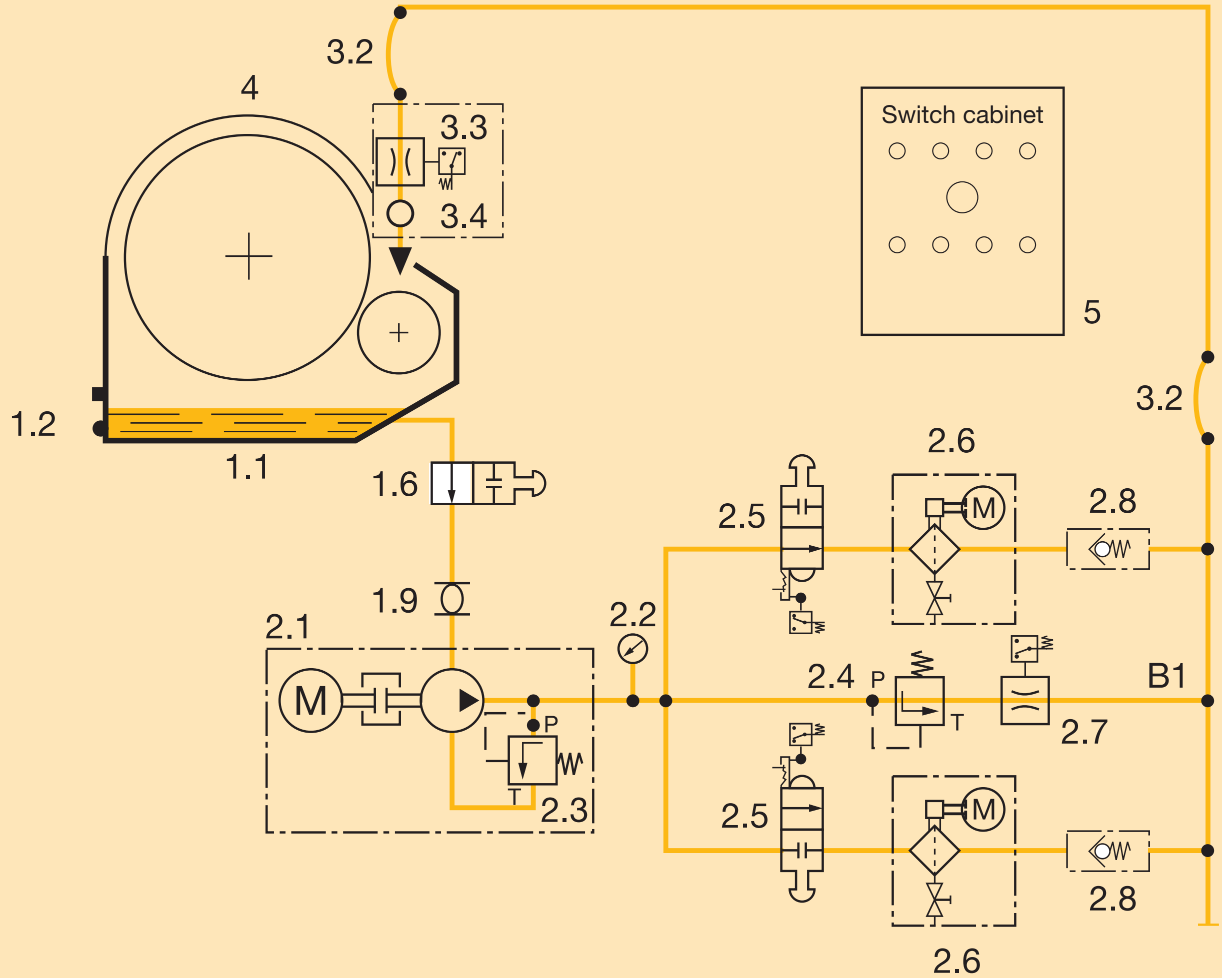
1 Lubricant reservoir
2 Shut-off valve
3 Lubricant feed pump
4 Pressure relief valve
5 Shut-off valve
6 Lubricant filter
7 Check valve
8 Lubricant distribution pipe
9 Flow sensor in lubricant distribution pipe

Fig. 17: Klübermatic PA: arrangement of lubricant pipes. The load-bearing tooth flanks of both the inward and the outward turning pinion are lubricated

4.1.3. Circulation lubrication

For circulation lubrication, the lubricant is fed by an externally driven pump. The main advantage as compared to immersion lubrication is the fact that the lubricant is filtered and then applied to the load-carrying tooth flanks in abundant quantity almost without any contaminants.

However, circulation lubrication will only be successful if the drive cover is sealed properly and the penetration of contaminants from the environment into the lubricant reservoir is prevented as well as lubricant leakage.



1.1 Lubricant reservoir
1.2 Level control
1.6 Shut-off valve
1.9 Compensator

2.1 Lubricant pump
2.2 Manometer and thermometer
2.3 Pressure control valve, 16 bar *(integrated in pump)*

2.4 Pressure control valve, 12 bar
2.5 Shut-off valve with electrical position indicator
2.6 Lubricant filter with powered lamella cleaning unit
2.7 Flow sensor
2.8 Check valve

3.2 Flexible line
3.3 Flow sensor
3.4 Lubricant distribution pipe

4 Gear rim cover

5 Switch cabinet

B1 Bypass line

Fig. 18: Flow chart of a Klübermatic PA for a single-pinion drive

4.1.3.1. Klübermatic PA circulation lubrication system

Most of the circulation lubrication systems used today are only designed for the application of gear oils and are not suitable for applying fluids or highly viscous lubricants. For this reason, Klüber developed a circulation lubrication system called Klübermatic PA for the application of type B *(for running-in lubrication)* and type C *(for operational lubrication)* lubricants for large gear drives.

The Klübermatic PA system is generally suitable to lubricate gear drives with one, two or more pinions in rotary kilns, mills and other machinery. It can be retrofitted to existing installations. Its main advantage is that the lubricant is permanently cleaned by filters – hence no need to stop the machine for cleaning – and that it is applied to the tooth flank surfaces very efficiently and in abundant quantity through special

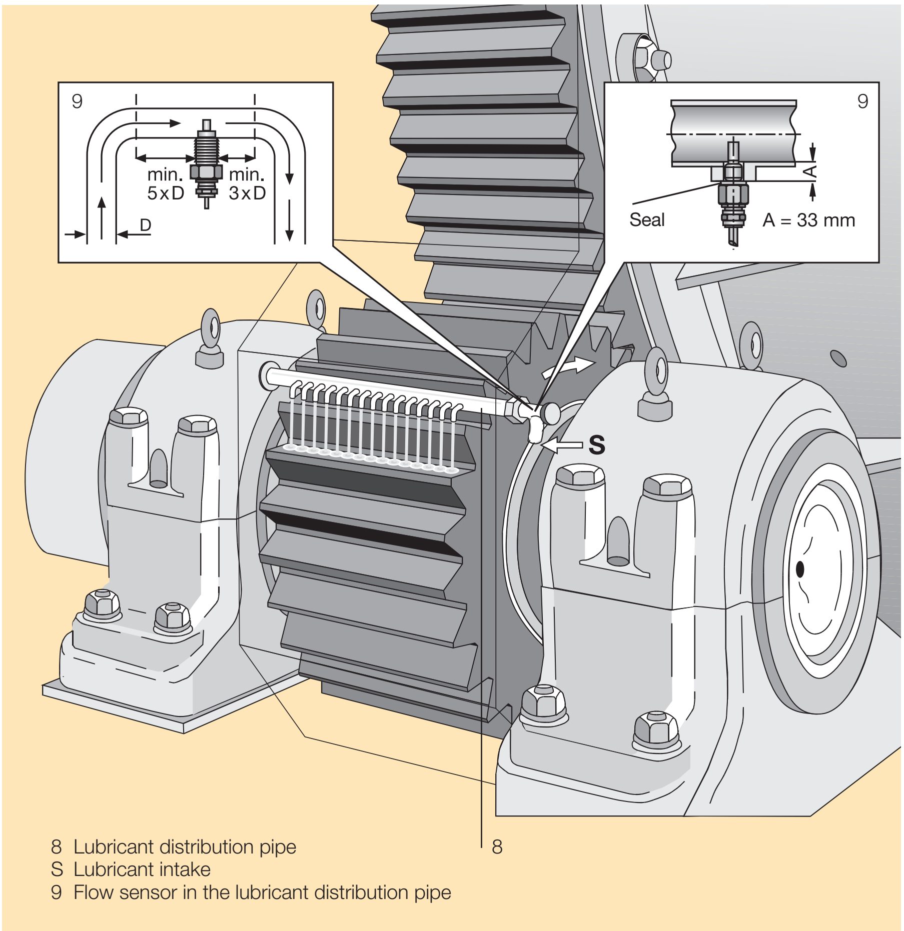


Fig. 19: Lubricant application through especially designed lubricant distribution pipes of the Klübermatic PA system

lubricant distribution pipes. The use of oils and fluids offers the additional benefit of a cleaning and cooling effect. In a double-pinion mill drive, for example, lubricant consumption can be reduced by up to 70% when Klübermatic PA is used instead of spray lubrication.

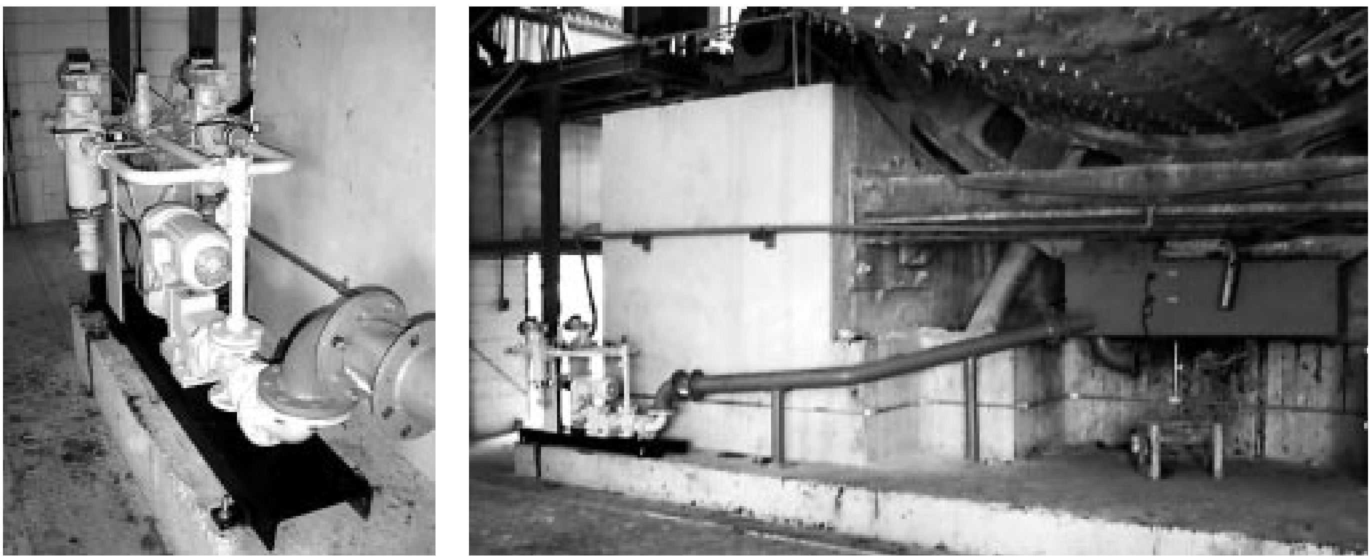


Fig. 20 and 20a: Klübermatic PA installed at a tube mill

4.2. Intermittent lubrication

4.2.1. Spray lubrication

Intermittent lubrication means that the lubricant is applied at intervals. This type of lubrication is always a total loss lubrication, which means that aspects of cost-effectiveness must be paid particular attention with this method.

As in the case of continuous lubrication there are various methods of application of intermittent lubrication. For modern and safe lubrication of large girth gear drives, however, only two methods of application are used:

- ❑ automatic spray lubrication

and

- ❑ manual lubrication by spray gun

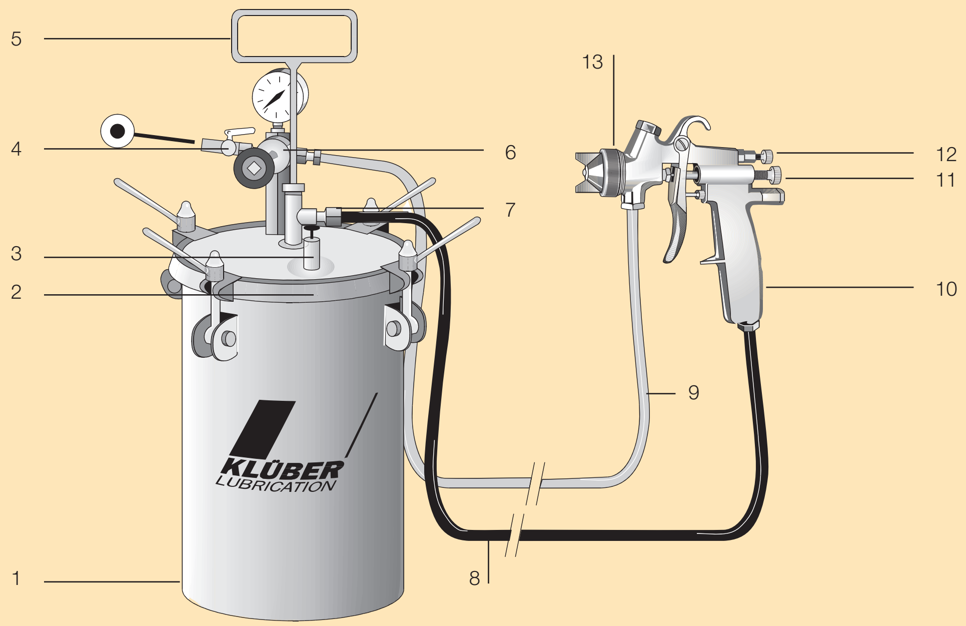
The following description of application methods covers only qualified adhesive spray lubricants such as the GRAFLOSCON and Klüberfluid series made by Klüber Lubrication.

4.2.2. Manual lubrication by spray gun

The most effective type of manual lubrication of large gear drives, such as in rotary cylinders, is currently by means of compressed manual spray guns.

They are best suited for operational lubrication in applications where stationary automatic lubrication systems cannot be installed and where lubrication is required during operation – of course without causing risk of accident.

Among the equipment used for this method are completely mounted manual spray systems such as Klübermatic LB *(Fig. 21 and 48)*.
It consists of a pressurized lubricant container with valves, a heavy-duty spray gun and connecting hoses for the lubricant and compressed air.



1 Pressurized container, 10 l, max. operating pressure 4 bar
2 Removable cover
3 Pressure relief valve *(depressurization)*
4 Shut-off valve, connection to compressed air system
5 Carrying handle
6 Adjustable pressure reducing valve to set the lubricant pumping pressure
7 Connection for tube nozzle
8 Lubricant tube
9 Compressed air tube
10 Spray gun, fan or circular jet
11 Adjustment screw to control the lubricant throughput
12 Adjustment screw to control the compressed air throughput
13 Spray head with fixing ring

Fig. 21: Klübermatic LB manual spraying equipment

The pressurized container is not subject to the legal regulations for pressure vessels.

This system is portable, easy to handle and only needs to be connected to the compressed air network at the site before it can be put into operation. With the spray gun different types of application are possible, e.g.

- ❑ operational lubrication with an extremely thin lubricant film and hence maximum lubrication economy,
- ❑ priming of open gear drives to check the contact and load-carrying pattern,
- ❑ lubricant application for repair, correction and forced running-in lubrication.

However, manual spray gun lubrication does have its limits, especially in running-in and operational lubrication over an elongated period of time.

4.2.3. Automatic spray lubrication

The right lubricating equipment for the right lubricants

Various manufacturers offer automatic spray lubrication systems of different designs, all of which are state of the art and are capable of handling operational lubricants with a high solid lubricant content as well as special running-in lubricants and correction lubricants. Lubricants which instead of containing solid lubricants have a very high viscosity can also be applied by spraying.

An important requirement for automatic spray lubrication systems is their suitability for the running-in procedures on girth gear drives, i.e. the systems must be designed for permanent operation and the application of large amounts of running-in or correction lubricant. Today, these lubricants are normally applied in a quasi-permanent operation in specified amounts and for a defined period of time.

Consequently, running-in lubrication determines the maximum lubricant throughput in continuous operation that must be possible with the spraying equipment, while optimized operational lubrication determines the lowest throughput. Due to the low consumption quantity during operational lubrication, the lubricant is applied in intervals, i.e. spraying and pause times alternate.

For correct dimensioning of the spray lubrication system *(minimum capacity of the lubricant pump)* it is critical that the lubricant quantity expected for running-in *(maximum requirement)* be determined.

The lubricant volumes are exclusively determined by the requirements of the drive and are independent of the spray system to be used, i.e. the lubricant pumps and the type of application. It is normally the size of the contact area to be lubricated *(single or double-pinion drive)*, the size of the drive unit *(diameter and width)* and the peripheral speed *(rpm)* that tell us how much lubricant is required.

But also the component temperature of the pinion and the gear rim and some other factors must be taken into account in determining the required lubricant quantity, even though the magnitude of their influence can often only be estimated: it is therefore obvious that determining the right lubricant quantity is a difficult task. Klüber

Lubrication has therefore evaluated the experience gathered over several decades to develop a diagram *(Fig. 22)* indicating approximate values of consumption quantities of running-in and operational lubricants.

The first step is determination of the specific lubricant quantity in g/cm of flank width and per operating hour – depending on the type of drive or machine *(see Table 2)*. Based on the actual flank width *(e.g. 60 cm for the pinion(s)*, the approximate quantity required per operating hour can then be determined. The flank width was chosen as a reference because this is the best way to take into account the specific power transmission in a drive.

NOTE
The quantities determined using the diagram only apply when using Klüber GRAFLOSCON B-SG 00 Ultra and C-SG 0 Ultra lubricants for tooth widths up to 1000 mm and modules up to 30 mm. For consumption quantities of transparent lubricants, see Table 2 and Diagram 22a.

With modules of 30 mm and larger drive widths, the required quantity will be higher, or a more viscous lubricant will have to be used, because the teeth take up more lubricant in such drives. Experience has shown that lower quantities are needed if lubricants of high viscosity are used. Also drives that are subject to less severe loads, e.g. in drums or rotary coolers, can be operated safely with lower lubricant quantities. However, to determine the lowest possible consumption quantities, lubrication of each drive must be adjusted step by step. The lubricant quantity can be reduced by 0.5 to 1.0 g/cm/op. hr. at intervals of 150 to 200 operating hours until the permissible minimum has been reached.

It should be noted that even identical drives *(same machine with same power rating)* may require a different amount of lubricant under different operating conditions *(temperature, vibrations, possibly existing damage, etc.)*. Maintenance personnel should therefore check the lubrication condition of the drive to determine the required lubricant quantity for each machine individually.

4.2.4. Application of lubricant

Ideally, the lubricant quantity sprayed continuously onto the gears would be just enough to ensure that the lubricant film, which is constantly being eroded by the friction bodies *(tooth flanks)*, maintains at all times the minimum thickness that is required to safely prevent scuffing.

However, in real life this is hardly feasible. If between 1 and 14 kg of operational lubricant are to be applied over 24 operating hours, it is simply not possible to continuously apply a lubricant film of constantly ideal thickness. A good compromise is interval lubrication, consisting of periods of excess lubrication during which the lubricant film does not have to be sustained from outside.

