11. LUBRICATION

11. LUBRICATION

11.1 Purposes of Lubrication

The main purposes of lubrication are to reduce friction and wear inside the bearings that may cause premature failure. The effects of lubrication may be briefly explained as follows:

(1) Reduction of Friction and Wear
Direct metallic contact between the bearing rings, rolling elements and cage, which are the basic components of a bearing, is prevented by an oil film which reduces the friction and wear in the contact areas.

(2) Extension of Fatigue Life
The rolling fatigue life of bearings depends greatly upon the viscosity and film thickness between the rolling contact surfaces. A heavy film thickness prolongs the fatigue life, but it is shortened if the viscosity of the oil is too low so the film thickness is insufficient.

(3) Dissipation of Frictional Heat and Cooling
Circulation lubrication may be used to carry away frictional heat or heat transferred from the outside to prevent the bearing from overheating and the oil from deteriorating.

(4) Others
Adequate lubrication also helps to prevent foreign material from entering the bearings and guards against corrosion or rusting.

11.2 Lubricating Methods

The various lubricating methods are first divided into either grease or oil lubrication. Satisfactory bearing performance can be achieved by adopting the lubricating method which is most suitable for the particular application and operating condition.
In general, oil offers superior lubrication; however, grease lubrication allows a simpler structure around the bearings. A comparison of grease and oil lubrication is given in Table 11.1.

Table 11. 1 Comparison of Grease and Oil Lubrication

Item	Grease Lubrication	Oil Lubrication
Housing Structure and Sealing Method	Simple	May be complex, Careful maintenance required.
Speed	Limiting speed is 65% to 80% of that with oil lubrication.	Higher limiting speed.
Cooling Effect	Poor	Heat transter is possible using forced oil circulation.
Fluidity	Poor	Good
Full Lubricant Replacement	Sometimes difficult	Easy
Removal of Foreign Matter	Removal of particles from grese is impossible.	Easy
External Contamination due to Leakage	Surroundings seldom contaminated by leakage.	Often leaks without proper countermeasures. Not suitable if external contamination must be avoided.

11.2.1 Grease Lubrication

(1) Grease Quantity
The quantity of grease to be packed in a housing depends on the housing design and free space, grease characteristics, and ambient temperature. For example, the bearings for the main shafts of machine tools, where the accuracy may be impaired by a small temperature rise, require only a small amount of grease. The quantity of grease for ordinary bearings is determined as follows.
Sufficient grease must be packed inside the bearing including the cage guide face. The available space inside the housing to be packed with grease depends on the speed as follows:
1/2 to 2/3 of the space … When the speed is less than 50% of the limiting speed.
1/3 to 1/2 of the space … When the speed is more than 50% of the limiting speed.

(2) Replacement of Grease
Grease, once packed, usually need not be replenished for a long time; however, for severe operating conditions, grease should be frequently replenished or replaced. In such cases, the bearing housing should be designed to facilitate grease replenishment and replacement.
When replenishment intervals are short, provide replenishment and discharge ports at appropriate positions so deteriorated grease is replaced by fresh grease. For example, the housing space on the grease supply side can be divided into several sections with partitions. The grease on the partitioned side gradually passes through the bearings and old grease forced from the bearing is discharged through a grease valve (Fig. 11.1). If a grease valve is not used, the space on the discharge side is made larger than the partitioned side so it can retain the old grease, which is removed periodically by removing the cover.

