Screws & bolts

A lubrication guide

Lubrication is our World

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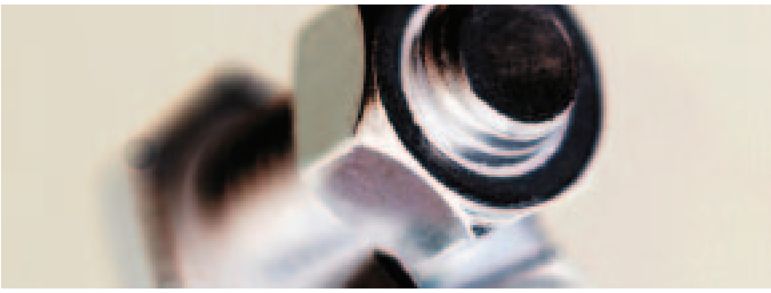
Introduction



Screws and bolts are releasable, power-locking fasteners. They should be tightened and released without much effort and definitely without damage to the screws, nuts or mating threads. Because high clamp forces are often desirable, lubrication is a necessity in many applications. Which lubricant to use for which application can be determined in a straightforward selection process, which you will find under
www.klueber.com/Technical Applications/Screws

Additionally, you may reference a small selection of lubricants for screws and bolts, indicating their major characteristics as well as friction coefficients and standard deviations, at the end of this brochure.

Basics

Screwed joints should normally have a specific clamp force to ensure that the components are held together by a sufficient and primarily constant force.

The clamp force that is sufficient for a particular application can be calculated on the basis of a number of parameters related to one another, namely the tightening torque $\mathbf{M_A}$, the clamp force $\mathbf{F_M}$ and the friction co-efficient $\boldsymbol{\mu}$. In the elastic deformation range of the screw, a linear relation exists between the tightening torque $\mathbf{M_A}$ and the clamp force $\mathbf{F_M}$, whose increase is influenced by the friction coefficient.

When a screw is being tightened, only the thread pitch torque $\mathbf{M_{GST}}$ generates the clamp force in the screw. The bearing surface friction torque $\mathbf{M_{KR}}$ and the thread friction torque $\mathbf{M_{GR}}$ cannot be used for generating the clamp force since the friction between the head, and possibly the nut, and the component surface, and the friction between the thread flanks of screw and nut or mating thread must be overcome:

$$\mathbf{M_A = M_{GST} + M_{GR} + M_{KR}}$$

The thread torque $\mathbf{M_G}$ *(with $M_G = M_{GSt} + M_{GR}$)* can be calculated for metric threads according to DIN 13 under consideration of the pitch angle, the thread geometry and the thread friction:

$$\mathbf{M_G = F_M \cdot (0.159 \cdot P + 0.577 \cdot d_2 \cdot \mu_G).}$$

The bearing surface friction torque is calculated as follows:

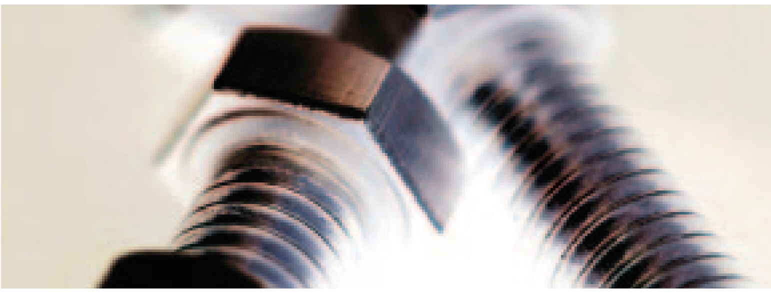
$$\mathbf{M_{KR} = F_M \cdot \mu_K \cdot (D_{KM}/2).}$$

The resulting total tightening torque is

$$\mathbf{M_A = F_M \cdot [0.159 \cdot P + 0.577 \cdot d_2 \cdot \mu_G + (D_{KM}/2) \cdot \mu_K].}$$

For a screw with certain dimensions according to standard, it follows from this equation that the tightening torque $\mathbf{M_A}$ depends solely on the clamp force $\mathbf{F_M}$, the friction coefficient between threads $\boldsymbol{\mu_G}$ and the bearing surface friction coefficient $\boldsymbol{\mu_K}$ because the mean diameter for the friction torque of the bearing surface $\mathbf{D_{KM}}$, the flank diameter of the screw thread $\mathbf{d_2}$ and the thread pitch **P** are constant values, which can be found in the pertinent product standards.