For operational reliability the most decisive factor is the duration of the individual spraying pulses. Reliability is best when the entire circumference of the pinion or the gear is covered with lubricant in one pulse. The lubricant quantities must ensure a film

Consumption quantities of GRAFLOSCON B-SG 00 Ultra and C-SG 0 Ultra

	Type of installation / drive	Required specific consumption quantities [g/cm*/op.hrs.] Running-in lubricant	Operational lubricant
1	Rotary drum drives *(e.g. cooling units)*	**4**	**1.0** to **1.5**
2	Single-pinion kiln drives	**5**	**1.5** to **2.0**
3	Single-pinion mill	**6**	**2.0** to **2.5**
4	Large single-pinion mill drives and double-pinion kiln drives	**7**	**2.5** to **3.0**
5	Double-pinion mill drives	**8**	**3.0** to **3.5**

** width of tooth flanks*

Table 2: Specific lubricant consumption quantities for running-in and operational lubrication

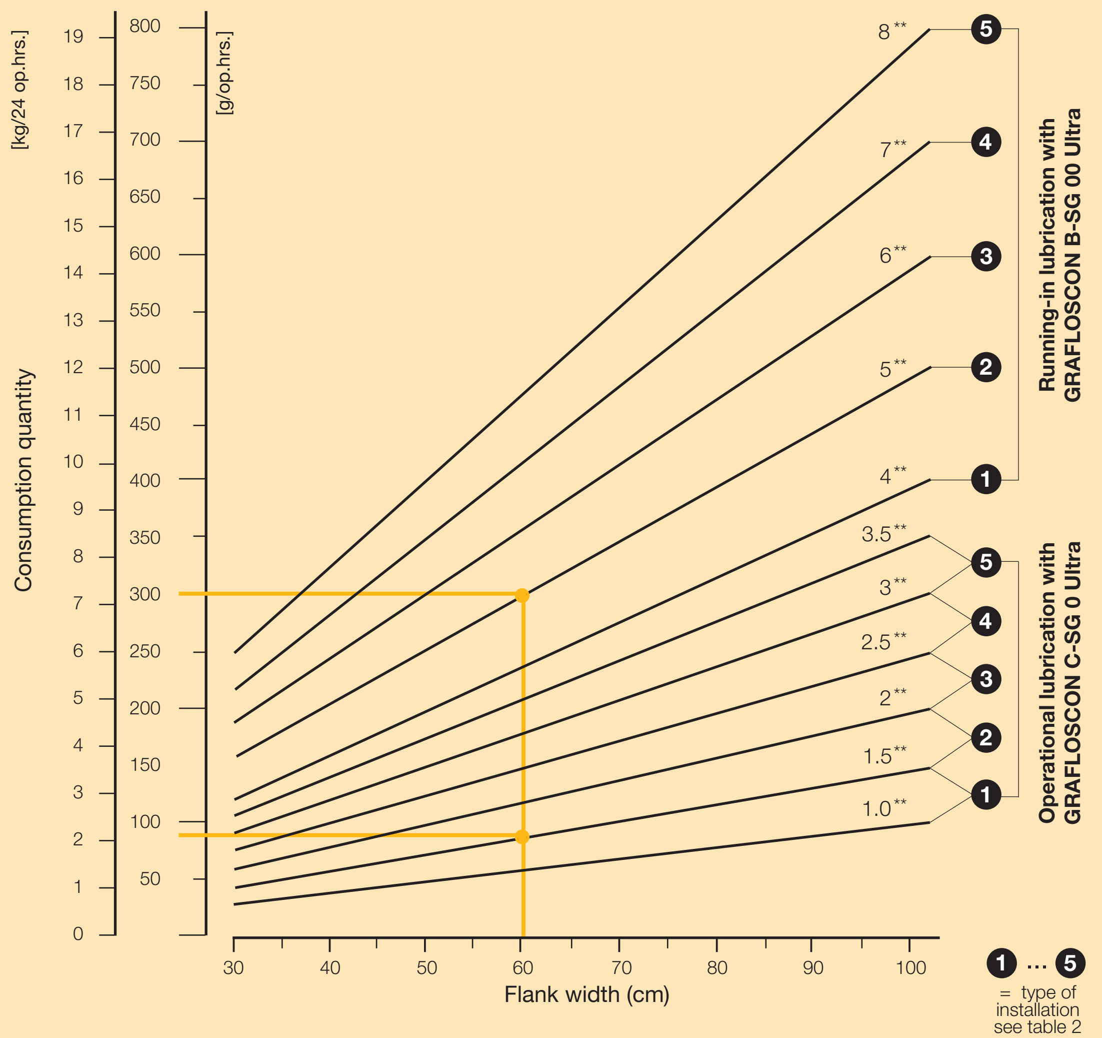


Fig. 22: Diagram for determining the specific lubricant consumption quantity required for running-in and operational lubrication

Consumption quantities of the transparent Klüberfluid lubricants

	Type of installation / drive	**Required specific consumption quantities** [g/cm*/op.hrs.] **Operational lubricant**
1	Rotary drum drives *(e.g. cooling units)*	**0.5** to **0.8**
2	Single-pinion kiln drives	**0.8** to **1.0**
3	Single-pinion mill drives of average dimensions	**1.0** to **1.3**
4	Single-pinion mill drives of large dimensions or double-pinion kiln drives	**1.3** to **1.5**
5	Double-pinion mill drives	**1.5** to **1.8**

** width of tooth flanks*

Table 2a: Specific lubricant consumption quantities for running-in and operational lubrication

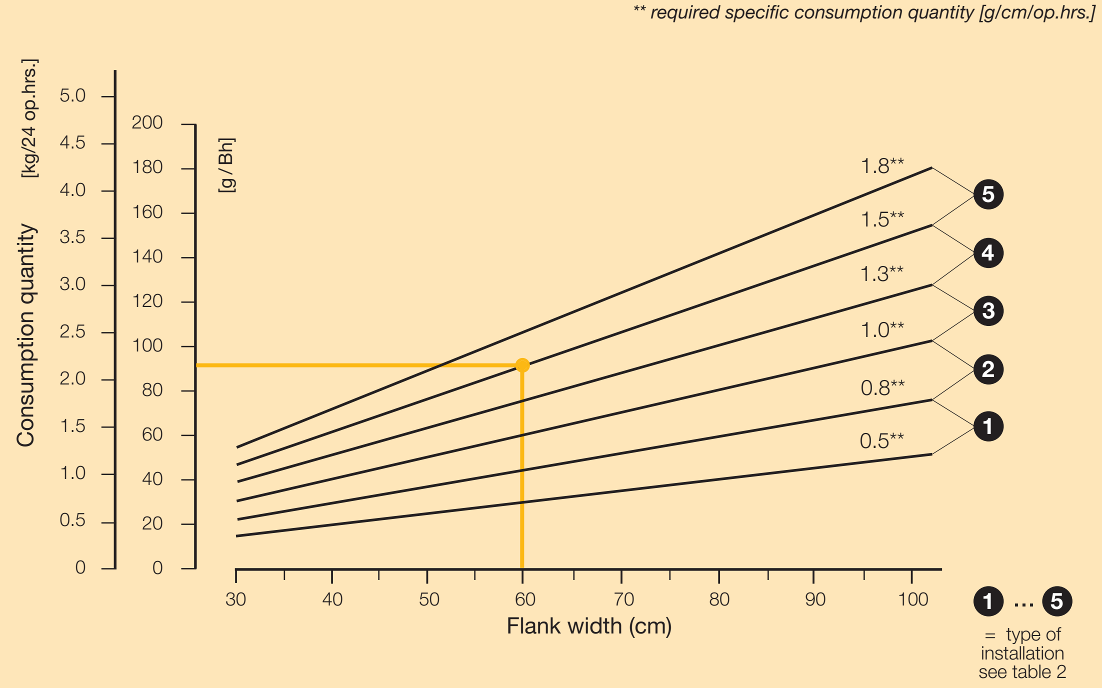


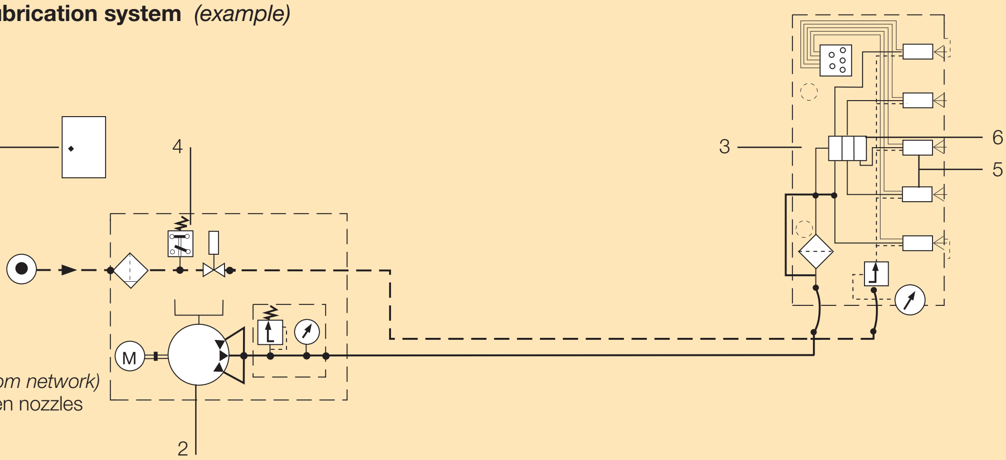
Fig. 22a: Diagram for determining the specific lubricant consumption quantity required for running-in and operational lubrication

Please note:
The specific quantity of the running-in lubricant Klüberfluid B-F 2 Ultra required is the same as of GRAFLOSCON B-SG 00 Ultra and can be found in Fig. 22.
The total recommended lubricant quantity of Klüberfluid B-F 2 Ultra is two or three 180 kg drums.
The total recommended lubricant quantity of GRAFLOSCON B-SG 00 Ultra is one or two 180 kg drums.

thick enough to offer reliable flank protection throughout the ensuing pause cycle. Shorter and more frequent spray cycles with shortest possible pauses result in utmost operational reliability in spray lubrication.

Compared with operational lubrication, running-in or correction lubrication of gear drives requires much larger amounts of lubricant. So the spraying pulses must be extended considerably to apply the larger amounts of lubricant, or the pause intervals shortened accordingly.

LINCOLN spray lubrication system *(example)*



1 Switch cabinet
2 Single-line piston pump
3 Nozzle plate
4 Compressed air unit *(from network)*
5 Lateral distance between nozzles approx. 150 mm
6 Lubricant distributor

WOERNER spray lubrication system *(example)*

1 Nozzle plate
2 Switch cabinet
3 Compressed air unit
4 Compressor
5 Electric barrel pump
6 Lateral distance between nozzles approx. 300 mm (block nozzle)

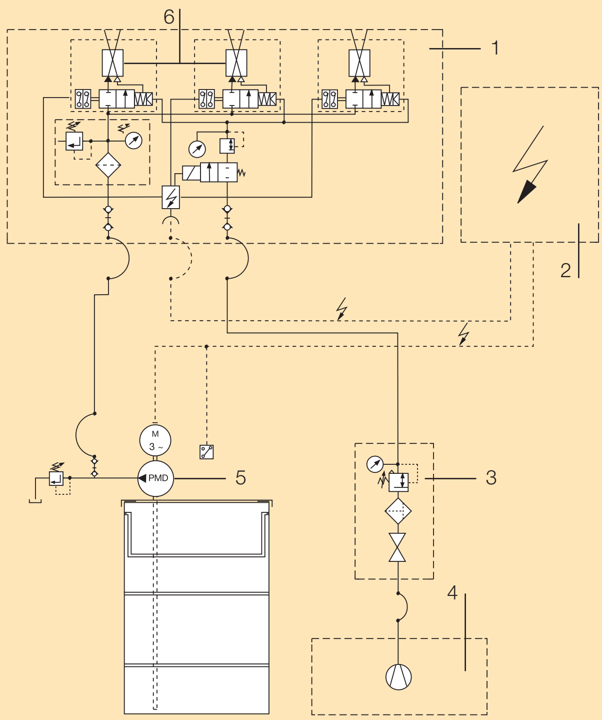


Fig. 23: Spray lubrication systems

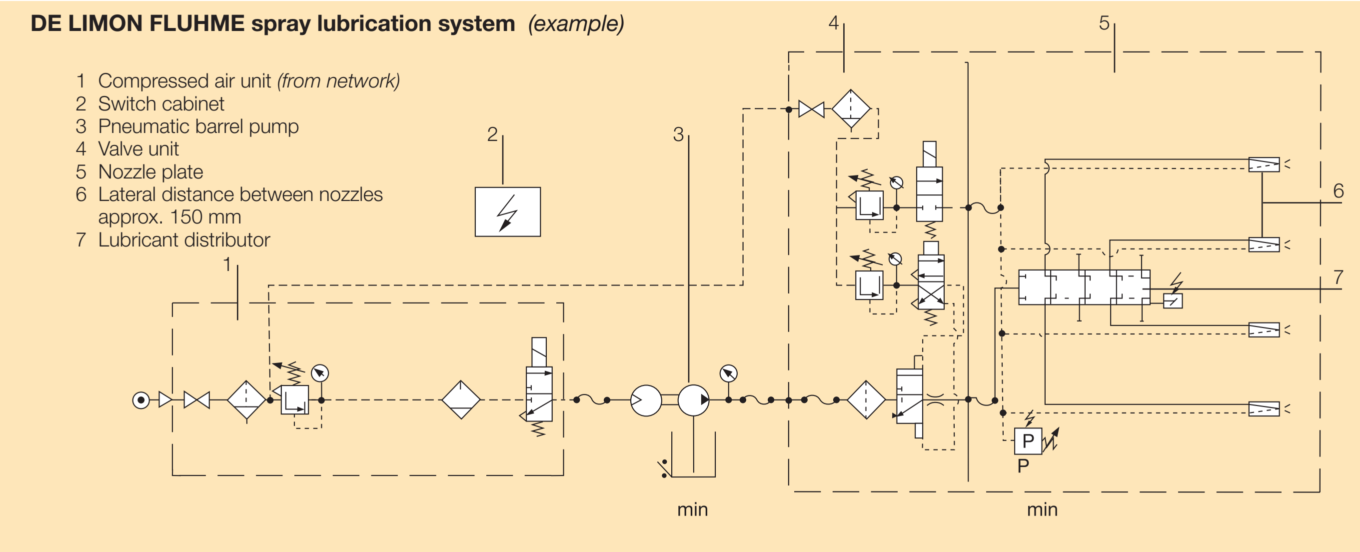


Fig. 23a: Spray lubrication systems

4.2.5.
Spray lubrication systems

Fig. 23 shows flowcharts of spray lubrication systems from different manufacturers which are used today for spraying modern adhesive lubricants on large girth gear drives. These systems differ in their design and components as follows:

- ❑ Lubricant pumps, e.g. electro-mechanical multi-piston pumps *(container pumps)* with automatic deposit filling by means of pneumatic barrel pumps or manual filling. Direct pumping by means of pneumatically or electro-mechanically driven package drums.

- ❑ Single or multi-line system design

- ❑ Lubricant feeding to the spray nozzles either direct from the lubricant pump or via an intermediate progressive distributor

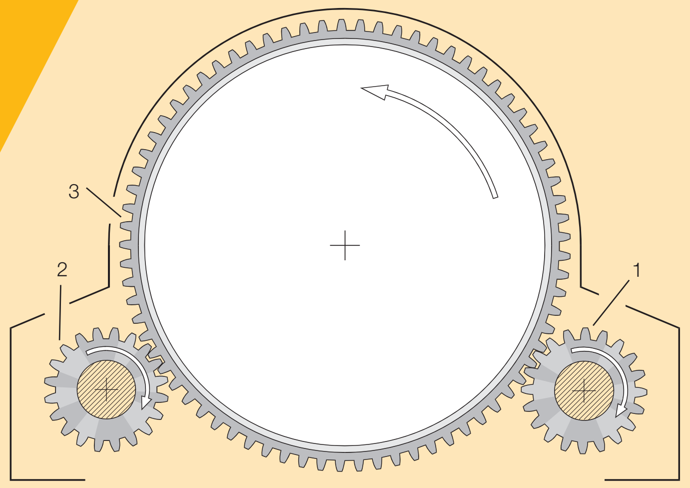
- ❑ Auto-control spray nozzles *(controlled by lubricant and/or air)* or externally controlled nozzles with and without monitoring units

The various spray systems also differ by their individual degrees of controllability of lubricant throughput in continuous and interval lubrication and the functional control of the entire system.

4.2.6.
Arrangement of nozzle plates

Fig. 24 shows the arrangement of nozzle plates that has proven most effective in the field. Positions 1 and 2 are generally preferred. Spraying of the gear rim from position 3 should only be considered if it can be ensured that the entire circumference of the gear rim is covered with lubricant during one spray pulse. This is particularly important in slow-running kiln drives.

In fast running modern kiln drives with modules > 30 mm, the lubricant can in principle also be applied to the load-bearing tooth flanks of the gear rim. The sliding direction at the gear rim is from the tip to the root of the tooth, which enhances longitudinal lubricant distribution. This applies in particular to modern, highly viscous, transparent lubricants in combination with state-of-the-art spray systems, which allow longer spraying times. Depending on the design of the drive cover, the nozzle plates should be arranged at the angles and in the positions indi-



Arrangement examples

Single-pinion drives
Generally recommended positions:
1a, 1b, 1c

Position 3:
only permissible with suitable spraying equipment, sufficient peripheral speed of the gear rim and a suitable lubricant

Double-pinion drives
Generally recommended positions:
1a, 1b, 1c and **2a, 2b, 2c**

Position **1** in combination with position **3:** only permissible with spraying equipment of sufficient capacity

Outward turning pinion | **Inward turning pinion**

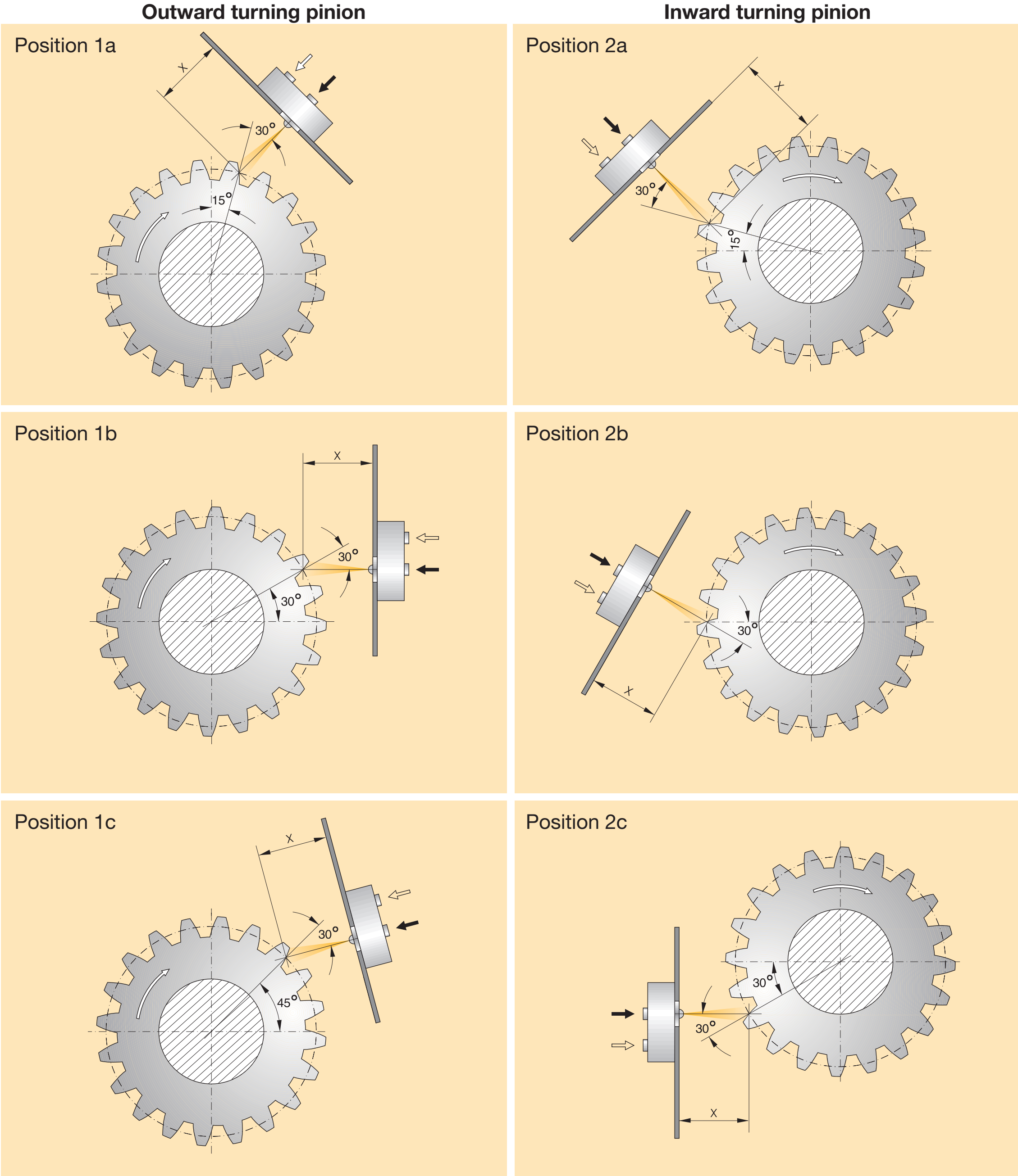


Fig. 24: Nozzle plate arrangement (x = 200 ± 50 mm)

cated in Fig. 24. The spray nozzles should not be installed to spray upwards since the spray heads would become clogged by dropping used lubricant. This would result in insufficient spray patterns and eventually in a complete failure of the lubricant supply system. Furthermore, maintenance would be impeded.