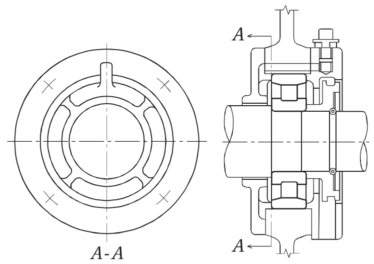
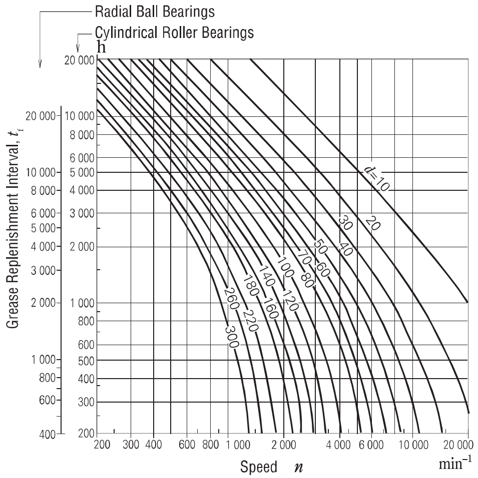
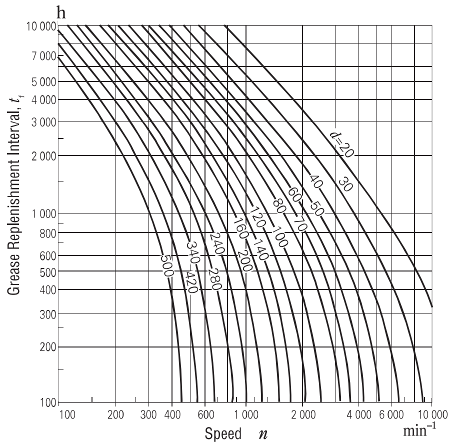


Fig. 11.1 Combination of Partitioned Grease Reservoir and Grease Valve

(3) Replenishing Interval
Even if high-quality grease is used, there is deterioration of its properties with time; therefore, periodic replenishment is required. Figs 11.2 (1) and (2) show the replenishment time intervals for various bearing types running at different speeds. Figs.11.2 (1) and (2) apply for the condition of high-quality lithium soap-mineral oil grease, bearing temperature of 70°C, and normal load (P/C=0.1).
· Temperature
If the bearing temperature exceeds 70°C, the replenishment time interval must be reduced by half for every 15°C temperature rise of the bearings.
· Grease
In case of ball bearings especially, the replenishing time interval can be extended depending on used grease type. (For example, high-quality lithium soap-synthetic oil grease may extend about two times of replenishing time interval shown in Fig.11.2 (1). If the temperature of the bearings is less than 70°C, the usage of lithium soap-mineral oil grease or lithium soap-synthetic oil grease is appropriate.)
It is advisable to consult NSK.
· Load
The replenishing time interval depends on the magnitude of the bearing load.
Please refer to Fig.11.2 (3).
If P/C exceeds 0.16, it is advisable to consult NSK.



(1) Radial Ball Bearings, Cylindrical Roller Bearings



(2) Tapered Roller Bearings, Spherical Roller Bearings

(3) Load factor

P/C	≦0.06	0.1	0.13	0.16
Load factor	1.5	1	0.65	0.45

Fig. 11.2 Grease Replenishment Intervals

(4) Grease Life of Sealed Ball Bearings

When grease is packed into single-row deep groove ball bearings, the grease life may be estimated using Equation (11.1) or (11.2) or Fig. 11.3:

(General purpose grease ([1]))

$$\log t = 6.54 - 2.6\frac{n}{N_{max}} - \left(0.025 - 0.012\frac{n}{N_{max}}\right)T \quad \text{......................}\mathbf{(11.1)}$$

(Wide-range grease ([2]))

$$\log t = 6.12 - 1.4\frac{n}{N_{max}} - \left(0.018 - 0.006\frac{n}{N_{max}}\right)T \quad \text{......................}\mathbf{(11.2)}$$

where t : Average grease life, (h)
n : Speed (min⁻¹)
N_{max} : Limiting speed with grease lubrication (min⁻¹) (values for ZZ and VV types listed in the bearing tables)
T : Operating temperature °C

Equations (11.1) and (11.2) and Fig. 11.3 apply under the following conditions:

(a) Speed, n

$$0.25 \leqq \frac{n}{N_{max}} \leqq 1$$

when $\frac{n}{N_{max}} < 0.25$, assume $\frac{n}{N_{max}} = 0.25$

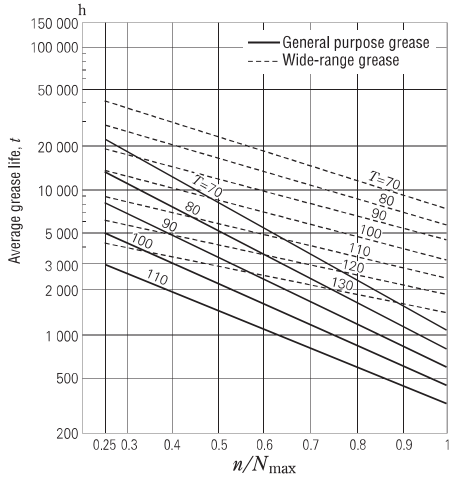


Fig. 11.3 Grease Life of Sealed Ball Bearings

(b) Operating Temperature, T
For general purpose grease ([1])

$$70\ °C \leqq T \leqq 110\ °C$$

For wide-range grease ([2])

$$70\ °C \leqq T \leqq 130\ °C$$

When $T < 70$ °C assume $T = 70$ °C

(c) Bearing Loads
The bearing loads should be about 1/10 or less of the basic load rating C_r.

Notes ([1]) Mineral-oil base greases (e.g. lithium soap base grease) which are often used over a temperature range of around – 10 to 110 °C.
([2]) Synthetic-oil base greases are usable over a wide temperature range of around – 40 to 130 °C.

11.2.2 Oil Lubrication

(1) Oil Bath Lubrication

Oil bath lubrication is a widely used with low or medium speeds. The oil level should be at the center of the lowest rolling element. It is desirable to provide a sight gauge so the proper oil level may be maintained (Fig. 11.4)

(2) Drip-Feed Lubrication

Drip feed lubrication is widely used for small ball bearings operated at relatively high speeds. As shown in Fig. 11.5, oil is stored in a visible oiler. The oil drip rate is controlled with the screw in the top.

(3) Splash Lubrication

With this lubricating method, oil is splashed onto the bearings by gears or a simple rotating disc installed near bearings without submerging the bearings in oil.
It is commonly used in automobile transmissions and final drive gears. Fig. 11.6 shows this lubricating method used on a reduction gear.

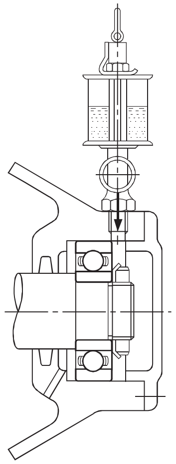


Fig. 11.5 Drip Feed Lubrication

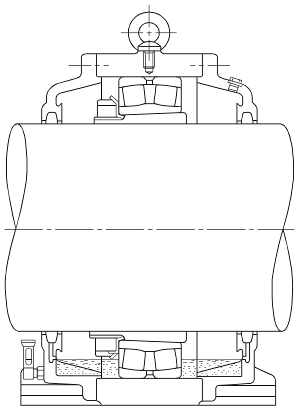


Fig. 11.4 Oil Bath Lubrication

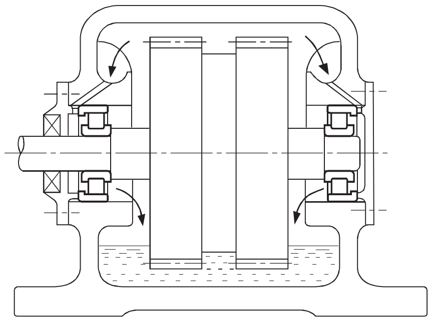


Fig. 11.6 Splash Lubrication

(4) Circulating Lubrication

Circulating lubrication is commonly used for high speed operation requiring bearing cooling and for bearings used at high temperatures. As shown in Fig. 11.7 (a), oil is supplied by the pipe on the right side, it travels through the bearing, and drains out through the pipe on the left. After being cooled in a reservoir, it returns to the bearing through a pump and filter.
The oil discharge pipe should be larger than the supply pipe so an excessive amount of oil will not back up in the housing.