Tribological requirements



While a screw or bolt is being tightened, the contact surfaces of the screw head – and possibly the nut – and the component along with the screw and mating threads constitute the tribological friction bodies. The behavior and in particular the friction of these surfaces will vary, depending on the intermediate substance *(lubricant)* between them.

During the tightening process, high surface pressures *(up to 1000 N/mm^2)* are generated, normally at a low sliding speed. There is contact between the surfaces *(mixed/boundary friction)*, which in turn increases friction. As this may cause damage to the surfaces, the permissible clamp force is limited. To prevent or minimize the mentioned effects, lubricants made for specific requirements are used.

1. Favorable and reliable friction coefficients

As described above, the percentage of the thread pitch torque in the tightening torque is increased by a low friction coefficient, leading to a higher clamp force and hence a better utilization of the strength offered by the screwed joint. **According to the VDI guidelines 2230 and VDA test sheet 235-101, friction coefficients between 0.08 and 0.16 are desirable.** At the same time, the friction coefficient should not be too low either; otherwise the self-locking effect might be impaired and the screwed joint undo itself. The limit value to be observed is approx. 0.04.

When designing a screwed joint, the spreading of the friction coefficient must also be taken into account. It is vital that the *(inevitable)* spreading be kept to a minimum. Owing to the spreading of the friction coefficient, a particular calculated/defined tightening torque may result in considerably varying clamp forces among the individual screws. This may in turn lead to varying embedment phenomena at the surface, on the thread flanks and on the contact surfaces. Insufficient clamp forces and resulting uneven tensions *(e.g. in flanges, lids, casings)* may be the consequence.

For this reason, this brochure does not only contain information on friction coefficients as measured for various material combinations, but also on the standard deviation, a statistical value describing the range of spreading.

2. Behavior during disassembly

In screwed joints exposed to normal temperatures, the release torque is usually lower than the tightening torque.

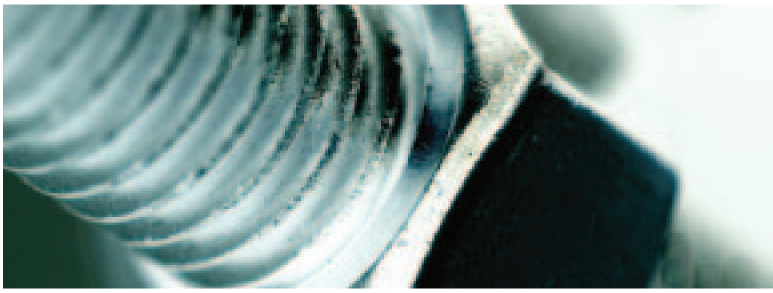
The matter becomes more difficult when the screwed joint is exposed to high temperatures up to 1000 °C. While screw manufacturers offer special steel screws for such temperatures, as are listed e.g. in DIN EN 10 269, the tribological behavior of the joint changes significantly at temperatures exceeding 200 or 300 °C. In this temperature range, chemical reactions may occur, involving the material surfaces and the ambient media. The lubricant used must be able to form a 'separating' layer between the material surfaces even under such high temperatures to avoid damage like fretting, seizures or cold welding, and allow smooth disassembly.

It is important to note that certain types of steel, for example special steel, aluminium and titanium alloys as well as screws and bolts with galvanized surfaces, have a tendency towards fretting already in the assembly stage. Seizures may occur both at low temperatures – referred to as cold welding – and under the influence of high temperatures. High temperatures in combination with high pressures heat up the material surfaces and partial welding becomes possible. Releasing such seized or welded screwed joints is problematic and sometimes even impossible. The surfaces of both the screw and the component are often damaged, rendering them unfit for further use, resulting in high costs and posing a safety hazard.