When determining the position of the nozzles, especially when the gear rim is to be sprayed, care should be taken that monitoring and maintenance works can be carried out without risk also while the machine is running.

Orientation of the spray nozzles *(Fig. 25)*
A spraying angle of 30° is best to achieve a good longitudinal distribution of the lubricant over the load-carrying tooth flanks. The nozzle distance “X” should be between 200 ± 50 mm. The exact distance depends on the position and the type of nozzle. Every type of nozzle requires also a particular distance between the individual nozzles, which depends on the air pressure as determined by the manufacturer, the number of nozzles and the type of lubricant. It ensures that the entire width of the tooth flank is covered with lubricant. Operational safety is reduced if the nozzles are not arranged properly.

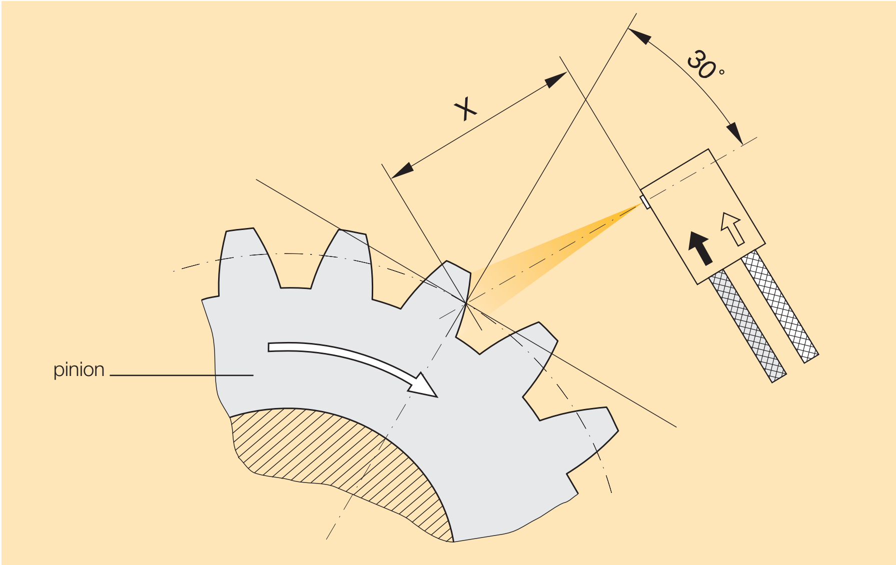


Fig. 25: Preferable orientation of a spray nozzle (x = 200 ± 50 mm)

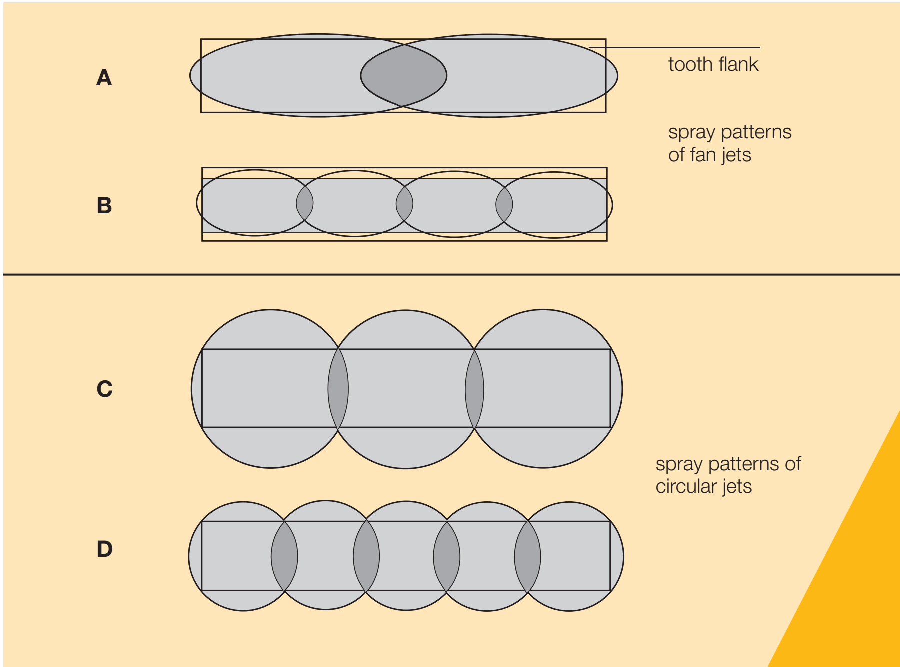


Fig. 26: Spray patterns depending on the number of nozzles and the spray geometry

4.2.7. Spray patterns, checking of spray patterns

An important factor in terms of operational reliability is a spray pattern without any gaps, i.e. the lubricant must be distributed evenly over the entire height and width of the tooth flanks, see Fig. 26. Even if the spray nozzles are controlled automatically, periodic checking of the spray pattern is an essential part of maintenance.

Due to their design, older spray systems had the disadvantage that the spray pattern in high-speed drives, e.g. in mills, could only be checked when the drive was stopped. Newly developed nozzle plates are hinged, which allows checking of the spray pattern while the drive is in operation *(Figs. 29–31)*.

This is of special advantage in kiln drives, which cannot be stopped whenever desired. In addition, this type of checking ensures maximum protection against accidents because it is not necessary to remove drive covers.

4.2.8. Lubricant pumps and reservoirs

How the lubricant is fed to the spray nozzles from the storage container depends on the design of the lubrication system. A differentiation is made between

a) spray lubrication systems with container pumps *(Fig. 32)*,

b) spray lubrication systems with barrel pumps *(Fig. 33)*,

c) spray lubrication systems fed from Klüber lubricant containers *(Fig. 35)*

The lubricant containers in type a) systems are filled manually or by means of a transfer pump from the original package. The latter is preferred because it prevents manipulation or contamination of the lubricant.

In type b) systems the lubricant is fed directly to the spray system with the required operating pressure by means of a barrel pump which is inserted into the original lubricant drum. In type c) systems the lubricant is fed from the Klüber lubricant container in various configurations.

Feed pumps may be driven electromechanically or pneumatically. It is important to have a level control system which indicates in time that lubricant should be refilled or the drum replaced to prevent the gear drive from being damaged or switched off due to insufficient lubrication.

As environmental impact is being paid more attention and consequently sanctioned with increasing costs, lubricants are less and less supplied in non-returnable drums but rather in large Klüber lubricant containers, which are refillable. This offers a number of advantages: costly disposal of empty drums is no longer necessary and the exchange intervals of the larger containers are much longer, saving on manpower and hence expenses.

Another advantage of the Klüber lubricant containers is the fact that several machines can be supplied with lubricant from a single container as long as the drives are located at a convenient distance.

Fig. 34 shows flow charts of different types of systems using Klüber lubricant containers.

Klüber containers have a gross weight of 1500 kg and can be easily moved by forklift trucks because they are equipped with lifting brackets. Connection of the container to transfer or feed pumps installed at the site *(5a or 5b)* is made easy through the use of an express coupling *(3)*, see Fig. 34.

A level control unit at the container indicates in time when the container should be replaced.

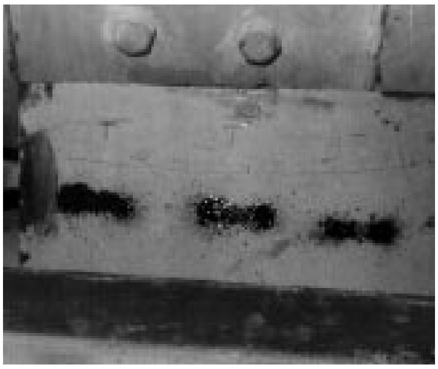


Fig. 27: Inadequate spray patterns; the individual patterns do not overlap

Fig. 28: Scuffing caused by partially insufficient lubrication (individual spray patterns do not overlap)

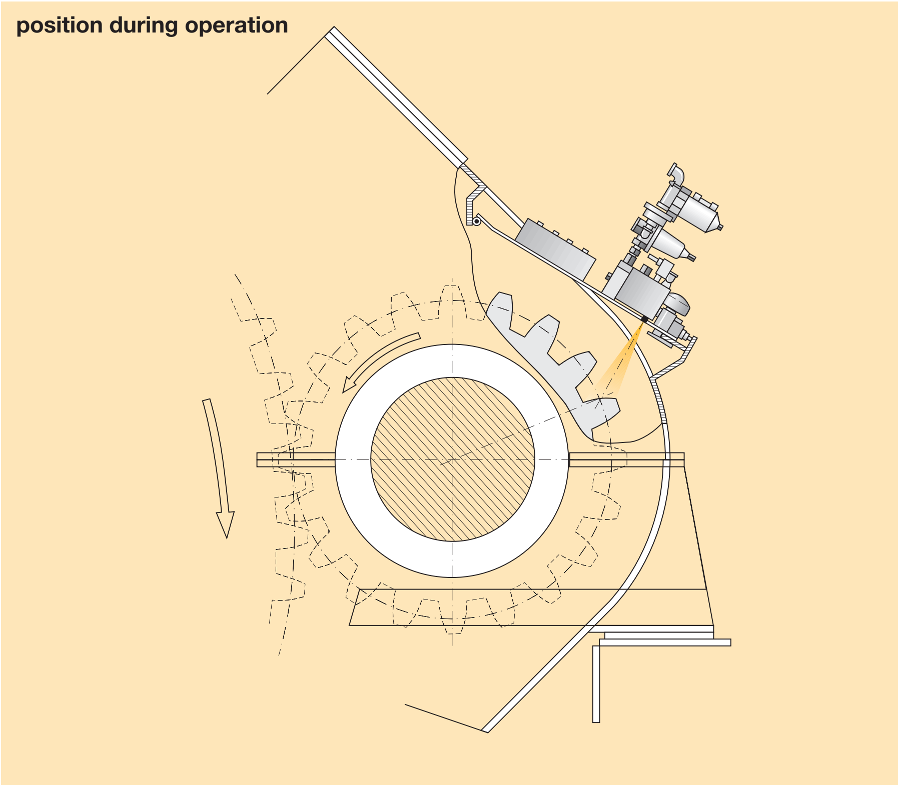


Fig. 29: Hinged nozzle plate, LINCOLN system

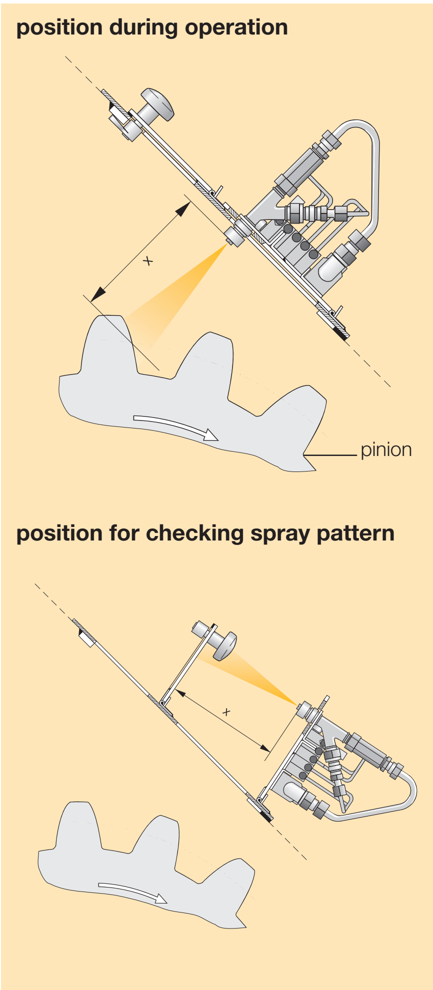


Fig. 30: Hinged nozzle plate, DE LIMON FLUHME

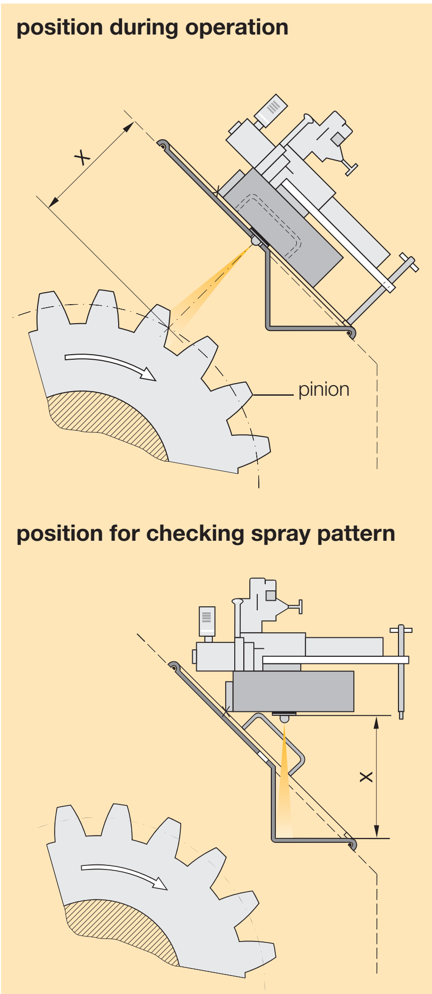
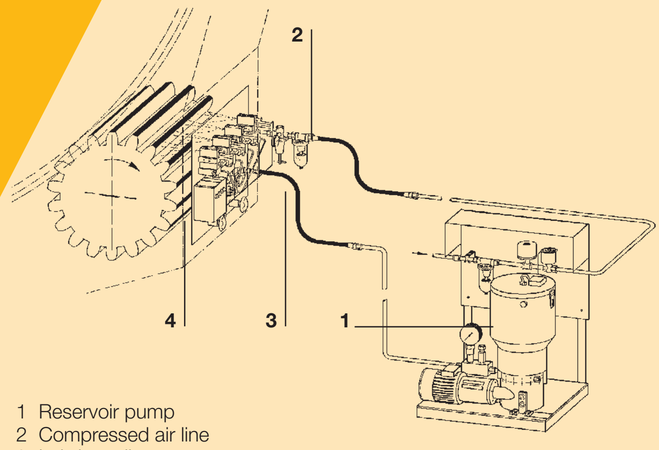
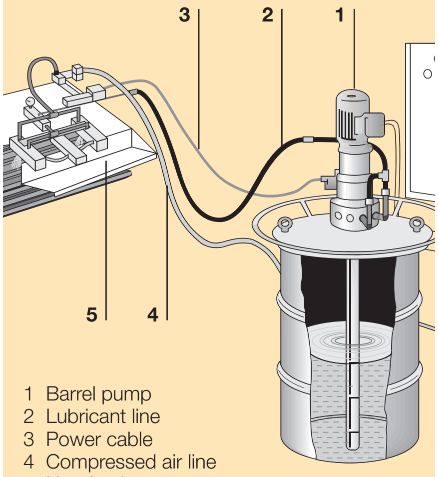


Fig. 31: Nozzle plate, WOERNER



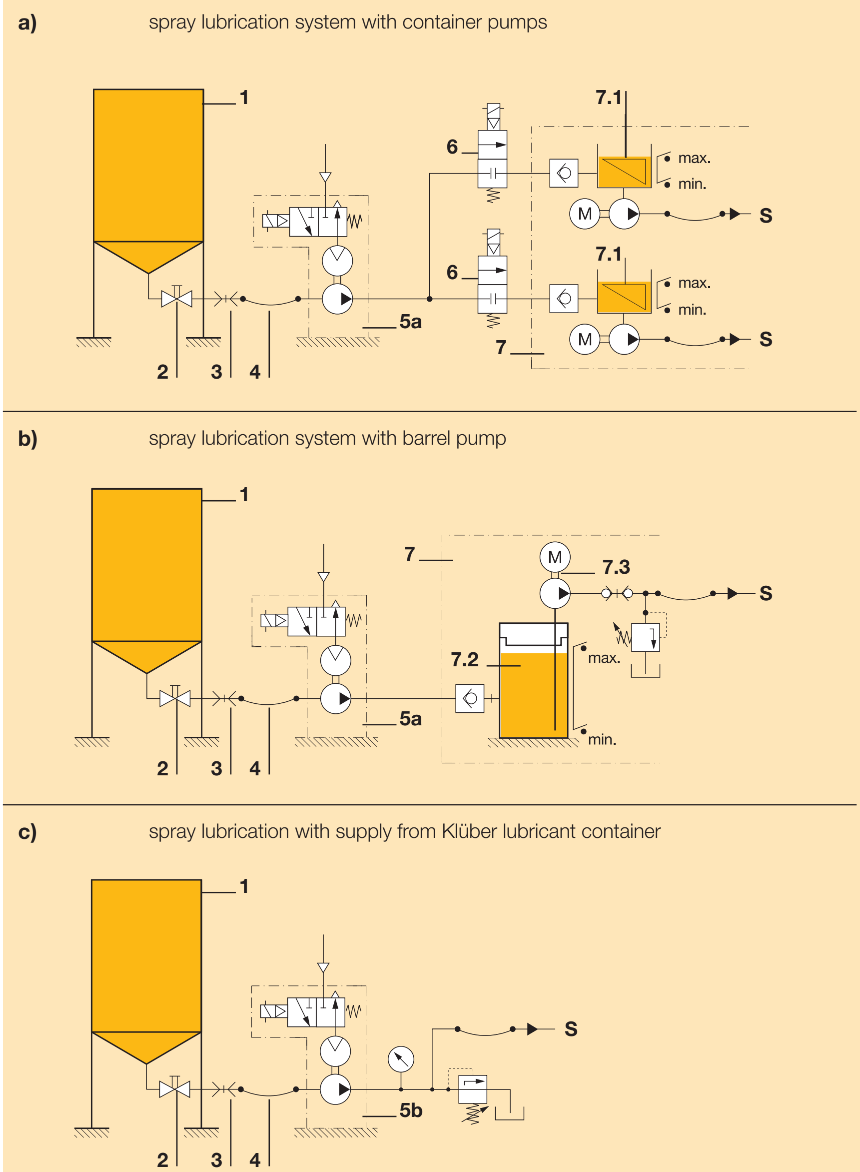
1 Reservoir pump
2 Compressed air line
3 Lubricant line
4 Nozzle plate

Fig. 32: Spray lubrication system with container pump, LINCOLN system



1 Barrel pump
2 Lubricant line
3 Power cable
4 Compressed air line
5 Nozzle plate

Fig. 33: Spray lubrication system with barrel pump, WOERNER system



Legend of Fig. a–c

1	Klüber lubricant container
2	Shut-off valve
3	Quick-action coupling
4	Hose
5	Transfer pump (a) or feeding pump (b)
6	Shut-off valve
7	Spray lubrication system
7.1	Container pump
7.2	Lubricant drum
7.3	Barrel pump
S	to spray system

Fig. 34: Lubricant supply with the Klüber lubricant container system

Spray lubrication systems with container pumps *(Fig. 32)*

The container pumps *(7.1)* are supplied with lubricant directly from the container *(1)* by means of a transfer pump *(5a)*. The pump is switched on and off via the level control unit in the lubricant containers. Even if several container pumps are connected to one container, overfilling of the pump containers is prevented by the shut-off valves, which are also controlled via the level control unit.