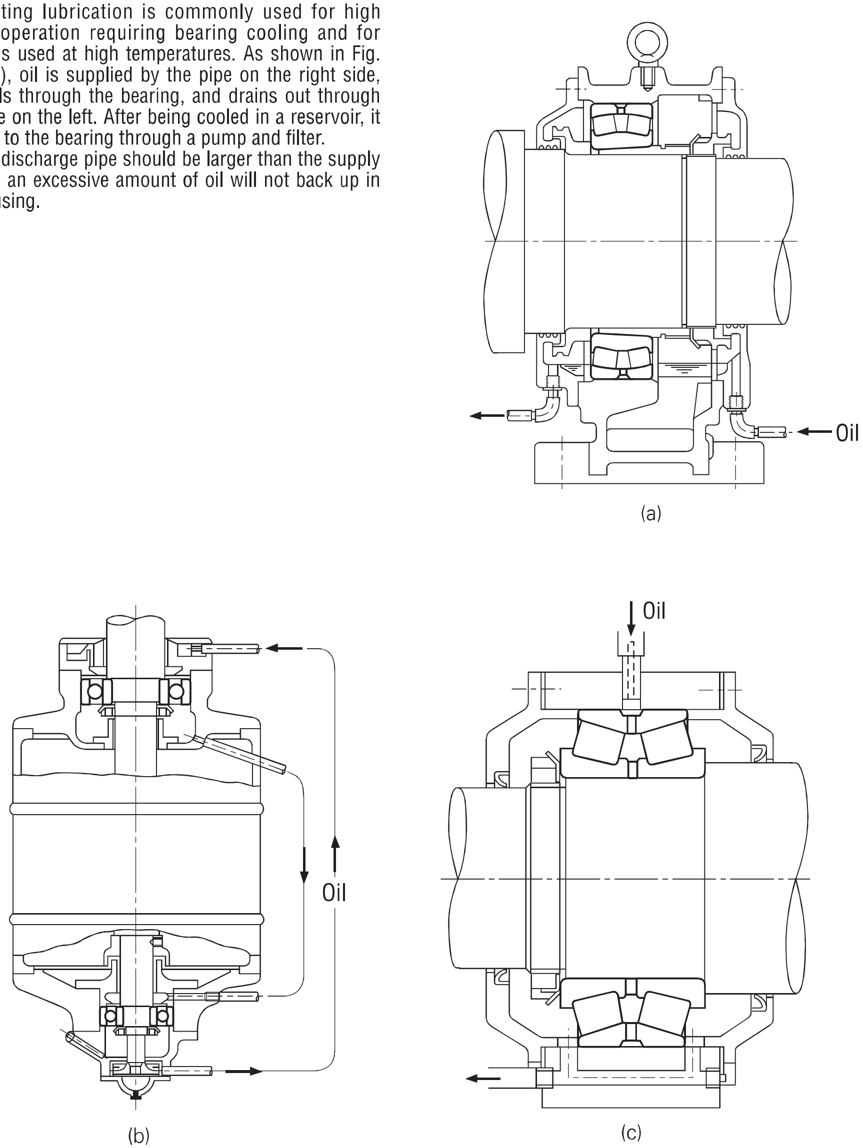
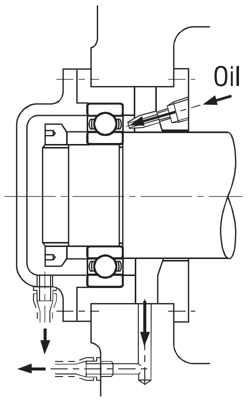