It should also be noted that the use of a wrong lubricant may damage the screws and components through harmful substances it may contain. Sulphur, in whatever form, may, for example, diffuse into nickel-chromium steel at temperatures over 350 or 400 °C and cause tension cracks. The same may happen with lubricants containing fluorine or chlorine.

Heavy metals or metals with a low melting point can also pose problem: besides the health hazard, they may melt under high loads, diffuse into the surfaces and lead to brittle fracture. For the above reasons, it is vital that an application for a screw lubricant be described as accurately as possible to determine the best suitable lubricant. *(We will provide you with a technical questionnaire especially compiled for screwed joints.)*

Lubricants



For the reasons outlined above, Klüber has developed special lubricants in co-operation with the manufacturers of screws and bolts. There are three basic types of lubricants that may be used for screw lubrication as they meet the described tribological requirements and offer additional benefits such as easy handling and corrosion protection.

1. Lubricating pastes

Pastes are consistent lubricants characterized by a very high percentage of solid lubricants *(> 20%)*. They are primarily used for friction bodies in applications that are subject to extreme conditions, e.g. very high surface pressures at low speeds and/or extremely high temperature. There are two basic types of paste composition:

a) Pastes containing various solid lubricants and a carrier oil – mineral and/or synthetic oil

b) Pastes that are based on a grease, i.e. besides the base oil and the solid lubricants they also contain a thickener *(soap)*. These products combine the advantages of a paste based only on solid lubricants – an excellent antiwear effect and high pressure resistance – with those of a lubricating grease – good resistance to drying out and bleeding.

Besides mineral oil, synthetic oils such as polyalphaolefins, polyglycols or ester are used as carrier oils. Solid lubricants are PTFE *(polytetrafluoroethylene)*, MoS_2 *(molybdenum disulfide)*, graphite, oxides or other inorganic compounds.

Notes on the application of pastes
All pastes should be applied as a thin film covering the whole surface. Overlubrication will not be beneficial, not even in terms of less friction; it will, instead, lead to excessive consumption, contamination and avoidable environmental impact. Prior to applying a paste, the surfaces to be lubricated should be thoroughly cleaned and degreased. Any machining residues or anticorrosive layers should also be removed carefully. The paste can be applied by means of a medium-hard, non-shedding quality brush or a sponge.

When lubricating screws or bolts make sure that the underside of the screw head and the contact side of the nut are covered with lubricant. This ensures that the required clamp force is attained with the specified tightening torque and that the joint can be easily released after exposure to high thermal stress.

2. Bonded coatings *(dispersions)*

Bonded coatings *(dispersions)* are a dry alternative to liquid or consistent lubricants. Their composition is similar to that of an industrial paint; their pigments however consist of substances with a lubricating effect.

The main constituents are:

Solid lubricant
(e.g. PTFE, MoS_2, graphite, or a combination of solid lubricants)

Binder
(organic or inorganic, single- or two-component resin)

Solvents
(organic or water-miscible)

Once the bonded coating *(the dispersion)* has been applied and hardened, a dry, thin adhesive layer forms, which acts as a lubricating layer between the friction bodies *(e.g. screw head and component or the threads of bolt and nut)*, thus reducing friction and wear.

Bonded coatings *(dispersions)* enable dry and clean lubrication, they protect against corrosion and may offer very low friction coefficients. They also allow highly effective lubrication at both high and low temperatures, under the influence of media or in a vacuum. In screwed joints, their low friction coefficients with only a minimum of spreading are highly beneficial in terms of tightening torque and clamp force.

Bonded coatings *(dispersions)* are suitable for a wide variety of materials and can be economically used for screws through the use of suitable application methods *(e.g. dip/spin coating). (More details on application methods are listed in the product information leaflet of the individual product.)*

3. Wax emulsions

These are water-miscible oil-in-water emulsions, whereby wax is distributed in the form of find droplets. They can be diluted with water and, once dried, may render a transparent sliding layer that is dry to the touch.

In tribological contact, this lubricating film shows a low friction coefficient that can be modified and controlled – just as the layer thickness – by adjusting the mixing ratio with water. Frequently used *(standard)* mixing ratios are 1 : 3 *(emulsion : water)* up to 1 : 10. For easy inspection of the layer, the emulsions may also contain a UV indicator.