Fig. 35: Lubricant container system from Klüber Lubrication

Spray lubrication system with barrel pump *(Fig. 33)*

The setup for lubricant supply from the barrel is retained. In addition, the barrel *(7.2)* is connected to the transfer pump *(5a)*. The fill level of the barrel should be monitored to switch the transfer pump on and off.

Direct feed *(Fig. 34)*

There is neither a drum nor a barrel pump. Instead, the spray system *(S)* is directly connected to the feed pump *(5b)*, which pumps the lubricant from the Klüber lubricant container *(1)* and supplies it to the spray system at the correct pressure.

Fig. 36: Original lubricant drums from Klüber Lubrication with flexible internal liners and mounted barrel pumps

5.

Klüber A – B – C System Lubrication

Priming lubricant type A – Running-in lubricant type B – Operational lubricant type C

Functional reliability and damage-free operation of large gear drives depend to a great deal on correct lubrication suiting the drive.

Due to their type of construction, gear drives – especially those of large production machines like tube mills and rotary kilns – are exposed to highly varied loads and different operating conditions during their service life, from their assembly to permanent operation under full load.

To ensure optimum lubrication at all operational stages and to protect the drives from damage right from the start, i.e. when the gears are rotated during assembly, Klüber has developed a systematic lubrication method for large gear drives which has been known worldwide for many years and is used successfully under the name of

A – B – C – system lubrication
The letters A – B – C denominate the individual steps of the system and refer to the following:

A = priming and pre-start lubrication
B = running-in lubrication
C = operational lubrication

Lubricants have been developed for every step which are not only suitable for the respective operating phase but which also take into account the type of lubrication and the method of application used.

In addition to the A – B – C system lubricants, another lubricant, 'type D', was developed for repair lubrication. It is used to restore damaged surfaces of tooth flanks such that the drive can continue to operate under acceptable conditions. This type of lubricant can also be used if the operating conditions call for a forced running-in of gear drives.

Repair lubrication and forced running-in are described in detail in this brochure.

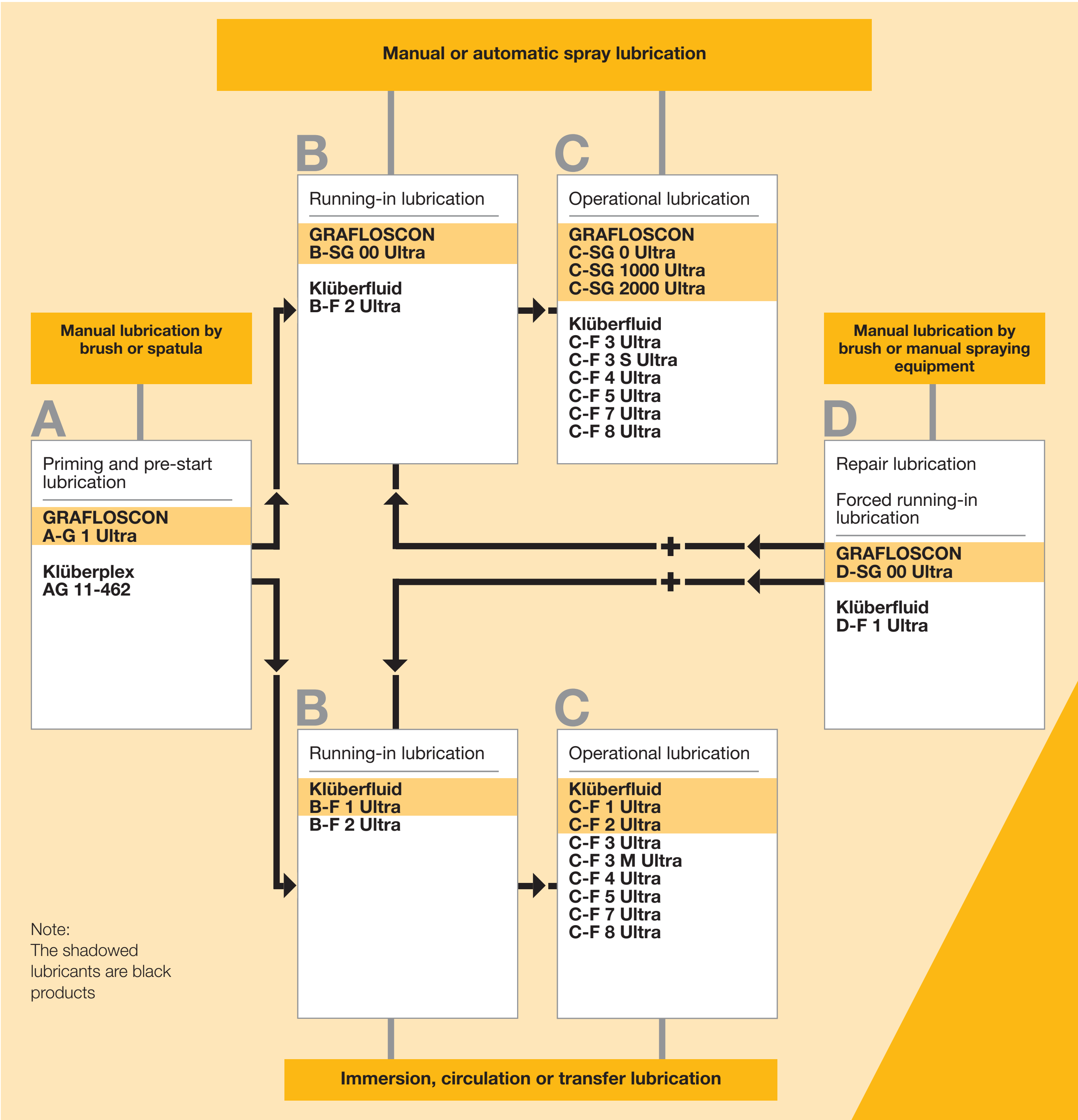


Fig. 37: Klüber's A – B – C system lubrication and D repair lubrication

5.1. Priming lubricants type A

Priming lubricants type A are products containing a high percentage of additives and are applied prior to the initial operation of gear drives. They may be used in all spur or helical girth gear drives, irrespective of the lubrication method used. Their main tasks are the following:

- They protect the teeth against corrosion until the drive is operated for the first time.
- During and after assembly of the drive, they keep the gears lubricated and prevent metallic contact between the tooth flanks, e.g. when the machine has to be rotated during the assembly procedure. This helps to avoid initial damage due to dry running, which might give rise to flank damage during operation later.
- They serve as a contrast substance for a first impression of the dynamic load-carrying pattern. The high content of solid particles of GRAFLOSCON A-G1 Ultra results in various shades of grey on the load-carrying tooth flanks, which make the points of contact and hence the contact ratio visible. While the light-colored priming lubricant Klüberplex AG 11-462 has largely the same properties, it is less suitable for use as a contrast substance to determine the dynamic load-carrying pattern.
- In drives with automatic spray lubrication they prevent initial scoring caused by deficient lubrication when the machine is started at its nominal speed. During the first hours of operation priming lubricants help to prevent critical conditions because the spraying units – even when set to continuous operation – only apply a rather small amount of lubricant to the tooth flanks and it takes

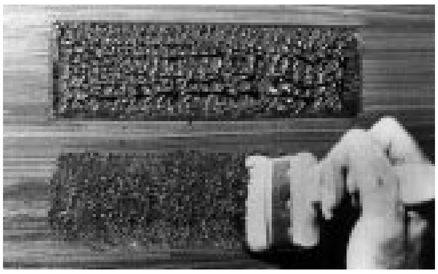
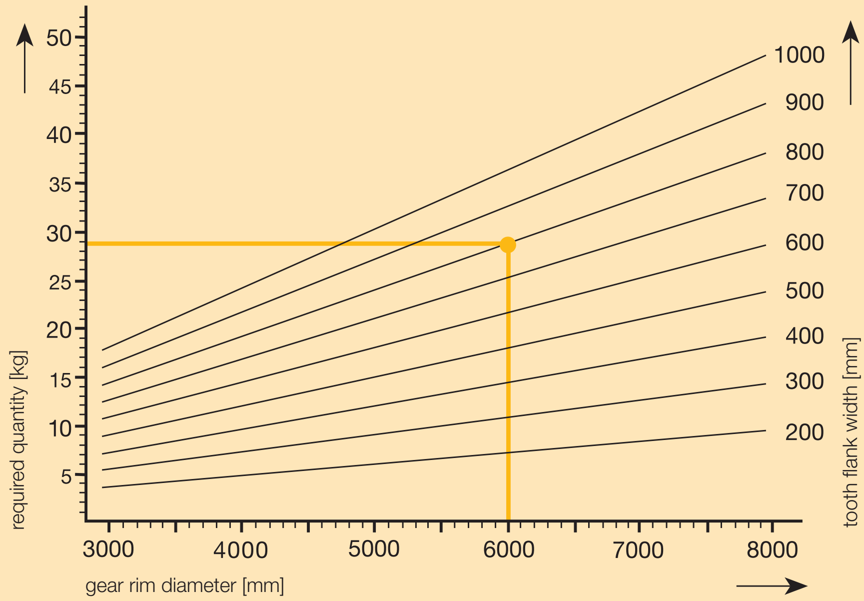


Fig. 38: Priming by brush

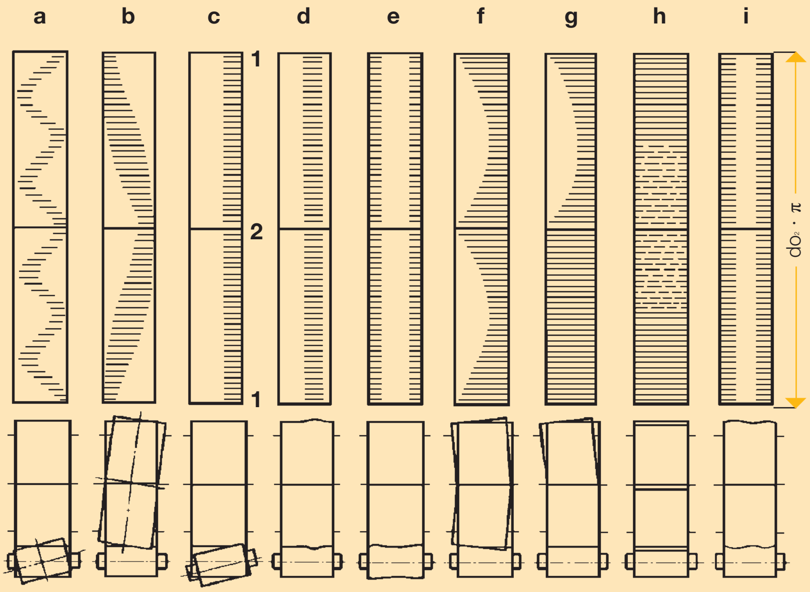


Example:

Reference circle diameter:	6000 mm
Tooth flank width:	800 mm
Determined quantity:	approx. 28.5 kg
Quantity to be purchased:	30 kg
consisting of one bucket of	25 kg*
and one bucket of	5 kg*

** Available pack sizes of GRAFLOSCON A-G 1 ULTRA and Klüberplex AG 11-462*

Fig. 39: Diagram to determine the required quantity of type A priming lubricant



a) Load-carrying pattern on the gear rim with a wobbling pinion. Check pinion seat.
b) Load-carrying pattern with a wobbling gear rim. Check seat and alignment of gear rim.
c) Load-carrying pattern with edge contact. Axes not parallel, realign pinion.
d) Pressure spot caused by production defect or thermal deformation of a certain area .
e) Load-carrying pattern with a pinion bent upwards on both sides, caused by inexpertly mounted tensioning elements.
f) Load-carrying pattern with slanted gear rim halves. Check screwed connections at interface and gear rim fixtures.
g) Load-carrying pattern with one slanted gear rim half. Check assembly.
h) Radial deviation of the gear rim. The load carrying pattern appears weaker over one half of the gear rim and more intense over the other. Realign.
i) Load-carrying pattern with raised surface defect of the gear rim on both sides due to excessive frictional heat coming from cover seals. Improve lubrication of the seals.

Fig. 40: Contact ratio/load-carrying pattern made visible by means of priming lubricant

some time until a uniform load-carrying lubricant film has formed.

Priming lubricants are always applied by means of brush or spatula. The pinion and gear rim should be thoroughly cleaned and be free of grease or rust. The priming lubricant layer on the load-carrying tooth flanks should have a thickness of approx. 1.5 mm, while all other surfaces should only carry a thin film for corrosion protection. Priming lubricants of type A must not be applied as a operating lubricants via immersion baths, circulation or installed spray systems.

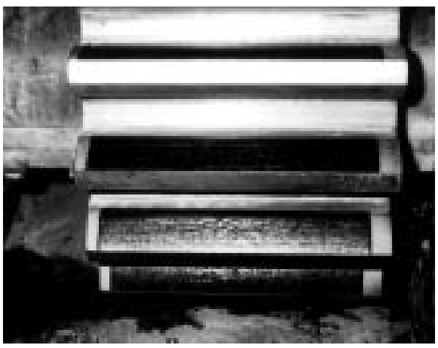


Fig. 41: Contact ratio/load-carrying pattern made visible by means of priming lubricant

5.1.1. Inspection of load-carrying pattern

As has been said above, a rough impression of the load-carrying pattern can be gained with the priming lubricant. The load-carrying pattern is visually inspected while the drive is running on an auxiliary motor or during standstill after it has been rotated completely once or several times. If the pattern is poor, the drive components can be realigned or otherwise corrected; the instructions of the drive or machine manufacturer should be observed for such activities. Fig. 40 gives an overview of possible causes for deviating load-carrying patterns.

5.2. Running-in lubricants type B

Running-in lubricants of type B are specifically used for the running-in of new or turned gear drives. They ensure that rough surfaces are smoothed quickly and that the contact ratio of the tooth flanks is improved. Due to their special additives they cause a controlled minimum of chemical/corrosive wear at the tooth flanks.

Running-in and correction lubrications is possible on all spur and helical gear drives and by means of all lubrication methods, i.e. manual as well as spray, immersion or circulation lubrication.

Fig. 42: Load-carrying pattern after ten operating hours with a running-in lubricant

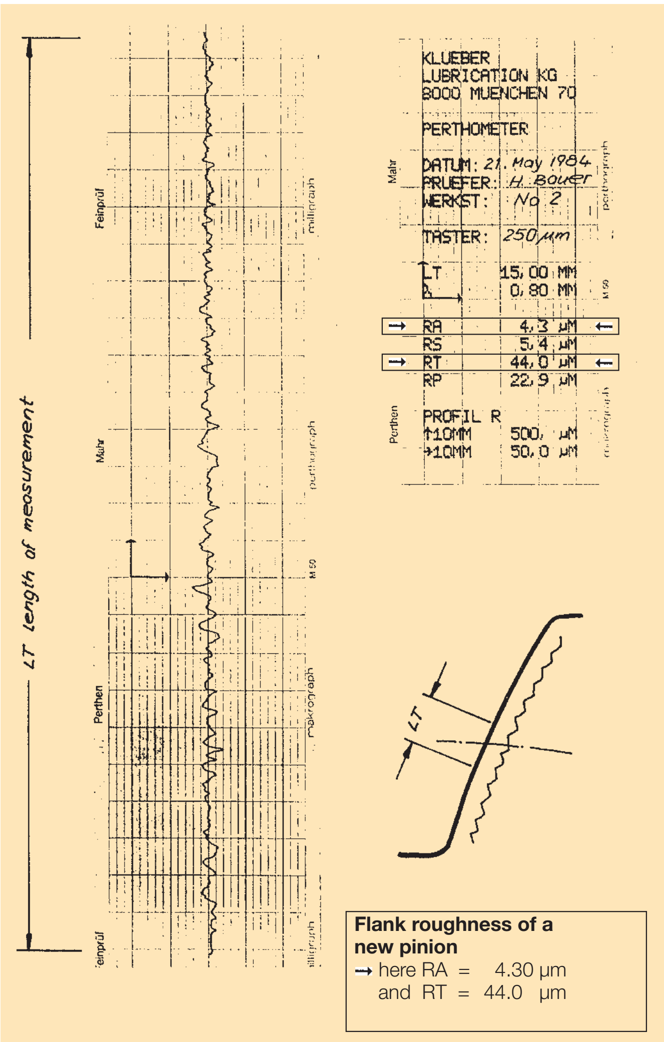


Fig. 43a: Surface roughness of a new pinion's tooth flank

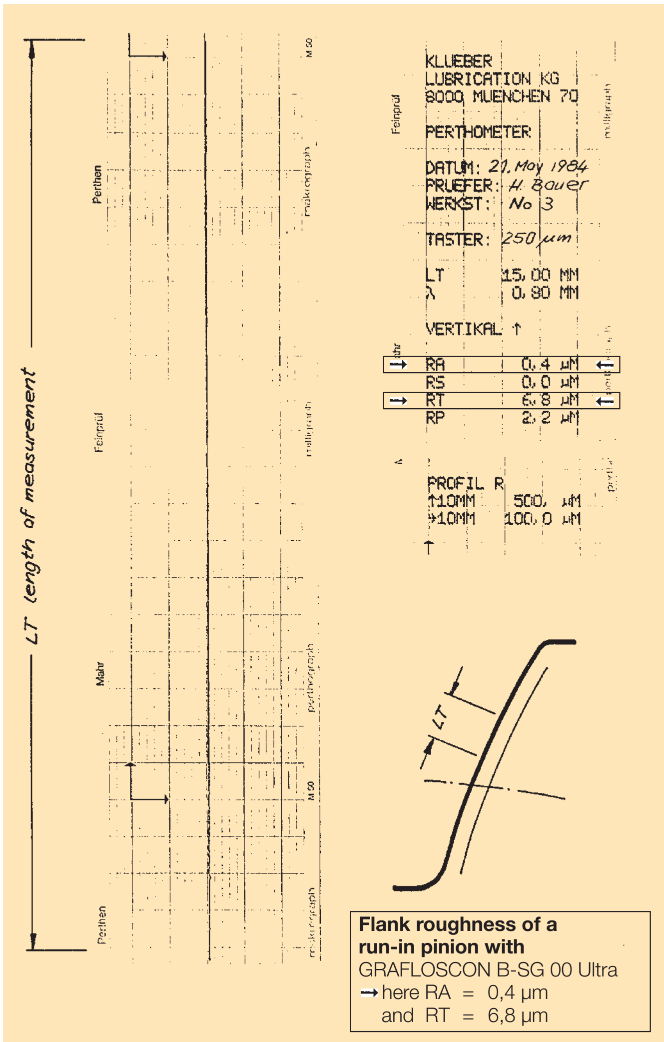


Fig. 43b: Surface roughness of a pinion's tooth flank after running-in with GRAFLOSCON B-SG 00 Ultra

During the running-in process, the intentionally caused wear is controlled through the amount of lubricant used and the time it is allowed to act on the component. The wear smoothens the tooth flanks, which creates optimum conditions for the prevention of pitting or other damage. As the high pressures occurring during initial operation bear the risk of scoring damage, the running-in lubricants contain highly effective EP additives to counteract this effect. These lubricants of type B are also used as correction lubricants that can improve the surface quality and hence increase the contact ratio in drives showing a deterioration in their load-carrying pattern.