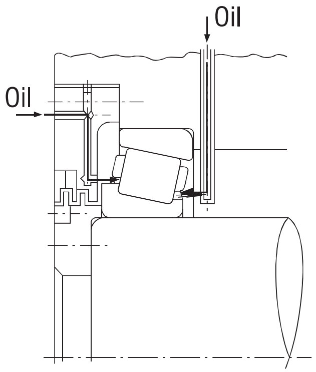
Fig. 11.7 Circulating Lubrication

(5) Jet Lubrication

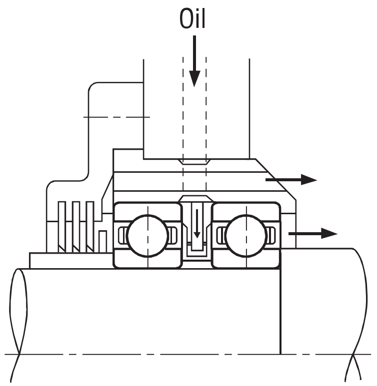
Jet lubrication is often used for ultra high speed bearings, such as the bearings in jet engines with a $d_m n$ valve (d_m: pitch diameter of rolling element set in mm; n: rotational speed in min^{-1}) exceeding one million. Lubricating oil is sprayed under pressure from one or more nozzles directly into the bearing.
Fig. 11.8 shows an example of ordinary jet lubrication. The lubricating oil is sprayed on the inner ring and cage guide face. In the case of high speed operation, the air surrounding the bearing rotates with it causing the oil jet to be deflected. The jetting speed of the oil from the nozzle should be more than 20 % of the circumferential speed of the inner ring outer surface (which is also the guide face for the cage).
More uniform cooling and a better temperature distribution is achieved using more nozzles for a given amount of oil. It is desirable for the oil to be forcibly discharged so the agitating resistance of the lubricant can be reduced and the oil can effectively carry away the heat.



(a)



(b)



(c)

Fig. 11.8 Jet Lubrication

(6) Oil Mist Lubrication

Oil mist lubrication, also called oil fog lubrication, utilizes an oil mist sprayed into a bearing. This method has the following advantages:
(a) Because of the small quantity of oil required, the oil agitation resistance is small, and higher speeds are possible.
(b) Contamination of the vicinity around the bearing is slight because the oil leakage is small.
(c) It is relatively easy to continuously supply fresh oil; therefore, the bearing life is extended.
This lubricating method is used in bearings for the high speed spindles of machine tools, high speed pumps, roll necks of rolling mills, etc (Fig. 11.9).
For oil mist lubrication of large bearings, it is advisable to consult NSK.

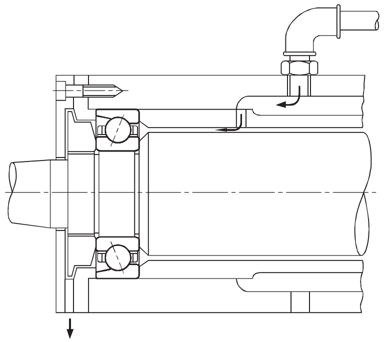


Fig. 11.9 Oil Mist Lubrication

(7) Oil/Air Lubricating Method

Using the oil/air lubricating method, a very small amount of oil is discharged intermittently by a constant-quantity piston into a pipe carrying a constant flow of compressed air. The oil flows along the wall of the pipe and approaches a constant flow rate.
The major advantages of oil/air lubrication are:
(a) Since the minimum necessary amount of oil is supplied, this method is suitable for high speeds because less heat is generated.
(b) Since the minimum amount of oil is fed continuously, bearing temperature remains stable. Also, because of the small amount of oil, there is almost no atmospheric pollution.
(c) Since only fresh oil is fed to the bearings, oil deterioration need not be considered.
(d) Since compressed air is always fed to the bearings, the internal pressure is high, so dust, cutting fluid, etc. cannot enter.
For these reasons, this method is used in the main spindles of machine tools and other high speed applications (Fig. 11.10).