Wax emulsions have proven particularly successful for use with small screws or self-cutting screws for wood or metal *(furniture, particleboards, building sector)*.

Like bonded coatings, they are suitable for economical mass-coating *(e.g. dip/spin coating)*, especially for screws of sizes up to M 14. *(More details on application methods are listed in the product information leaflet of the individual product.)*

Your benefits

The following benefits can be attained if the “right” lubricant is used on a screwed joint.

- ❑ Higher clamp forces (F_M) can be attained with the same tightening torques (M_A).
- ❑ Less spreading of the friction coefficients leads to less spreading of the clamp forces.
- ❑ Better utilization of the strength of the screwed joint.
- ❑ A lower friction coefficient may allow smaller screws/nuts to be used.
- ❑ Lower tightening torques become possible.

The following calculation example underlines these benefits.

$$M_A = F_M \left[0.16 \cdot P + 0.58 \cdot d_2 \cdot \mu_G + \frac{D_{KM}}{2} \cdot \mu_K\right]$$

Screw M10 · 1.5 · 50 acc. to DIN EN ISO 4017;
Material A2-70 to DIN EN ISO 3506-1.
Nut M10 DIN EN ISO 4032; material A2-80 acc. to DIN EN ISO 3506-1

Screw lubricated with Klüberpaste HEL 46-450

P = 1.5 mm
d_2 = 9.026 mm
D_{KM} = 12.8 mm
μ_K = 0.105 *(mean value)*
μ_G = 0.126 *(mean value)*
F_{Mzul} = 18.4 kN for 90% utilization of yield stress acc. to VDI guidelines 2230

$$M_A = 18.4\ \text{kN}\ [0.16 \cdot 1.5 + 0.58 \cdot 9.026 \cdot 0.126 + \frac{12.8}{2} \cdot 0.105]\ \text{mm} = \mathbf{28.9\ Nm}$$

With the standard deviation of the friction coefficient in the thread and under the head S_G, S_K

S_K = 0.011
S_G = 0.032

the spreading of the clamp force can be determined that may maximally occur with a tightening torque M_A = 28.9 Nm.

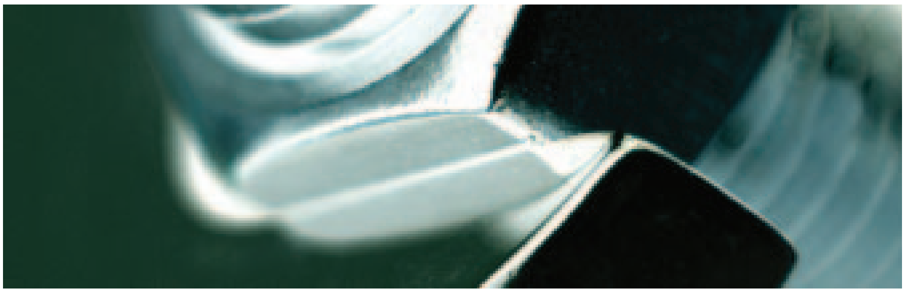
For μ_{Kmin} = 0.105 – 0.011 = 0.094
and μ_{Gmin} = 0.126 – 0.032 = 0.094

$$F_{Mmax} = \frac{28.9\ \text{Nm}}{[0.16 \cdot 1.5 + 0.58 \cdot 9.026 \cdot 0.094 + \frac{12.8}{2} \cdot 0.094]\ \text{mm}} = \mathbf{21.7\ kN}$$

and for μ_{Kmax} = 0.105 + 0.011 = 0.116
and μ_{Gmax} = 0.126 + 0.032 = 0.158

$$F_{Mmin} = \frac{28.9\ \text{Nm}}{[0.16 \cdot 1.5 + 0.58 \cdot 9.026 \cdot 0.158 + \frac{12.8}{2} \cdot 0.116]\ \text{mm}} = \mathbf{16.0\ kN}$$

Exemplary calculation for the required tightening torque M_A of a screwed joint acc. to VDI guideline 2230 (October 2001)