How running-in lubrication works

Based on the technical knowledge we have today about large girth gear drives it can be claimed that a gear's rolling strength and scuffing load capacity are substantially improved if flank roughness is reduced and the effective contact ratio increased. The initial contact ratio of a gear – even when the pinion(s) and the driven gearwheel are properly aligned – is often no higher than 50–60%. This means that when new gear drives are put into operation there is always a danger that the partial overloading of the tooth flanks may cause damage *(initial pittings, local scuffings)* that might aggravate severely during subsequent operation. To avoid this initial damage new gear drives should be run in with a type B running-in lubricant prior to operation under full load. Running-in means that some limited wear is intentionally generated at the tooth flanks while at the same time they are protected against scuffing wear to avoid the aforementioned initial damage. In this way, surface roughness is reduced within a short period of time and waviness or inaccuracies of shape are compensated for as far as possible to achieve a high contact ratio and a good load distribution.

Fig. 43a and 43b illustrate what a Klüber type B running-in lubricant can achieve in terms of reducing surface roughness. These curves are based on positive impressions of a new pinion

Fig. 44a

Fig. 45a

Fig. 44a: magnification 20-fold

Photograph of the surface of a new pinion flank taken with a scanning electron microscope
Module 25 mm, Rt = 44 µm
RA = 4.3 µm

Fig. 44b: magnification 50-fold

Fig. 45a: magnification 20-fold (negative)

Photograph of the surface of a pinion flank after running in taken with scanning electron microscope
Module 25 mm, Rt = 6.8 µm
RA = 0.4 µm

Fig. 45b: magnification 160-fold

Fig. 44b

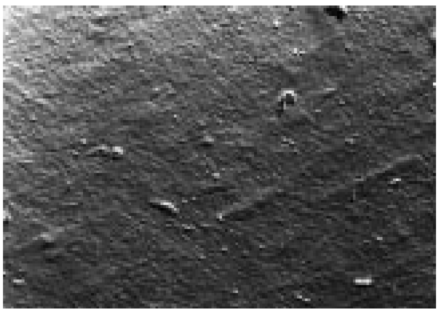


Fig. 45b

flank (m = 25 mm) and of one that had just been run in for 250 operating hours. The possible improvements are also shown on the photos of a new and a run-in pinion flank *(Fig. 44a and b and 45a and b)* made with a scanning electron microscope. The running-in lubrication described enables surface corrections by approx. Ra 10 µm.

5.2.1. Running-in with automatic spray lubrication

Prior to starting the running-in process, the automatic spraying equipment should be set to quasi-permanent operation with short pauses and the throughput volume shown in the diagram. The spray pattern should be checked and, if necessary, corrected. Spraying should commence before the drive starts running. The lubricant quantities can be determined by means of the tables and diagrams in this brochure. If possible, start the running-in at low machine load and raise it step by step; this is easy with ball mills. For drives that need to be run at full load from the start, “forced running-in lubrication” is a viable option.

The total amount of lubricant needed for the running-in depends on the type of machine and the size of the drive, normally between 180 and 360 kg *(one to two drums)*. Should this turn out not to be enough and the running-in lubricant be used up before the procedure is completed, drive operation may continue with the same throughput volume of operating lubricant of type C until more running-in lubricant has been supplied. The running-in lubricant and the operating lubricant are compatible, so conversion from one to the other does not require any cleaning of the spraying equipment.

The running-in procedure should never be discontinued prematurely because no more running-in lubricant is available. Especially when working with large drives, two drums of running-in lubricant should be provided. Any surplus may be used for correction lubrication that may become necessary at a later date. Running-in is completed when the tooth flanks are smooth and the contact ratio is sufficient. When this is the case will be determined by the plant staff and possibly a service technician of Klüber Lubrication.

5.2.2. Running-in lubrication with immersion

Fill lubricant of type B into the bath until the teeth of paddle elements are fully immersed. Upon starting the drive, observe the lubricant level, which may decrease considerably due to the amount of lubricant carried away by the teeth. To avoid insufficient lubrication, the bath should be refilled to attain a level where the teeth are half or the paddle elements fully immersed. Should not be enough type B running-in lubricant be available to make up for lubricant losses during the running-in procedure, use a type C operating fluid of the same lubricant group for refilling.

The purpose of the running-in process should normally be attained after approx. six months, i.e. the tooth flanks should be smooth and the load-carrying area sufficient. Whether this is the case is determined by the customer and a Klüber service engineer together. The running-in lubricant should then be drained immediately, the gear rim cover cleaned and the operating lubricant filled in. The running-in of kiln drives with immersion lubrication has some specific requirements: normally, kilns are not stopped for an exchange of lubricant, so the lubricant may stay in the immersion bath for several months and may tend to thicken due to foreign particles, abrasion and ground solid lubricant. To prevent such thickening, the lubricant should be drained from the reservoir as far as possible while the drive continues to operate, and be replaced by fresh running-in lubricant. This ensures the lubricant remains fluid until the running-in procedure is completed. During the short interval between draining and refilling, the drive should be lubricated manually, preferably with manual spraying equipment Klübermatic LB. The running-in lubricant should be fully replaced by the operating lubricant after 7,000 operating hours maximum.

5.2.3. Running-in lubrication with Klübermatic PA

If necessary, clean the lubricant reservoir and fill it with running-in lubricant of type B.

Prior to starting the drive, the lubrication system should be switched on and the lubricant distribution pipes be checked to see if a continuous flow of lubricant ensures sufficient lubricant supply to the load-bearing tooth flanks of the pinion. The lubricant reservoir must contain a constantly sufficient supply of lubricant.

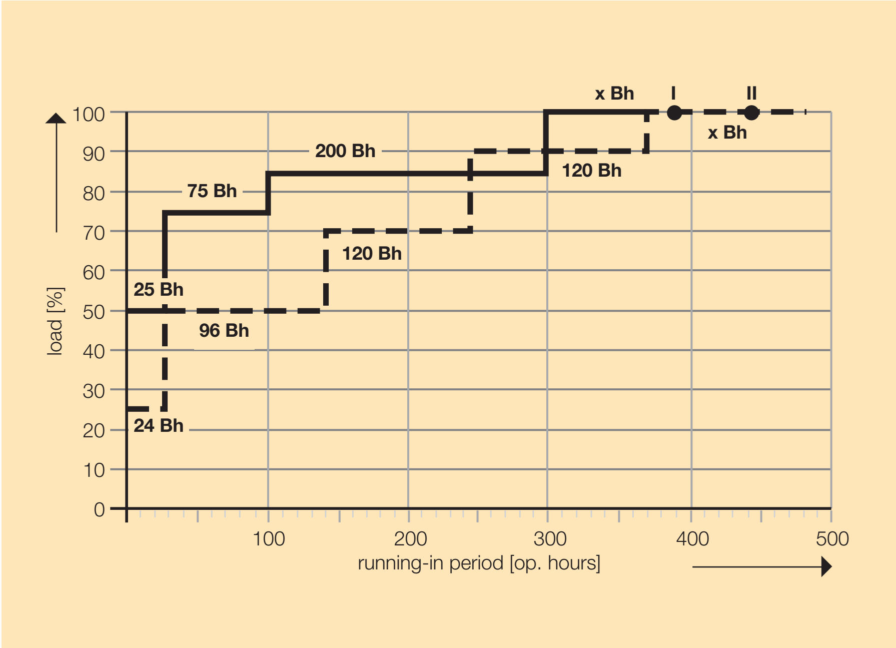


Fig. 46: Running-in schedule for stepwise increase of load in a ball mill

Whenever the drive is stopped, e.g. to add grinding media for the next higher load stage, the lubrication system should always be switched on and its function checked before the drive is started again. Upon completion of the running-in procedure, the running-in lubricant is completely replaced by the operating lubricant. This is the case after 7,000 operating hours maximum.

5.2.4. Running-in with stepwise increase of load

New or turned gear drives should not be operated under full load from the start because the contact ratio often is initially too low. Instead, they should be run in according to a predetermined load/time schedule, with the transition to the next load stage only being carried out when a specific contact ratio has been reached. In mills the load can be increased by filling in the grinding elements. Fig. 46

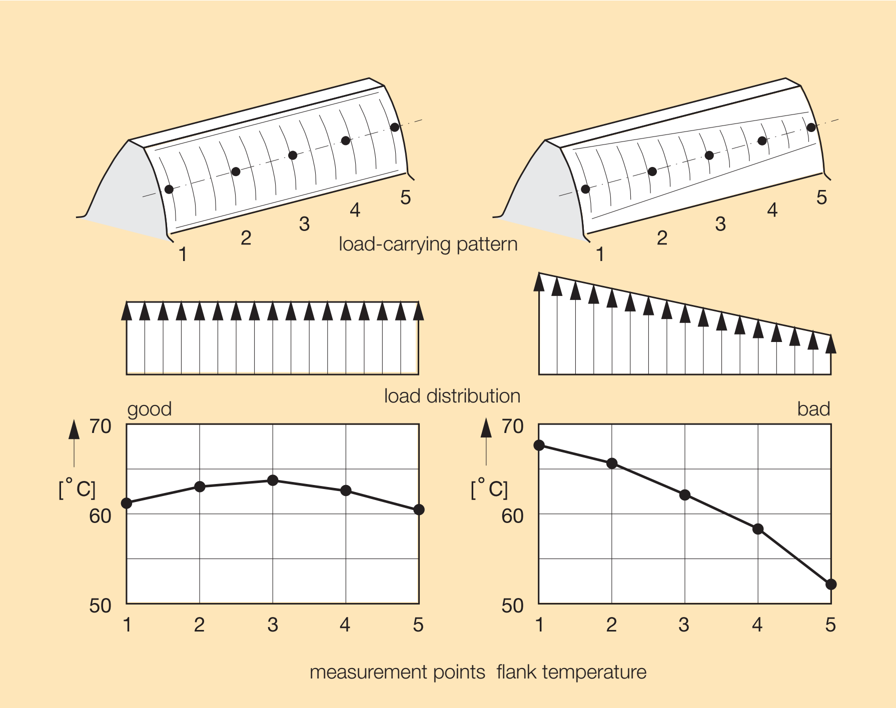


Fig. 47: Checking of the load-carrying pattern by means of infrared measurement

shows examples of stepwise load increase in a ball mill. The actual load steps, however, can only be determined on the basis of the operating instructions of the drive and machine manufacturers. Process-related facts often need to be taken into account as well since the machines have to fulfill their specific task within a network of installations. Every plant manufacturer has therefore set up his own instructions on load stages, which must be observed with priority. The running-in process is completed when at 90 to 100% load the tooth flanks have become as smooth as possible and the contact ratio attained is sufficient for continuous operation under full load. Drives whose tooth flanks already have a good surface quality, a high contact ratio and a good load distribution in the beginning can be run in without stepwise increasing of the load.

The drive should be inspected daily to detect any initial tooth flank damage and prevent deterioration. The contact pattern should be checked under dynamic conditions by means of a stroboscope to be able to carry out corrections if necessary.

Measuring the pinion flank temperature during operation under load with an infrared thermometer has proven effective for recognizing an uneven load distribution on the flanks. A temperature difference of more than 5 °C – measured over the entire flank width from face to face – indicates an uneven load distribution, which might require realignment of the gears or some other correction.

6.
Forced running-in *(accelerated running-in)*

Accelerated running-in is carried out if the machines can only be run in under full load or if no running-in lubricant can be used.

This is the case e.g. with rotary kilns or coal mills in power plants, where the machines are directly coupled to the heating system. To avoid initial damage, the running-in process must be accelerated to achieve maximum flank smoothness and contact ratio within a short period of time.

To this end the conventional type B running-in lubricant is reinforced by an active compound *(lubricant type D)*, which is manually applied to the pinion's and/or the gear rim's load-carrying tooth flanks. This active compound, which is usually used for 'repair lubrication', has a stronger abrasive effect than the type B lubricant, which means that the flanks are smoothed and the contact ratio is increased within a shorter period of time.

The active compound is applied with Klübermatic LB manual spraying equipment *(Fig. 48)*; it must not be applied by means of automatic spraying equipment.

The active compound is sprayed onto the tooth flanks at certain intervals depending on the condition of the flanks.

During forced running-in the condition of the tooth flanks should be checked regularly by means of a stroboscope to be able to react immediately if any flank damage occurs.

In addition, the load distribution on the tooth flanks should be checked at regular intervals by measuring the temperature with an infrared thermometer.

The duration of running-in must be made dependent on the degree of smoothness and the contact ratio of the load-carrying tooth flanks achieved and cannot be determined prior to the treatment. It is up to the responsible engineer to decide when the forced running-in process is completed.

The next decision to be taken is if an immediate conversion to the type C operational lubricant is possible or if the drive should be operated for a certain time with the type B running-in lubricant to optimize the flank surfaces.

Modern pinion and gear rim materials, the better surface quality of the tooth flanks attained in improved production processes, and the high contact ratio in drives with tiltable pinions are making stepwise or forced running-in superfluous in more and more cases.

NOTE:
Forced running-in is a complex matter requiring special knowledge. To avoid damage it is therefore strongly advised to have an experienced Klüber engineer carry out this type of running-in process. This is particularly important when the machines cannot be stopped during running-in for inspection. For warranty reasons it is also important to obtain the approval for forced running-in from the machine or the drive manufacturer. Pinions with hardened surfaces must be treated with particular caution. *(Nitrided surfaces, for example, have very thin hardened layers.)*

6.1.
Forced running-in of drives with automatic spray lubrication

In such drives, a type B running-in lubricant is continuously sprayed onto the tooth flanks, observing the normal instructions for running-in in terms of quantity etc. In addition, the active compound *(lubricant type D)* is applied manually by Klübermatic LB.

Fig. 48: Klübermatic LB

6.2.
Forced running-in of drives with immersion lubrication

The running-in lubricant of type B is filled into the bath to support lubrication. In addition, the active compound *(lubricant type D)* is sprayed onto the tooth flanks manually by Klübermatic LB. To prevent the active compound from being washed off by the running-in fluid, the bath should only be filled to a level where one third of the tooth height is immersed at maximum.

6.3.
Forced running-in of drives lubricated by Klübermatic PA

The circulation lubrication system remains inactive during the forced running-in process. To prevent the active compound from entering the Klübermatic PA lubrication circuit, which would cause wear during operation later, the lubricated components and the reservoir must be disconnected from the lubrication lines. Upon completion of the running-in process, the gear rim cover and the lubricant reservoir must be cleaned to remove all residues of the active compound.

The lubricant is applied to the tooth flanks as described under 6.2. To lubricate the drive and protect it against wear, a Klüberfluid type B running-in lubricant or, if this is not available, an operating lubricant of type C must be regularly applied by means of a second manual spraying device, in addition to the active compound.

7.
Operational lubricants type C

Type C lubricants are modern adhesive lubricants tailored to suit the operational conditions of girth gear drives. They meet all extreme pressure requirements of gear drives, e.g. of ball mills or rotary kilns.

In addition, the adhesive spray lubricants also fulfill the special requirements of modern spraying equipment. Type C operational lubricants are characterized by the following properties:

- ❑ excellent adhesion
- ❑ good load-carrying capacity
- ❑ maximum wear protection
- ❑ protection against scoring
- ❑ good corrosion protection

All these lubricants were designed to offer the prerequisites for thin-film lubrication (e.g. base oil viscosity). Consistency, EP additives and solid lubricant content were selected to ensure that the tooth flanks receive maximum protection even under difficult operating conditions.

A main advantage as compared to conventional lubricants is the fact that Klüber's operational lubricants are free from bitumen and heavy metals as well as raw materials containing solvents or chlorine. They are thus easy to handle, gears and pinions are easier to clean and the disposal of the used and old lubricant is less problematic. This is of importance primarily in applications with total loss lubrication (e.g. spray lubrication).

An essential advantage of Klüber adhesive spray lubricants is the fact that only a small quantity of lubricant is required to lubricate a gear drive reliably, and consequently the amount of used lubricant is also quite low. Small quantities always ensure high cost-efficiency, low environmental impact and low disposal costs, resulting in a considerable cost reduction for the operator.

Type C operational lubricants are compatible with type B running-in lubricants of the same product line. This is of advantage since lubricant losses during the running-in stage in an immersion-lubricated drive can be topped up with the operational lubricant as the running-in lubricant is being used up. Spray lubrication systems can proceed directly from running-in lubrication to operational lubrication, which is important in machines which are difficult to stop. Another advantage over bituminous lubricants is that the tooth flanks can be inspected any time without difficulty. This can be done while the machine is in operation with a stroboscope or when the machine is shut down without having to clean the tooth flanks. Transparent lubricants are even better in this respect than the black ones.

7.1.
Operational lubrication of spray-lubricated drives

The transition to operational lubrication is generally made when the running-in process has been completed, i.e. when the tooth flank surface has reached its maximum smoothness and when a contact ratio of at least 80% has been attained. After the transition, the lubricant volume of the running-in stage should be retained for another 50 operating hours. After that, the quantity should not be reduced abruptly but in steps of 0.5 to 1.0 g/cm every 150 to 200 operating hours.

As the lubricant is being reduced, the spray system should be adjusted such that the pauses between two spray cycles are a short as possible. Brief and more frequent spraying is better for an even distribution of the lubricant on the drive, which enhances operational reliability.

The pause cycles should not exceed 5 minutes in mills and 10 minutes in kilns. However, the exact cycle times depend on the lubricant used, the condition of the drive, the operating conditions, the spray systems and other influences and must therefore be decided individually at the site. Both shorter and longer pause times are possible, provided sufficient lubricant is supplied to the components. The specific consumption quantities can be obtained from the tables in this brochure, taking into account the type of drive, tooth flank width and the lubricant quantities required per time unit. The specific consumption volumes listed are based on the following assumptions:

- ❑ No tooth flank damage
- ❑ Sufficient contact ratio (> 80%)
- ❑ Careful and regular inspection and maintenance of the drive and the spray lubrication system
- ❑ Normal operating conditions
- ❑ Good spray pattern
- ❑ Use of operational lubricants made by Klüber
- ❑ The lubricant temperature must be set to allow unimpeded pumping and spraying. This depends on the type of lubrication system used.

7.2. Operational lubrication of immersion and circulation-lubricated drives

Also during operational lubrication, the lubricant level in the immersion bath will decrease considerably and hence require refilling. While the machine is running, the level should be such that teeth are immersed to between one third to half of their length. Paddle elements should be fully immersed in the lubricant.