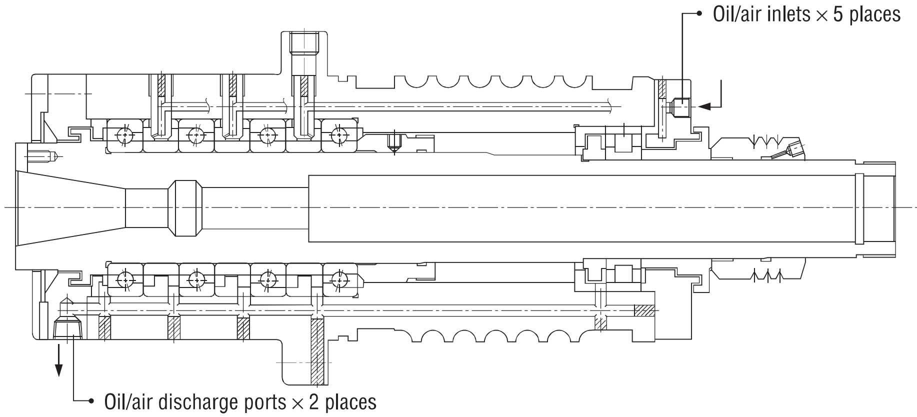


Fig. 11.10 Oil/Air Lubrication

11.3 Lubricants

11.3.1 Lubricating Grease

Grease is a semi-solid lubricant consisting of base oil, a thickener and additives. The main types and general properties of grease are shown in Table 11.2. It should be remembered that different brands of the same type of grease may have different properties.

(1) Base Oil

Mineral oils or synthetic oils such as silicone or diester oil are mainly used as the base oil for grease. The lubricating properties of grease depend mainly on the characteristics of its base oil. Therefore, the viscosity of the base oil is just as important when selecting grease as when selecting an oil. Usually, grease made with low viscosity base oils is more suitable for high speeds and low temperatures, while greases made with high viscosity base oils are more suited for high temperatures and heavy loads.
However, the thickener also influences the lubricating properties of grease; therefore, the selection criteria for grease is not the same as for lubricating oil. Moreover, please be aware that ester-based grease will cause acrylic rubber material to swell, and that silicone-based grease will cause silicone-based material to swell.

(2) Thickener

As thickeners for lubricating grease, there are several types of metallic soaps, inorganic thickeners such as silica gel and bentonite, and heat resisting organic thickeners such as polyurea and fluoric compounds.
The type of thickener is closely related to the grease dropping point ([1]); generally, grease with a high dropping point also has a high temperature capability during operation. However, this type of grease does not have a high working temperature unless the base oil is heat-resistant. The highest possible working temperature for grease should be determined considering the heat resistance of the base oil.
The water resistance of grease depends upon the type of thickener. Sodium soap grease or compound grease containing sodium soap emulsifies when exposed to water or high humidity, and therefore, cannot be used where moisture is prevalent. Moreover, please be aware that urea-based grease will cause fluorine-based material to deteriorate.

Note ([1]) The grease dropping point is that temperature at which a grease heated in a specified small container becomes sufficiently fluid to drip.