For a lightly oiled screw with the friction coefficients

μ_K = 0.229 *(mean value)*
μ_G = 0.303 *(mean value)*

and the standard deviations

S_K = 0.041
S_G = 0.058

$\mathbf{F_{Mzul}}$ = 13.8 kN for 90% utilization of the yield stress acc. to VDI guideline 2230. Consequently, the tightening torque

$$\mathbf{M_A = 45.4\ Nm}$$

and with μ_{Kmin} = 0.188
μ_{Gmin} = 0.245

$$\mathbf{F_{Vmax}} = \frac{45.4\ \text{Nm}}{[0.16 \cdot 1.5 + 0.58 \cdot 9.026 \cdot 0.245 + 6.4 \cdot 0.188]\ \text{mm}} = \mathbf{16.6\ kN}$$

and with μ_{Kmax} = 0.270
μ_{Gmax} = 0.361

$$\mathbf{F_{Vmin}} = \frac{45.4\ \text{Nm}}{[0.16 \cdot 1.5 + 0.58 \cdot 9.026 \cdot 0.361 + 6.4 \cdot 0.27]\ \text{mm}} = \mathbf{11.8\ kN}$$

Exemplary calculation for the required tightening torque M_A of a screwed joint acc. to VDI guideline 2230 (October 2001)

Your benefits obtained with the "right" screw lubricant

- Reliable screwed joints due to constant and sufficient clamp forces
- Assembly and disassembly without damage *(for certain applications and lubricants also after exposure to high temperatures)*
- Cost savings if, due to a lower friction coefficient, smaller bolts and nuts can be used
- Further possible benefits in special applications:

  Eco-friendly, rapidly biodegradable lubricants

  Lubricants certified as NSF-H1 or H2 *(e.g. for food-processing industry)*

  Clean handling due to dry lubrication, e.g. bonded coatings or lubricating wax emulsions

Product survey

Selection criteria	Product name	Base oil / thickener	Color
High-temperature screw paste	**Klüberpaste HEL 46-450**	Polyalkylene glycol/ester oil solid lubricant	black
Lubricating and assembly paste, NSF H1 registered, high temperatures	**Klüberpaste UH1 96-402**	Polyalkylene glycol/silicate solid lubricant	light grey
Lubricating and assembly paste, NSF H1 registered, normal temperatures	**Klüberpaste UH1 84-201**	Synthetic hydro-carbon oil, solid lubricants	white
White multi-purpose paste	**Klüberpaste 46 MR 401**	Polyalkylene glycol/Li soap, solid lubricant	whithish
Rapidly biodegrad-able lubricating and assembly paste	**Klüberbio EM 72-81**	Ester oil/ solid lubricant/ polyurea	whithish

Selection criteria	Product name	Index	Dry to the touch at … [°C] after … [min] approx.	Baking tem-perature [°C] Hardening time [min]	Color
Bonded coating based on MoS_2	**UNIMOLY C 220**	1	20/5	20/30	grey
Bonded coating based on PTFE	**Klübertop TP 03-111**	1	25/30	160/60	black
Bonded coating based on graphite	**Klübertop TG 05-371**	1	100/5	250/15 *(or 180/60)*	greyish-black
High-temperature screw dispersion	**Klüberplus S 04-807**	1	20/15	180/15	grey
Lubricating wax emulsion	**Klüberplus SK 12-205**	2 3	20/10	–	transparent

Index 1: Pretreated screws with zinc-phospatized surface
Index 2: Friction values and standard deviation with a mixing ratio of 1:3
Index 3: Color of the water-free lubricating film

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

Friction values and standard deviations for “standard screw materials”