Lubricant change intervals depend on the individual application conditions. A decisive factor is the sealing of the drive cover against ambient influences. However, 14,000 operating hours should not be exceeded.

Parameters determining whether an operational lubricant is still fit for use include:

- ❑ Contamination by dust, sand particles and the like
- ❑ Abrasive metal particles
- ❑ Percentage of water in the lubricant
- ❑ Viscosity
- ❑ Ageing

If operating conditions are particularly difficult, the lubricant should be analyzed at least once every 4,000 operating hours.

Inspection:
To ensure problem-free operation, the lubricant level should be monitored and the tooth flank condition checked at regular intervals. Circulation lubrication systems of large drives are to be inspected and maintained according to the instructions by the system manufacturer. Safety equipment should also be regularly checked.
It is particularly important to remove residues from the lubricant filters at the prescribed intervals.

8.
Repair and correction lubricants of type D

Repair lubrication
Not too long ago tooth flank damage was repaired exclusively by highly abrasive mechanical methods – often quite ineffectively. The tooth flank quality obtained often did not come up to expectations in terms of functional reliability and service life of the drive. The costs were very high and the repair periods quite long.

Today tooth damage is frequently repaired by means of repair lubricants. With these lubricants it is possible to repair even heavily damaged tooth flanks to such an extent that the drives can operate under acceptable conditions. In addition, repair lubrication can avoid an extension of the initial damage and prevent new damage. *(See Fig. 49 to 52)*

Repair lubrication also helps to prevent propagation of existing and the formation of new damage.

Depending on the type and degree of the tooth flank damage it may be necessary to treat the flanks mechanically *(grinding, milling)* prior to repair lubrication. The effect of the repair lubricants developed by Klüber is based on highly active and effective compounds.

These compounds have a grease-like nature and are adapted chemically and physically to subject metallic surfaces to mechanical, chemical and corrosive wear. Thus a small amount of lubricant is required to remove just the right amount of tooth flank material within a short period of time.

The material is worn off evenly at the contact points. Surface wear and hence damage repair can be controlled with the amount and application duration of the active compound. The material removal is limited by the thickness of the hardened tooth flank surface layer.

A decisive advantage of repair lubrication over mechanical repair methods is that the machine remains fully operable and that a high load even increases the success of the repair lubrication. The short machine downtimes which are required for control and documentation work are of minor significance as compared to a production standstill of several days.

Successful repair lubrication is achieved faster in mill drives than in kiln drives due to the faster rotation and the consequent higher sliding speed on the tooth flanks as well as the more frequent tooth contact at shorter intervals.

This is the reason why larger quantities of repair lubricant must be applied in kiln drives, of course depending on the damage to be repaired.

Scuffings, scratches and scorings are easy to repair. Plastic deformation can be repaired up to a certain extent.

Where pittings are encountered, progress of the damage and the formation of new pitting is prevented by eroding material at the overloaded flank parts, which leads to a more even load distribution over the tooth flanks and hence a reduction of specific tooth flank peak loads.

Before starting any repair lubrication it is of utmost importance to address the primary cause of the existing damage in order to avoid repetition.

To document the condition of the tooth flanks before and after repair lubrication as well as the contact ratio, it is recommended to take photographs and make silicone impressions of some representative tooth flanks. They can be used for comparison at a later date and show the actual conditions of the flanks and how they have changed.

The repair lubricant is applied to the load-carrying tooth flanks of the pinion and the gear rim by means of the Klübermatic LB, as described under 6.

While repair is in progress, more of the active compound is sprayed on manually, depending on the tooth flank condition, until repair is regarded as completed.

Repair lubrication should always be backed by a running-in lubricant of type B. It provides additional lubrication and serves for ‘finishing’ the flanks.

If no running-in lubricant is available, operating lubricant of type C may be used as a substitute.

CAUTION:
Repair lubricants of type D must not be used in immersion baths, circulation lubrication systems or automatic spray lubrication equipment.

NOTE
Since repair lubrication is a complex task that may provoke damage if performed inexpertly, it should only be carried out by qualified and experienced service staff.

Specialists from Klüber Lubrication will be pleased to assist you with

- ❑ damage evaluation
- ❑ investigation of damage causes
- ❑ tooth flank documentation
- ❑ repair lubrication, if necessary involving mechanical pretreatment of the tooth flanks

Repair lubrication is not suitable to correct the following:

- ❑ burrs at the tip and the side of the teeth
- ❑ raised areas in the pitch circle
- ❑ wear marks at the tooth root
- ❑ sharp edges and deep pittings

Such damage requires mechanical treatment by means of a manual grinder or an end-milling cutter.

It is **not** possible to repair progressive pittings in underdimensioned drives.

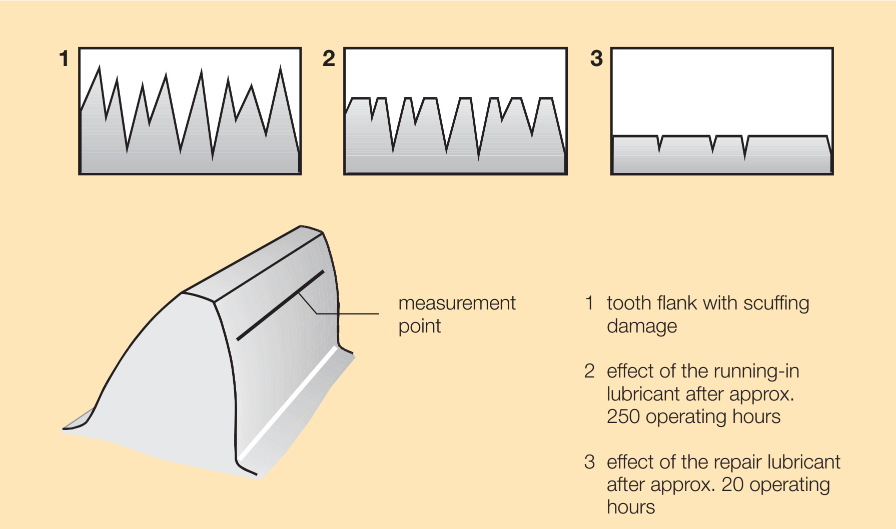


Fig. 49: Smoothing of flanks during damage repair

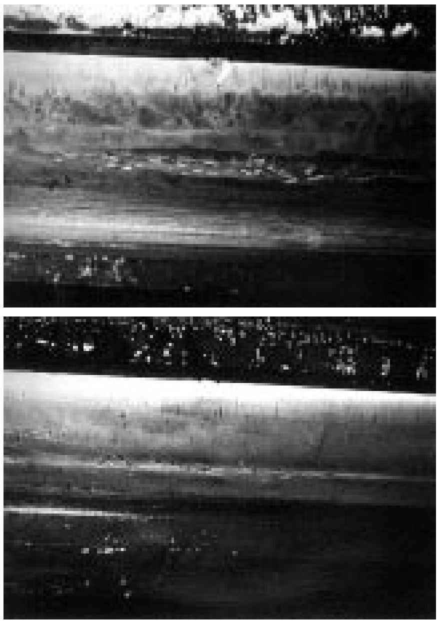


Fig. 52: Damage repair by repair lubrication. The lower photograph clearly shows the effect of the repair lubricant.

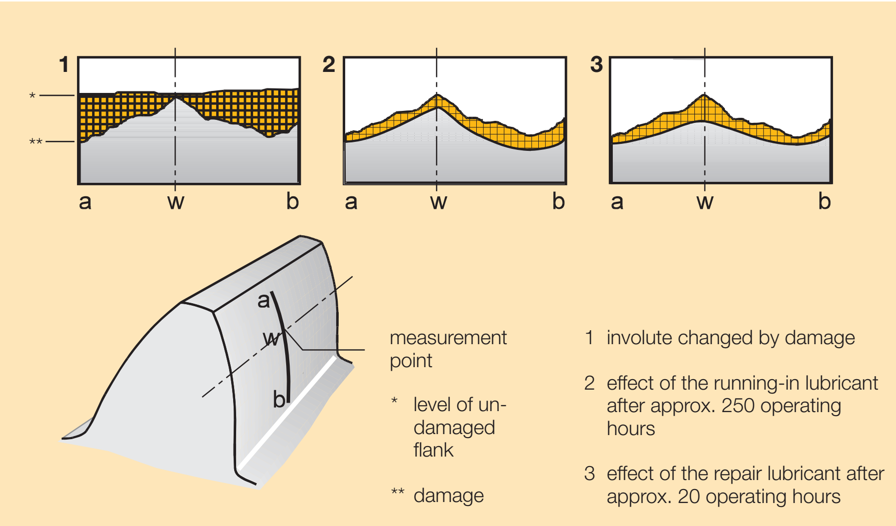


Fig. 50: Change of the involute shape during damage repair

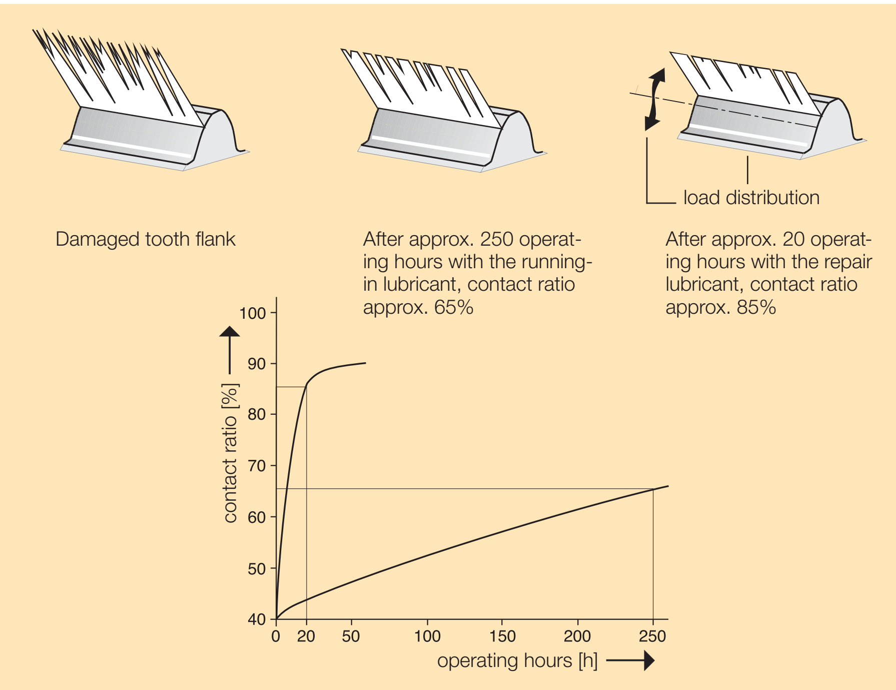


Fig. 51: Effect of damage repair on the load distribution across the face width

9.

Lubrication and maintenance of girth gear drives

The maintenance of gear drives depends on the lubricant application method and may vary considerably. In manually lubricated drives, maintenance usually is restricted to observing the lubricating condition and removing the old lubricant at regular intervals, which contains impurities and is therefore liable to damage the gear rim and pinion.

In immersion-lubricated drives, the lubricant must be exchanged regularly depending on the degree of contamination and ageing. This also applies to drives lubricated by means of a circulation lubrication system. The lubricant level has to be checked regularly.

When a gear drive is lubricated automatically by means of circulation lubrication systems, e.g. the Klübermatic PA system, or spray lubrication systems, the focus of maintenance is on the lubricating equipment. Maintenance should be carried out in accordance with the manufacturer's instructions. The following maintenance checklist is intended to improve inspection and maintenance works in order to avoid malfunctions.

Maintenance items referring to both systems (circulation lubrication and spray lubrication) are marked with a *. All other items only refer to spray lubrication systems.

Checklist for inspection and repair

1 Check functional reliability of control equipment and fault alert systems regularly.*

2 Check lubricating condition.*

3 Check and clean lubricant filter regularly.*

4 Remove dust and dirt from lubrication systems regularly.*

5 Check spray pattern at least once a month; if required, adjust nozzle alignment.

6 Remove lubricant sedimentations from spray nozzle plate and spray head every two weeks.

7 Drain lubricant sump regularly *(depending on sump size)*.

8 Fill lubricant containers cautiously. Avoid contamination during manual filling.*

9 Check feed and transfer pumps for wear of mechanical drive components *(in accordance with manufacturer's instructions)* and determine the actual pumping capacity as compared to the nominal value once a year.*

10 Check spray nozzles and distributor for leakages and functional reliability as required, but at least once a year, and replace components if necessary. The equipment should only be dismantled for cleaning and repair purposes by qualified personnel.

11 Remove old lubricant from the pinion area at least twice a year depending on the cover design.*

12 If a separate compressor is used, check it regularly in accordance with the manufacturer's instructions.

13 Maintain compressed air filters and water separators regularly depending on the amount of water.

14 Check cover seal once a year and replace it if required.*

These procedures are preventive measures to ensure operational reliability.

The inspection and results, the type of work carried out, the machine number and the date should be documented in a log book. This data can be used as a basis for corrective action if certain faults recur.

10. Services offered by Klüber

10.1. Inspection

To prevent drive damage and avoid malfunctions it is recommended to inspect gear drives at regular intervals and to document the actual condition of the load-carrying tooth flanks. By comparing and analyzing the documents a general overview of the wear condition of the tooth flanks is obtained and appropriate measures can be initiated if any damage was found.

10.2. Technical documentation

Inspections of gear drives include the following activities and are concluded with a comprehensive technical report:

- Vibration measurements on the pinion bearings *(speed of oscillation in mm/s)*
- Tooth flank temperature measurements *(absolute temperature and temperature difference Δt)* while the drive is operating
- Photo-documentation of the tooth flank surfaces
- Silicone rubber impressions of the tooth flank surfaces *(if required)*
- Visual inspection of the tooth flanks by means of stroboscope while the drive is operating
- Assessment of the tooth flanks' load bearing area and condition
- Inspection of spray pattern
- Optimization of the spray pattern and the lubricant quantities *(if required)*

10.3. Repairs

Repair of tooth flank damage (see chapter 8) is carried out by Klüber service engineers.

Damaged tooth flanks can be mechanically treated by milling (pitting) or grinding (scoring, burrs and wear steps) before using repair lubricant type D or the running-in lubricant type B.

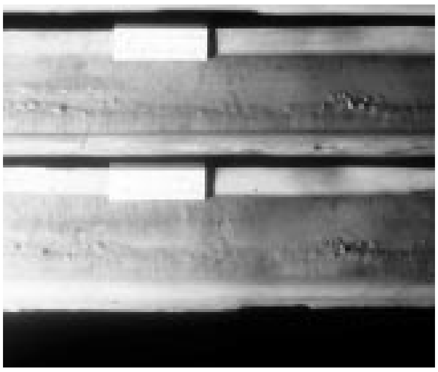


Fig. 53: Silicone rubber impression of a damaged tooth flank

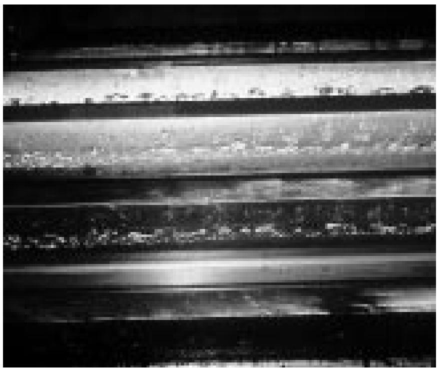


Fig. 54: Damaged tooth flank

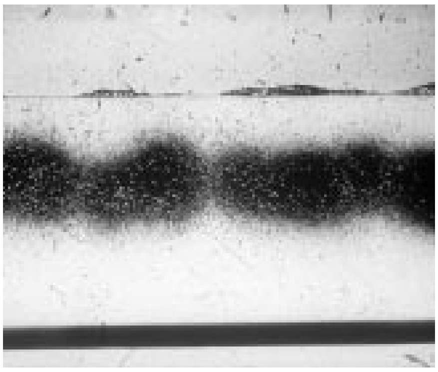


Fig. 55: Optimized spray pattern

11.
Used lubricant analyses and documentation

Determining the condition of operational lubricants type C *(immersion and circulation lubrication)*

11.1.
Lubricant analyses

The condition of the operational lubricant has to be analyzed at regular intervals in order to ensure trouble-free operation of gears with immersion or circulation lubrication systems. Lubricant analyses also allow drawing conclusions on the condition of the machines and the operating conditions. Thus, early detection of failures is often possible. Also, lubricant change intervals can be exactly determined. Consequently, machine uptimes are higher, repair and downtimes can be scheduled, repair costs are lower and environmental impact is reduced. Klüber Lubrication offers these extensive services to all of their customers, in many cases even free of charge.

11.2.
Taking samples

Lubricant samples should represent the average lubricant quality. Therefore, it is important to carefully select where and when samples are taken and if necessary, we recommend consulting with the Klüber expert. Experience has shown that samples should always be taken from the immersion bath or circulation lubrication system under the same service conditions while the machine is running at operating temperature in order to obtain a representative sample. If it is not possible to take samples during operation of the machine, this should be done immediately after the machine has come to a stop to prevent segregation or sedimentation.

The same procedure applies to analyses carried out at regular intervals. Klüber Lubrication provides customers with sample containers. Only new and clean sample containers should be used and tightly closed immediately after being filled with the sample.

11.3.
Documentation of the lubricant sample and recommendations for further steps to be taken

Immediately after taking samples attach a sample identification label, fill in an laboratory analysis sheet and send the sample to Klüber Lubrication using appropriate packing material.

Upon completion of the analysis Klüber Lubrication informs the customer in writing about the results, provides information about further use of the lubricant and the next date of sampling. We recommend having the results of the lubricant analysis expertly interpreted by a specialist of Klüber Lubrication, who will make qualified comments on the condition of the lubricant and the machine.

12.
Transparent Klüber lubricants for large girth gear drives

Priming
Running-in lubrication
Forced running-in lubrication
Operational lubrication
Repair lubrication

The highly viscous and transparent operational lubricants represent a new generation of products which in the next few years will supersede most of the black, graphite-containing greases used for the lubrication of large girth gear drives.

With a view to maximum protection of nature and the environment Klüber Lubrication München KG started developing adequate lubricants also for use in large drives in the early 90's.

The transparent Klüberfluid C-F ... Ultra lubricants have been used throughout the world for about ten years and several hundred girth gear drives are currently lubricated with these products with great success, and the figure is still rising. A reference list is available.

The leading manufacturers of rotary tubular kilns and tube mills for the heavy industries as well as the manufacturers of drives have included the Klüberfluid C-F ... Ultra lubricants in their lube charts. When applied through spray systems, these lubricants can reduce consumption by up to 50 % compared to adhesive lubricants used so far. In the case of immersion or circulation lubrication, lubricant change intervals can be extended to 14,000 hours and more depending on the operating conditions.

The requirements to be met by the new generation of lubricants are:

- ❑ high protection of tooth flanks
- ❑ free of heavy metals, solvent-containing raw materials, graphite and bitumen
- ❑ good adhesion to the tooth flanks
- ❑ good corrosion protection
- ❑ low consumption
- ❑ easy and low-cost disposal
- ❑ little maintenance
- ❑ precise inspection results
- ❑ longer life of components
- ❑ long life of lubricant film
- ❑ reduction of temperatures and oscillations

The transparent Klüberfluid Ultra lubricants fully meet all these requirements and have proven successful around the globe.

In the FZG test A/8.3/90 acc. to DIN 51 354 these lubricants easily achieve a load stage of > 12 with wear being below < 0.2 mg/kWh. A welding load of 6,500 N to 8,000 N is achieved in the four-ball test acc. to DIN 51 350 part 4. Klüberfluid products can be used for spray, immersion and circulation lubrication.