Service temperature range* [°C] approx.	Friction values for initial tightening**	Standard deviation (S)	Notes
– 40 to 1000 above 200 °C dry lubrication	μ_K = 0.09 μ_G = 0.11	S_K = 0.009 S_G = 0.02	Protects against seizure even at high temperatures. Approved acc. to VW-TL 52112
– 30 to 1200 above 200 °C dry lubrication	μ_K = 0.15 μ_G = 0.17	S_K = 0.008 S_G = 0.026	For normal and high-temperature applications, e.g. in the food, pharmaceutical and chemical industries
– 45 to 120	μ_K = 0.10 μ_G = 0.13	S_K = 0.004 S_G = 0.017	For the food, pharmaceutical and chemical industries
– 40 to 150	μ_K = 0.17*** μ_G = 0.15***	S_K = 0.011*** S_G = 0.024***	For screw and bolt connections in the normal temperature range
– 30 to 120	μ_K = 0.13 μ_G = 0.11	S_K = 0.012 S_G = 0.011	For use in agricultural and forestry machines and water resources industry

Service temperature range* [°C] approx.	Friction values for initial tightening**	Standard deviation (S)	Notes
– 180 to 350	μ_K = 0.06 μ_G = 0.07	S_K = 0.003 S_G = 0.007	Dry lubricant for high pressures. Low friction values
– 40 to 180	μ_K = 0.12 μ_G = 0.14	S_K = 0.005 S_G = 0.006	Good resistance to chemical agents and oils. Good corrosion protection. Low standard deviations
– 40 to 300	μ_K = 0.06 μ_G = 0.08	S_K = 0.007 S_G = 0.019	Good lubricating characteristics also in humid environment. Wide service temperature range
– 40 to 1000	μ_K = 0.14 μ_G = 0.14	S_K = 0.006 S_G = 0.028	Dry and clean alternative to high-temperature screw pastes
– 40 to 90	μ_K = 0.11 μ_G = 0.13	S_K = 0.011 S_G = 0.021	Ready-to-handle; can be diluted with tap water

*** (measured with screws M 10x30-8.8, DIN EN ISO 4017, black and nut M 10-8, DIN-EN ISO 4032, bright; number of screws: 20 each*
μ_K = bearing surface friction coefficient, μ_G = thread friction coefficient
**** For batches with batch numbers higher than 628909*

For further details on the individual products, please see the corresponding product information leaflet

Product survey

Selection criteria	Product name	Base oil / thickener	Color
High-temperature screw paste	**Klüberpaste HEL 46-450**	Polyalkylene glycol/ester oil solid lubricant	black
Lubricating and assembly paste, NSF H1 registered, high temperatures	**Klüberpaste UH1 96-402**	Polyalkylene glycol/silicate solid lubricant	light grey
Lubricating and assembly paste, NSF H1 registered, normal temperatures	**Klüberpaste UH1 84-201**	Synthetic hydrocarbon oil, solid lubricants	white
White multi-purpose paste	**Klüberpaste 46 MR 401**	Polyalkylene glycol/Li soap solid lubricant	whitish

Selection criteria	Product name	Index	Dry to the touch at ... [°C] after ... [min] approx.	Baking temperature [°C] Hardening time [min]	Color
Bonded coating based on MoS_2	**UNIMOLY C 220**	–	20/5	20/30	grey
Bonded coating based on graphite	**Klübertop TG 05-371**	–	100/5	250/15 *(or 180/60)*	greyish-black
Lubricating wax emulsion	**Klüberplus SK 12-205**	1 2	20/10	–	transparent

Index 1: Friction values and standard deviation with a mixing ratio of 1:3
Index 2: Color of the water-free lubricating film

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

Friction values and standard deviations for special steel A 2-70

Service temperature range* [°C] **approx.**	**Friction values for initial tightening****	**Standard deviation** (S)	**Notes**
– 40 to 1000 above 200 °C dry lubrication	μ_K = 0.11 μ_G = 0.13	S_K = 0.011 S_G = 0.032	Protects against seizure even at high temperatures. Approved acc. to VW-TL 52112
– 30 to 1200 above 200 °C dry lubrication	μ_K = 0.11 μ_G = 0.13	S_K = 0.007 S_G = 0.007	For normal and high-temperature applications, e.g. in the food, pharmaceutical and chemical industries
– 45 to 120	μ_K = 0.09 μ_G = 0.19	S_K = 0.009 S_G = 0.022	For the food, pharmaceutical and chemical industries
– 40 to 150	μ_K = 0.13*** μ_G = 0.15***	S_K = 0.010*** S_G = 0.020***	For screw and bolt connections in the normal temperature range

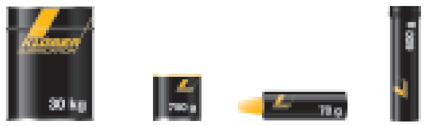
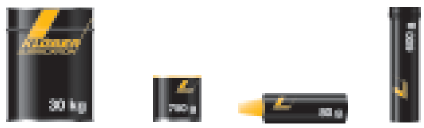
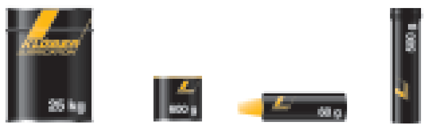
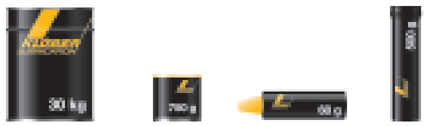
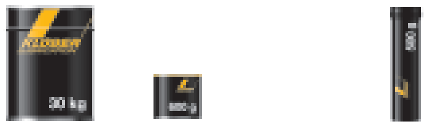
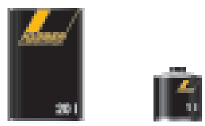
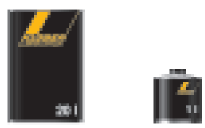
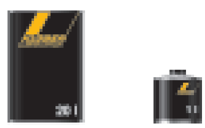
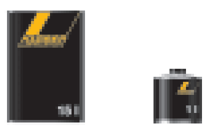
Service temperature range* [°C] **approx.**	**Friction values for initial tightening****	**Standard deviation** (S)	**Notes**
– 180 to 350	μ_K = 0.05 μ_G = 0.08	S_K = 0.007 S_G = 0.007	Dry lubricant for high pressures. Low friction values
– 40 to 300	μ_K = 0.06 μ_G = 0.11	S_K = 0.005 S_G = 0.051	Good lubricating characteristics also in humid environment. Wide service temperature range
– 40 to 90	μ_K = 0.14 μ_G = 0.12	S_K = 0.018 S_G = 0.017	Ready-to-handle; can be diluted with tap water

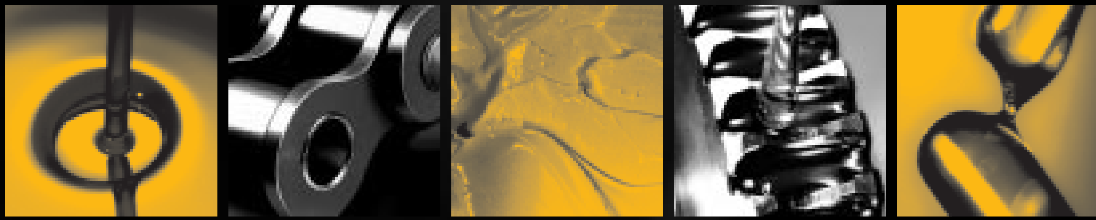
** *(measured with screws M 10x50-8.8, DIN EN ISO 4017, bright, A2-70, DIN ISO 3506-1, and nut M10, DIN EN 4032-1, bright, A2-80, DIN EN ISO 3506; number of screws: 20 each* *μ_K = bearing surface friction coefficient, μ_G = thread friction coefficient*

*** *For batches with batch numbers higher than 628909*

For further details on the individual products, please see the corresponding product information leaflet

Product catalogue

Product	Pack sizes
Klüberpaste HEL 46-450	
Klüberpaste UH1 96-402	
Klüberpaste UH1 84-201	
Klüberpaste 46 MR 401	
Klüberbio EM 72-81	
UNIMOLY C 220	
Klübertop TP 03-111	
Klübertop TG 05-371	
Klüberplus S 04-807	
Klüberplus SK 12-205	



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Lubricating pastes

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Please send the following documents**:**

- ❑ **Rolling bearing lubricants**
- ❑ **Lubricants for vacuum technology**
- ❑ **Lubricants for clean room production**
- ❑ **Lubricants for the food-processing and pharmaceutical industries**

❑ **Please contact me for an** appointment**.**

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