These lubricants provide an elasto-hydrodynamical effect, which separates the smooth tooth flanks. In this respect, a very good lubricant distribution and lubricant film thickness as well as properly adjusted gear drives are of decisive importance. When using transparent Klüberfluid C-F ... Ultra the lubricant film on the tooth flanks can be made visible by means of a UV lamp of min. 366 nm wave length.

The application notes made in this brochure on graphite-containing lubricants also apply to most graphite-free products, however, ambient and product temperatures have to be taken into close consideration. If the specified application temperature cannot be reached, the spray system as well as nozzles, lubricant drum or container, should be heated.

In the case of immersion lubrication it might be necessary to heat the lubricant reservoir. When using the circulation lubrication equipment Klübermatic PA at low ambient temperatures, the whole pump and filter system should be placed into a heated room; also the lubricant reservoir and the feed and return lines should be heated and insulated.

The A – B – C system lubrication also applies to the transparent Klüberfluid products, i.e.

A = priming
B = running-in or correction lubrication
C = operational lubrication

12.1. Priming with Klüberplex AG 11-462

For priming the light-colored grease Klüberplex AG 11-462 has been formulated. If this product is not available, Klüberfluid C-F 3 Ultra might also be used as a priming lubricant due to its good adhesion. Application methods and quantities are the same as in the case of graphite-containing lubricants. The load patterns of light-colored and transparent lubricants are less distinct.

12.2. Running-in lubrication with Klüberfluid B-F 2 Ultra

The same applies as said under chapter 5.2.

12.3. Forced running-in lubrication with Klüberfluid D-F 1 Ultra

Chapter 6 “Forced running-in lubrication” also applies to this Klüberfluid product, however pressure marks are hardly visible because of the lubricant’s light grey color. Due to its transparency, however, the tooth flank condition can be monitored by stroboscope which immediately identifies any changes.

Checking the load distribution on the tooth flanks by means of infrared temperature measurement while the machine is running is of particular importance.

12.4. Operational lubrication

- Klüberfluid C-F 3 Ultra
- Klüberfluid C-F 3 M Ultra
- Klüberfluid C-F 3 S Ultra
- Klüberfluid C-F 4 Ultra
- Klüberfluid C-F 5 Ultra
- Klüberfluid C-F 7 Ultra
- Klüberfluid C-F 8 Ultra

We currently offer seven lubricant types mentioned above. Klüberfluid C-F 5 Ultra and Klüberfluid C-F 7 Ultra are fully synthetic products unlike the other semi-synthetic lubricants, which are composed of synthetic and mineral oils as well as polymers and special additives. The main distinctive feature of these lubricants is their kinematic viscosity ranging from 3,100 mm^2/s at 40 °C to 25,000 mm^2/s at 40 °C. These products are also used for other friction points like rolling and plain bearings. For further details we ask you to refer to the respective product information leaflets.

Apart from Klüberfluid C-F 3 S Ultra, all products can be used for spray, immersion and circulation lubrication provided the ambient, operating and lubricant temperatures are appropriate – this especially applies to Klüberfluid C-F 3 M Ultra *(see product information leaflet)*.

For determining the consumption quantities of running-in and operational lubricants please refer to table 3 and Fig. 57.

Klüberfluid C-F 3 S Ultra contains a solvent and can only be used for spray lubrication. The solvent is an eco-friendly natural product.

IMPORTANT NOTE
The gear rim cover and shaft seals should be oiltight in order to prevent lubricant leakage and ingress of impurities. As the flow behavior of the Klüberfluid oils differs from that of GRAFLOSCON greases, the gear rim cover has to show much better sealing properties when switching from a GRAFLOSCON grease to a Klüberfluid oil to avoid leakage. Y-seals have proven efficient for this purpose.

Unlike in the past, these seals are today no longer filled with grease, but the penetration by the operating lubricant is sufficient to lubricate the sealing lips.

These measures have to be taken in order to ensure proper lubrication of the drives and will pay off because lubricant consumption can be reduced by up to 50% versus total loss lubrication with the graphite-containing operational lubricant type C. Lower lubricant consumption also means considerable cost savings in disposal and maintenance.

12.5. Repair lubrication with Klüberfluid D-F 1 Ultra

Repair lubrication with or without prior mechanical treatment of the tooth flanks is carried out as described in chapter 6.

13.
Lubricant film thickness

Lambda

Lambda (λ) is the ratio of the lubricant film thickness (hc) divided by the average surface roughness of the gearing ($R_a1 + R_a2$). Table 3 shows the Lambda values calculated for the individual lubricants:

GRAFLOSCON = adhesive grease
Klüberfluid = highly viscous oil

$$\text{Lambda } \lambda = \frac{hc}{\frac{R_a1 + R_a2}{2}}$$

If Lambda is greater than 2 *(i.e. the lubricant film thickness is twice as high as the surface roughness Ra)*, the gear is operating under full-film hydrodynamic lubrication, i.e. the tooth flanks are completely separated by the lubricant film.

If Lambda is between 0.7–2, the gear is operating under mixed friction conditions, i.e. there may be metal-to-metal contact between the mating tooth surfaces.

If Lambda is less than 0.7, the gear is operating under boundary lubrication conditions, meaning that there definitely is a metal-to-metal contact between the tooth flank surfaces. The Lambda value should always be greater than 2.

Since 1995 we have gained many positive results which confirm these theoretical findings and the efficiency of the Klüberfluid products.

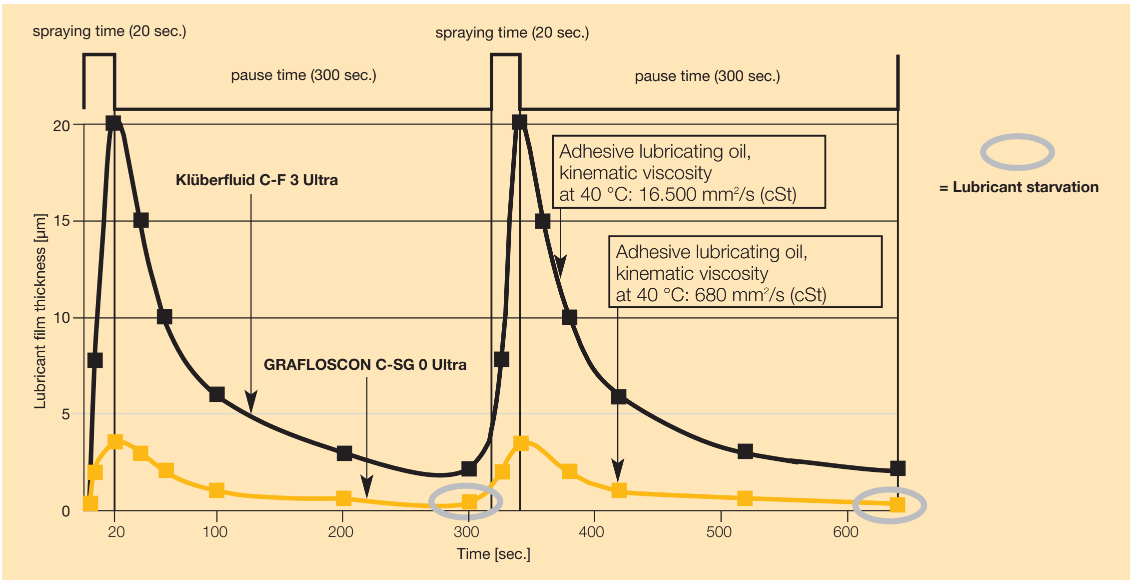


Fig. 56a: Diagram of lubricant film thickness with intermittent lubrication – long pause times **not recommended**

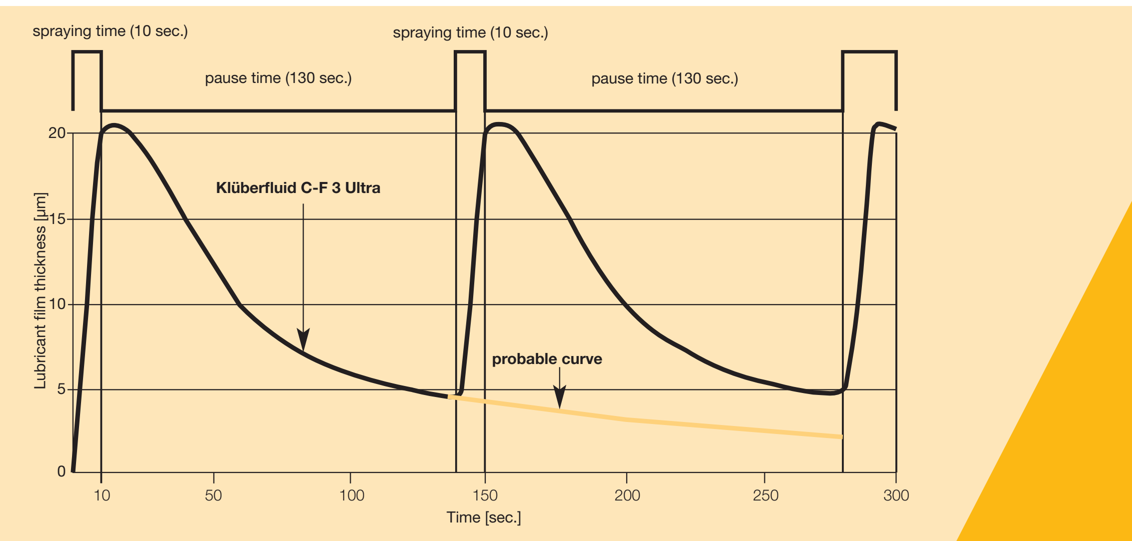


Fig. 56b: Diagram of lubricant film thickness with intermittent lubrication – short pause times **recommended**

Film thickness calculation

(based on continuous lubrication)
Gear rim and pinion drive of a tube mill

Input power P	1550 kW	Speed factor of pinion / wheel	110 / 15.5 min^{-1}
Torque of pinion	134 kNm	Peripheral speed ν	4.538 m / s
Module m	25.4 mm	Tooth number of pinion / wheel	31 / 220
Face width b	625 mm	Pressure angle	20 °
Helix angle	0 °	Center distance a	3190 mm

Tooth flank roughness prior to running-in lubrication: R_a = 4.3 µm after running-in lubrication: R_a = 0.4 µm

Product	Operating temperature tooth flank [°C]	Kinematic viscosity at temperature ν* [mm²/s]		
		40 °C	60 °C, approx.	100 °C
GRAFLOSCON C-SG 0 Ultra	60	680	200	40
GRAFLOSCON C-SG 0 Ultra	60	680	200	40
GRAFLOSCON C-SG 1000 Ultra	60	1000	260	44
GRAFLOSCON C-SG 1000 Ultra	60	1000	260	44
GRAFLOSCON C-SG 2000 Ultra	60	2000	550	95
GRAFLOSCON C-SG 2000 Ultra	60	2000	550	95
Klüberfluid C-F 3 Ultra	60	16500	3850	500
Klüberfluid C-F 3 Ultra	60	16500	3850	500
Klüberfluid C-F 3 M Ultra	60	25500	5900	750
Klüberfluid C-F 3 M Ultra	60	25500	5900	750
Klüberfluid C-F 4 Ultra	60	3100	910	165
Klüberfluid C-F 4 Ultra	60	3100	910	165
Klüberfluid C-F 5 Ultra	60	4900	1670	350
Klüberfluid C-F 5 Ultra	60	4900	1670	350
Klüberfluid C-F 7 Ultra	60	23000	6575	1000
Klüberfluid C-F 7 Ultra	60	23000	6700	1000
Klüberfluid C-F 8 Ultra	60	8000	2100	320
Klüberfluid C-F 8 Ultra	60	8000	2100	320

* ν = Viscosity based on typical measured values

** R_a = Average peak-to-valley height (acc. to DIN 4768 sheet 1), arithmetic average height of all profile ordinates y after eliminating form errors and waviness, R_a value varies between 1/3 and 1/7 of the R_z value (DIN 4767)

*** h_c = Lubricant film thickness in the pitch circle *(maximum value) at 60 °C*

Table 3

Flank roughness R_a** [µm]	Film thickness h_c*** [µm]	Lambda λ****
4.3	2.53	0.63
0.4	2.55	6.38
4.3	3.01	0.75
0.4	3.04	7.60
4.3	5.10	1.28
0.4	5.16	12.90
4.3	19.9	4.98
0.4	20.2	50.42
4.3	27.0	6.74
0.4	27.3	68.20
4.3	7.3	1.82
0.4	7.4	18.38
4.3	11.1	2.78
0.4	11.2	28.08
4.0	30.2	7.60
0.4	31.0	77.50
4.3	13.0	3.26
0.4	13.2	32.94

**** $\lambda = \dfrac{hc}{\dfrac{R_a 1 + R_a 2}{2}}$

R_a 1 – Tooth flank roughness wheel 1
R_a 2 – Tooth flank roughness wheel 2

Evaluation:

Lambda < 0.7	Dry friction/boundary lubrication *(no EHL)*
0.7 < Lambda < 2.0	Mixed friction *(partially EHL)*
Lambda > 2.0	Fluid friction/hydrodynamic lubrication *(full EHL)*

14. Klüber A – B – C system lubrication and D repair lubrication

with black, non-transparent products containing graphite

Overview

A – Priming and pre-start lubrication

GRAFLOSCON A-G 1 Ultra	Manual application by brush or spatula

B – Running-in and correction lubrication

GRAFLOSCON B-SG 00 Ultra	Application with automatic spray lubrication systems or compressed-air manual spraying equipment, e.g. Klübermatic LB
Klüberfluid B-F 1 Ultra	For immersion lubrication with or without paddle wheel and for circulation lubrication with the Klübermatic PA system

C – Operational lubrication

GRAFLOSCON C-SG 0 Ultra GRAFLOSCON C-SG 1000 Ultra GRAFLOSCON C-SG 2000 Ultra	Application with automatic spray lubrication systems or compressed-air manual spraying equipment, e.g. Klübermatic LB
Klüberfluid C-F 1 Ultra Klüberfluid C-F 2 Ultra	For immersion lubrication with or without paddle wheel and for circulation lubrication with the Klübermatic PA system

D – Repair lubrication, forced running-in lubrication

GRAFLOSCON D-SG 00 Ultra	For manual application by brush or compressed-air manual spraying equipment, e.g. Klübermatic LB

15.

Klüber A – B – C system lubrication and D repair lubrication

with light-colored or transparent lubricants

Overview

A – Priming and pre-start lubrication

Klüberplex AG 11-462 Klüberfluid C-F 3 Ultra Klüberfluid C-F 3 S Ultra	Manual application by brush or spatula Manual application by brush or spatula Application by manual spraying equipment, e.g. Klübermatic LB

B – Running-in and correction lubrication

Klüberfluid B-F 2 Ultra	Application via compressed-air manual spraying equipment, e.g. Klübermatic LB For immersion lubrication with or without paddle wheel and for circulation lubrication with the Klübermatic PA system. For spray lubrication via automatic spraying systems

C – Operational lubrication

Klüberfluid C-F 3 Ultra Klüberfluid C-F 3 M Ultra* Klüberfluid C-F 3 S Ultra** Klüberfluid C-F 4 Ultra Klüberfluid C-F 5 Ultra Klüberfluid C-F 7 Ultra Klüberfluid C-F 8 Ultra	Application with automatic spray lubrication systems and for immersion lubrication with or without paddle wheel, as well as for circulation lubrication with e.g. Klübermatic PA. Also suitable for compressed-air manual spraying equipment, e.g. Klübermatic LB, depending on the ambient, product and operating temperature

D – Repair lubrication, forced running-in lubrication

Klüberfluid D-F 1 Ultra	For manual application by brush or manual spraying equipment, e.g. Klübermatic LB

** only for transfer lubrication by transfer pinion*
*** only for automatic spray lubrication*

A – Priming and pre-start lubrication

with transparent lubricants or lubricants containing graphite

LUBRICANTS	
GRAFLOSCON A-G 1 Ultra	black *(with graphite)*
Klüberplex AG 11-462	light-colored
Klüberfluid C-F 3 Ultra	transparent
Klüberfluid C-F 3 S Ultra	transparent

Application
For spur and helical gear drives, for running-in and operational lubrication irrespective of the chosen type of lubricant and application method.

Purpose

❑ Initial lubrication during the first assembly-related revolutions of the machine, to protect the drive from dry running and its consequences.

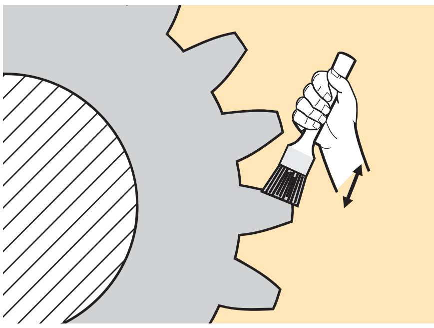
❑ Protection against corrosion until the machine is finally put into operation.

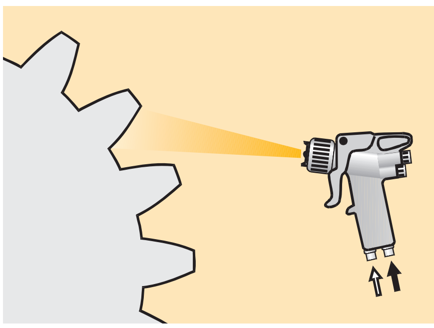
❑ Determination of the dynamic contact ratio as the lubricant appears in different shades of grey on the tooth flanks. Easy assessment of the load distribution.

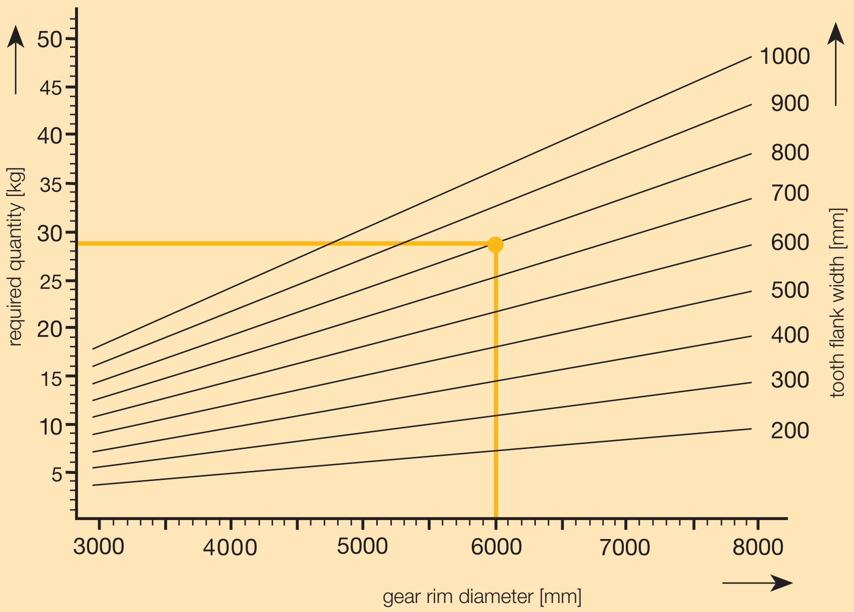
❑ Prevention of deficient lubrication in spray-lubricated drives until a reliable lubricant layer has formed.

Lubricant application
Manual application to thoroughly cleaned pinions and gear rims which are free from grease and rust.

Application by brush, spatula or manual spraying equipment; e.g. Klübermatic LB: While the drive is stopped, apply a thick layer of lubricant *(approx. 1.5 mm)* to all load-carrying tooth flanks of the pinion and the gear rim by means of a stiff brush. Cover the other surfaces with a thin layer for corrosion protection *(see chapter 5.1)*.







Required quantities

Example:

Reference circle Ø:	6000 mm
Tooth flank width:	800 mm
Determined quantity:	approx. 28.5 kg ± 10%
Quantity to be purchased:	30 kg

Fig. 57: Diagram: Required priming lubricant quantity

B – Running-in lubrication and correction lubrication

with transparent lubricants or lubricants containing graphite

LUBRICANT

GRAFLOSCON B-SG 00 Ultra	black (containing graphite) for spray lubrication (1 or 2 180 kg drums)
Klüberfluid B-F 1 Ultra	black (containing graphite) for immersion/circulation lubrication
Klüberfluid B-F 2 Ultra	transparent for immersion/circulation/ spray lubrication (2 or 3 180 kg drums)

Depending on the type and the size of the drive, one to three 180 kg drums are normally required for running-in with spray lubrication.

Application
For spur and helical gear drives. Application with automatic spraying systems or manual compressed-air hand spraying equipment, e.g. Klübermatic LB or immersion and circulation lubrication.

Purpose

- ❑ Reduction of surface roughness and raised areas on the load-carrying tooth flanks by way of intentional wear

- ❑ Increase of the contact ratio and achievement of a uniform load distribution

- ❑ Reduction of potential danger of scuffings due to partially increased flank pressure during running-in

Preparation *(with automatic spray lubrication)*
Fill lubricant container or connect lubricant line to barrel pump or pump installed in the container system.

Determine the lubricant consumption quantity using the diagrams (Fig. 22 or 22a). Set automatic spraying unit to quasi-operational lubrication and start operation before switching on the machine. Check spray pattern.

Preparation *(with immersion and circulation lubrication)*
Fill immersion bath or lubricant reservoir and fill up after first revolutions of the drive.

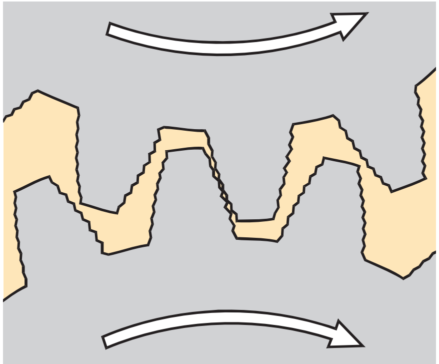
Running-in process
Start with a low machine load and increase in steps. This presents no problem with ball mills *(see running-in schedule in chapter 5.2)*. If required, carry out forced running-in with drives which only operate under full load (see chapter 6). The running-in lubricant is to be exchanged for an operational lubricant (see above) after a maximum of 7,000 operating hours.

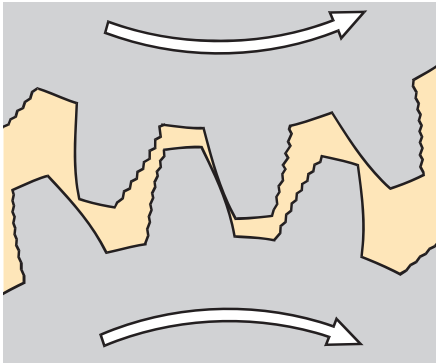
Inspection
Inspect the condition of the tooth flanks every day during the running-in process. For inspection methods see chapter 10.

Specific consumption quantities for running-in lubricants

	Type of installation / drive	Required specific consumption quantities [g/(cm* · operating hour)]
1	Drives of rotary drums *(e.g. cooling units)*	**4**
2	Single-pinion kiln drives	**5**
3	Single-pinion mill drives	**6**
4	Large single-pinion mill drives and double-pinion kiln drives	**7**
5	Double-pinion mill drives	**8**

The indicated specific consumption quantities apply only to GRAFLOSCON B-SG 00 Ultra applied by spraying.
* *width of tooth flanks in cm*





Examples of calculating the consumption quantity

	Double-pinion mill drive (type 5)	**Drive of rotary drum** (type 1)
Required specific consumption quantity [g / (cm · operating hour)]	8	4
Flank width [cm]	85	40
Consumption quantity / operating hour, [g]	8 · 85 = **680**	4 · 40 = **160**
Consumption quantity / 24 operating hours, [kg]	0.68 · 24 = **16.32**	0.16 · 24 = **3.84**

For double-pinion drives the consumption quantity **should not be doubled** but distributed evenly to both nozzle plates.

C – Operational lubrication

with black lubricants containing graphite –
spray lubrication

LUBRICANTS
GRAFLOSCON C-SG 0 Ultra
GRAFLOSCON C-SG 1000 Ultra
GRAFLOSCON C-SG 2000 Ultra

Conversion to operational lubrication
The conversion from running-in to operational lubrication takes place when the tooth flank surfaces are sufficiently smooth and the contact ratio is at least 80%.

When switching to operational lubrication the lubricant quantity set for the running-in process is maintained for another 50 operating hours. Afterwards the lubricant quantity should not be reduced abruptly but in steps of 0.5 to 1 g / (cm · operating hour) at intervals of 150 to 200 operating hours.

When reducing the consumption quantity the control unit of the spray system should be set to ensure that the intervals between the spray cycles are as short as possible. Short and frequent spray cycles make sure that the lubricant is supplied evenly to the drive and thus increase functional reliability.

Consumption quantities
The following table shows the required consumption quantities which can be used as a basis to calculate the quantity required per time unit depending on the type of installation and the flank width. The consumption quantities can also be determined using the diagram Fig. 22. See also the following NOTE. The consumption quantities indicated in the diagram refer to GRAFLOSCON C-SG 0 Ultra.

With GRAFLOSCON C-SG 1000 Ultra the consumption can be reduced by 10 % and with GRAFLOSCON C-SG 2000 Ultra by 20%.

Inspections
Regular inspections of the flank condition and the spray pattern are required to ensure reliable operation. The spray system should be maintained thoroughly in accordance with the manufacturer's instructions.

Specific consumption quantities for operational lubricants containing graphite

	Type of installation / drive	**Required specific consumption quantities** [g/(cm* · operating hour)]
1	Drives of rotary drums *(e.g. cooling units)*	**1.0** to **1.5**
2	Single-pinion kiln drives	**1.5** to **2.0**
3	Single-pinion mill drives	**2.0** to **2.5**
4	Large single-pinion mill drives and double-pinion kiln drives	**2.5** to **3.0**
5	Double-pinion mill drives	**3.0** to **3.5**

** width of tooth flanks in cm*

Examples of calculating the consumption quantity

	Double-pinion mill drive (type 5)	**Drive of a rotary drum** (type 1)
Required specific consumption quantity [g / (cm · operating hour)]	3.5	1.5
Flank width [cm]	85	40
Consumption quantity / operating hour, [g]	3.5 · 85 = **297.5**	1.5 · 40 = **60**
Consumption quantity / 24 operating hours, [kg]	0.297 · 24 = **7.14**	0.060 · 24 = **1.44**

For double-pinion drives the consumption quantity **should not be doubled** but distributed evenly to both nozzle plates.

NOTE

The indicated specific consumption quantities are based on the following assumptions:

- ❑ no major damage to the tooth flanks
- ❑ sufficient contact ratio
- ❑ thorough and regular inspection and maintenance of the gear drive and the spray system
- ❑ normal operating conditions
- ❑ good spray pattern
- ❑ application of a type C GRAFLOSCON operational lubricant

C – Operational lubrication

with transparent lubricants – Spray lubrication

LUBRICANT	SERVICE TEMPERATURE RANGE[1]
Klüberfluid C-F 3 Ultra	(15 to 120 °C)
Klüberfluid C-F 3 M Ultra	(50 to 100 °C – only with manual spraying equipment)
Klüberfluid C-F 3 S Ultra	(0 to 80 °C)
Klüberfluid C-F 4 Ultra	(5 to 80 °C)
Klüberfluid C-F 5 Ultra	(– 5 to 80 °C)
Klüberfluid C-F 7 Ultra	(15 to 120 °C)
Klüberfluid C-F 8 Ultra	(10 to 80 °C)

Conversion to operational lubrication
The conversion from running-in to operational lubrication takes place when the tooth flank surfaces are sufficiently smooth and the contact ratio is at least 80%.

When switching to operational lubrication the lubricant quantity set for the running-in process is maintained for another 50 operating hours. Afterwards the lubricant quantity should not be reduced abruptly but in steps of 0.5 to 1 g / (cm · operating hour) at intervals of 150 to 200 operating hours.

When reducing the consumption quantity the control unit of the spray system should be set to ensure that the intervals between the spray cycles are as short as possible. Short and frequent spray cycles make sure that the lubricant is supplied evenly to the drive and thus increase functional reliability.

Consumption quantities
The following table shows the required consumption quantities which can be used as a basis to calculate the quantity required per time unit depending on the type of installation and the flank width. The consumption quantities can also be determined using the diagram Fig. 22a.

Inspections
Regular inspections of the flank condition and the spray pattern are required to ensure reliable operation. The spray system should be maintained thoroughly in accordance with the manufacturer's instructions.

[1] See Note on page 71

Specific consumption quantities for transparent operational lubricants

Type of installation / drive		Required specific consumption quantities [g/(cm* · operating hour)]
1	Drives of rotary drums *(e.g. cooling units)*	**0.5** to **0.8**
2	Single-pinion kiln drives	**0.8** to **1.0**
3	Single-pinion mill drives	**1.0** to **1.3**
4	Large single-pinion mill drives and double-pinion kiln drives	**1.3** to **1.5**
5	Double-pinion mill drives	**1.5** to **1.8**

** width of tooth flanks in cm*

Examples of calculating the consumption quantity

	Double-pinion mill drive (type 5)	**Drive of a rotary drum** (type 1)
Required specific consumption quantity [g / (cm · operating hour)]	1.8	0.8
Flank width [cm]	85	40
Consumption quantity / operating hour, [g]	1.8 · 85 = **153.0**	0.8 · 40 = **32**
Consumption quantity / 24 operating hours, [kg]	153 · 24 = **3.67**	32 · 24 = **0.77**

For double-pinion drives the consumption quantity **should not be doubled** but distributed evenly to both nozzle plates.

NOTE

The indicated specific consumption quantities are based on the following assumptions:

- ❑ no major damage to the tooth flanks
- ❑ sufficient contact ratio
- ❑ thorough and regular inspection and maintenance of the gear drive and the spray system
- ❑ normal operating conditions
- ❑ good spray pattern

The lubricant temperature must be set to allow unimpeded pumping and spraying. This depends on the type of lubrication system used.

C – Operational lubrication

with black lubricants containing graphite – immersion and circulation lubrication

LUBRICANT	SERVICE TEMPERATURE RANGE[1)]
Klüberfluid C-F 1 Ultra	(– 15 to 60 °C)
Klüberfluid C-F 2 Ultra	(5 to 100 °C)

Conversion to operational lubrication
The conversion from running-in to operational lubrication takes place when the tooth flank surfaces are sufficiently smooth and the contact ratio is at least 80%.

Immersion lubrication
Since the running-in lubricant will lose its abrasive effect in the course of time, it can remain in the bath. However, the bath should be topped up with an operational lubricant *(see above)*. It is also required to completely exchange the bath for an operational lubricant after a maximum of 7,000 operating hours.

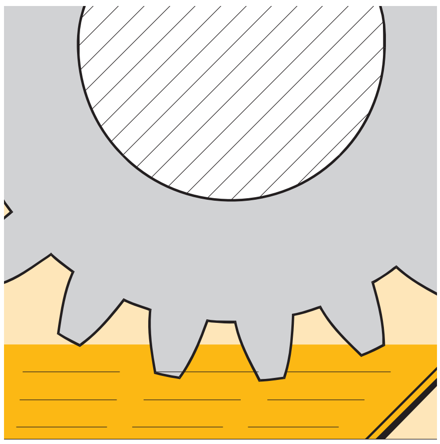
NOTE:
When the machine operates the lubricant level in the immersion trough may decrease considerably as the lubricant adheres to the tooth flanks. If required, top up the lubricant to 0.3 to 0.5 x tooth height or to a level which fully covers the paddle wheel elements while the machine operates.

Lubricant change intervals
The lubricant change intervals for Klüberfluids C-F 1 Ultra and C-F 2 Ultra are between 7,000 and 14,000 operating hours depending on the operating conditions. The drive cover seal plays an important role.

Parameters having a decisive influence on the lubricant's useful life include:

- ❑ contamination by penetrating dust, sand particles, etc.
- ❑ metal abrasion
- ❑ percentage of water contained in the lubricant
- ❑ penetration
- ❑ ageing

Inspections
Regular inspection of the flank conditions and the lubricant level is essential to ensure trouble-free operation. Circulation lubrication systems are to be checked in accordance with the manufacturer's maintenance and operating instructions. It is of special importance to clean the lubricant filters at the predetermined intervals and to drain the accumulated residues.



Advantages of Klüberfluids

- ❑ free from bitumen, solvents and lead
- ❑ favorable viscosity-temperature behavior
- ❑ low evaporation losses
- ❑ easy cleaning and disposal
- ❑ minimal danger of self-ignition
- ❑ easy control of tooth flank condition
- ❑ no channeling – due to good backflow behavior when used within the specified temperature range
- ❑ heating of immersion bath and cooling of the lubricant only required in special cases

[1)] See Note on page 71

C – Operational lubrication

with transparent lubricants – immersion and circulation lubrication

LUBRICANT	SERVICE TEMPERATURE RANGE[1)]
Klüberfluid C-F 3 Ultra	(15 to 120 °C)
Klüberfluid C-F 3 M Ultra	(40 to 140 °C)
Klüberfluid C-F 4 Ultra	(0 to 110 °C)
Klüberfluid C-F 5 Ultra	(– 5 to 110 °C)
Klüberfluid C-F 7 Ultra	(– 5 to 120 °C)
Klüberfluid C-F 8 Ultra	(10 to 120 °C)

Conversion to operational lubrication
The conversion from running-in to operational lubrication takes place when the tooth flank surfaces are sufficiently smooth and the contact ratio is at least 80%.

Immersion lubrication
Since the running-in lubricant will lose its abrasive effect in the course of time, it can remain in the bath.

The purpose of the running-in process should normally be attained after approx. six months, i.e. the tooth flanks should be smooth and the load-carrying area sufficient. Whether this is the case is determined by the customer and a Klüber service engineer together. The running-in lubricant should then be drained immediately, the gear rim cover cleaned and the operating lubricant filled in. The running-in of kiln drives with immersion lubrication has some specific requirements: normally, kilns are not stopped for an exchange of lubricant, so the lubricant may stay in the immersion bath for several months and may tend to thicken due to foreign particles, abrasion and ground solid lubricant. To prevent such thickening, the lubricant should be drained from the reservoir as far as possible while the drive continues to operate, and be replaced by fresh running-in lubricant. This ensures the lubricant remains fluid until the running-in procedure is completed. During the short interval between draining and refilling, the drive should be lubricated manually. It is also required to completely exchange the bath for an operational lubricant after a maximum of 7,000 operating hours.

NOTE:
When the machine operates the lubricant level in the immersion trough may decrease considerably as the lubricant adheres to the tooth flanks. If required, top up the lubricant to 0.3 to 0.5 x tooth height or to a level which fully covers the paddle wheel elements while the machine operates.

Circulation lubrication
The running-in lubricant is to be exchanged for an operational lubricant *(see above)* after a maximum of 7,000 operating hours.

Lubricant change intervals
The lubricant change intervals for the transparent Klüberfluid C lubricants are up to 14,000 operating hours depending on the operating conditions. The drive cover seal plays an important role.

Parameters having a decisive influence on the lubricant's useful life include:

- ❑ contamination by penetrating dust, sand particles, etc.
- ❑ metal abrasion
- ❑ percentage of water contained in the lubricant
- ❑ viscosity
- ❑ ageing

Inspections
Regular inspection of the flank conditions and the lubricant level is essential to ensure trouble-free operation. Circulation lubrication systems are to be checked in accordance with the manufacturer's maintenance and operating instructions. It is of special importance to clean the lubricant filters at the predetermined intervals and to drain the accumulated residues.

Advantages of Klüberfluids

- ❑ free from bitumen, solvent-containing raw materials, lead and solid matters
- ❑ favorable viscosity-temperature behavior
- ❑ low evaporation losses
- ❑ easy cleaning and disposal
- ❑ easy control of tooth flank condition when the drive is running
- ❑ no channeling – due to good backflow behavior when used within the specified temperature range
- ❑ heating of immersion bath and cooling of the lubricant only required in special cases
- ❑ low maintenance required – less costs

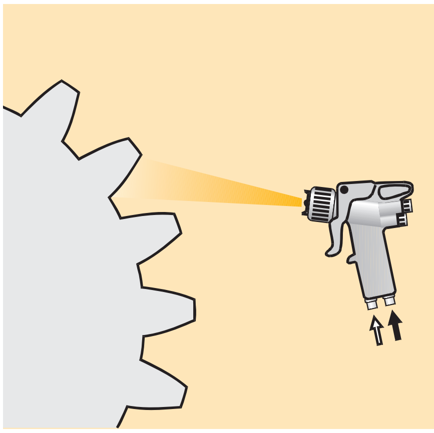
[1)] See Note on page 71

D – Repair and correction lubrication

LUBRICANT
For repair lubrication and for correction or forced running-in lubrication

GRAFLOSCON D-SG 00 Ultra	containing graphite
Klüberfluid D-F 1 Ultra	light-colored

Running-in and repair lubricant; for necessary or desired accelerated correction.



NOTE

The following types of damage cannot be removed by way of repair lubrication:

- ❑ burrs at the tip and the side of the teeth
- ❑ raised areas in the pitch circle
- ❑ wear marks at the tooth root
- ❑ sharp edges and deep pittings

Application
Spur and helical gear drives irrespective of the type of lubrication and application method selected for running-in and operational lubrication.

Purpose
Repair lubrication, removal of tooth flank damage with or without prior mechanical treatment, e.g.

- ❑ scuffings, scratches, scoring
- ❑ pittings
- ❑ material cratering

Correction lubrication
- ❑ higher tooth flank contact ratio and smoother tooth flanks

Application of GRAFLOSCON D-SG 00 Ultra and Klüberfluid D-F 1 Ultra
The repair lubricant is applied manually by brush or with a manual spraying unit, e.g. Klübermatic LB. Kiln drives require larger quantities of the type D lubricant than e.g. mill drives, which are quicker to repair because of the higher speed and the resulting higher sliding speed on the tooth flanks and the more frequent tooth contacts.

How to carry out repair lubrication
Before starting repair lubrication it is of utmost importance to determine the primary causes of the existing damage and to rectify them in order to prevent the fault from recurring. Repair lubrication must always be carried out together with type B running-in lubricants. These are used for additional lubrication and 'finishing' the flank surfaces. If necessary, a type C operational lubricant may also be used as a substitute.

Due to the complexity of the repair process and the involved danger of inadvertently causing damage, repair lubrication should only be carried out by a trained and experienced Klüber engineer.

How to carry out correction lubrication and forced running-in lubrication
Correction lubrication is carried out in the same way as running-in lubrication.

IMPORTANT
GRAFLOSCON D-SG 00 Ultra and Klüberfluid D-F 1 Ultra must not be used in immersion baths, circulation lubrication systems and automatic spraying equipment.

The types of damage indicated under "NOTE" require mechanical pretreatment by means of a manual grinder or an end-milling cutter.

It is not possible to repair progressive pittings in under-dimensioned drives.

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[1] ***SERVICE TEMPERATURES***
Service temperatures are guide values which depend on the lubricant's composition, the intended use and the application method. Lubricants change their consistency, shear 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.

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