Table 11.2 Grease Properties

Name (Popular name) / Thickener / Base Oil / Properties	Lithium Grease			Sodium Grease (Fiber Grease)	Calcium Grease (Cup Grease)	Mixed Base Grease	Complex Base Grease (Complex Grease)	Non-Soap Base Grease (Non-Soap Grease)	
Thickener	Li Soap			Na Soap	Ca Soap	Na + Ca Soap, Li + Ca Soap, etc.	Ca Complex Soap, Al Complex Soap, Li Complex Soap, etc.	Urea, Bentonite, Carbon Black, Fluoric Compounds, Heat Resistant Organic Compound, etc.	
Base Oil	Mineral Oil	Diester Oil, Polyatomic Ester Oil	Silicone Oil	Mineral Oil	Mineral Oil	Mineral Oil	Mineral Oil	Mineral Oil	Synthetic Oil (Ester Oil, Polyatomic Ester Oil, Synthetic Hydrocarbon Oil, Silicone Oil, Fluoric Based Oil)
Dropping Point, ℃	170 to 195	170 to 195	200 to 210	170 to 210	70 to 90	160 to 190	180 to 300	> 230	> 230
Working Temperatures, ℃	–20 to +110	–50 to +130	–50 to +160	–20 to +130	–20 to +60	–20 to +80	–20 to +130	–10 to +130	< +220
Working Speed, %([1])	70	100	60	70	40	70	70	70	40 to 100
Mechanical Stability	Good	Good	Good	Good	Poor	Good	Good	Good	Good
Pressure Resistance	Fair	Fair	Poor	Fair	Poor	Fair to Good	Fair to Good	Fair	Fair
Water Resistance	Good	Good	Good	Poor	Good	Poor for Na Soap Grease	Good	Good	Good
Rust Prevention	Good	Good	Poor	Poor to Good	Good	Fair to Good	Fair to Good	Fair to Good	Fair to Good
Remarks	General purpose grease used for numerous applications	Good low temperature and torque characteristics. Often used for small motors and instrument bearings. Pay attention to rust caused by insulation varnish.	Mainly for high temperature applications. Unsuitable for bearings for high and low speeds or heavy loads or those having numerous sliding-contact areas (roller bearings, etc.)	Long and short fiber types are available. Long fiber grease is unsuitable for high speeds. Attention to water and high temperature is requred.	Extreme pressure grease containing high viscosity mineral oil and extreme pressure additive (Pb soap, etc.) has high pressure resistance.	Often used for roller bearings and large ball bearing.	Suitable for extreme pressures mechanically stable	Mineral oil base grease is middle and high temperature purpose lubricant. Synthetic oil base grease is recommended for low or high temperature. Some silicone and fluoric oil based grease have poor rust prevention and noise.	

Note ([1]) The values listed are percentages of the limiting speeds given in the bearing tables.

Remark The grease properties shown here can vary between brands.

(3) Additives

Grease often contains various additives such as antioxidants, corrosion inhibitors, and extreme pressure additives to give it special properties. It is recommended that extreme pressure additives be used in heavy load applications. For long use without replenishment, an antioxidant should be added.

(4) Consistency

Consistency indicates the "softness" of grease. Table 11.3 shows the relation between consistency and working conditions.

Table 11.3 Consistency and Working Conditions

Consistency Number	0	1	2	3	4
Consistency([1]) 1/10 mm	355 to 385	310 to 340	265 to 295	220 to 250	175 to 205
Working Conditions (Application)	·For centralized oiling ·When fretting is likely to occur	·For centralized oiling ·When fretting is likely to occur ·For low temperatures	·For general use ·For sealed ball bearings	·For general use ·For sealed ball bearings ·For high temperatures	·For high temperatures ·For grease seals

Note ([1]) Consistency: The depth to which a cone descends into grease when a specified weight is applied, indicated in units of 1/10mm. The larger the value, the softer the grease.

(5) Mixing Different Types of Grease

In general, different brands of grease must not be mixed. Mixing grease with different types of thickneners may destroy its composition and physical properties. Even if the thickeners are of the same type, possible differences in the additive may cause detrimental effects.

11.3.2 Lubricating Oil

The lubricating oils used for rolling bearings are usually highly refined mineral oil or synthetic oil that have a high oil film strength and superior oxidation and corrosion resistance. When selecting a lubricating oil, the viscosity at the operating conditions is important. If the viscosity is too low, a proper oil film is not formed and abnormal wear and seizure may occur. On the other hand, if the viscosity is too high, excessive viscous resistance may cause heating or large power loss. In general, low viscosity oils should be used at high speed; however, the viscosity should increase with increasing bearing load and size.

Table 11.4 gives generally recommended viscosities for bearings under normal operating conditions.

For use when selecting the proper lubricating oil, Fig. 11.11 shows the relationship between oil temperature and viscosity, and examples of selection are shown in Table 11.5.

Table 11. 4 Bearing Types and Proper Viscosity of Lubricating Oils

Bearing Type	Proper Viscosity at Operating Temperature
Ball Bearings and Cylindrical Roller Bearings	Higher than 13mm²/s
Tapered Roller Bearings and Spherical Roller Bearings	Higher than 20mm²/s
Spherical Thrust Roller Bearings	Higher than 32mm²/s

Remark 1mm²/s=1cSt (centistokes)

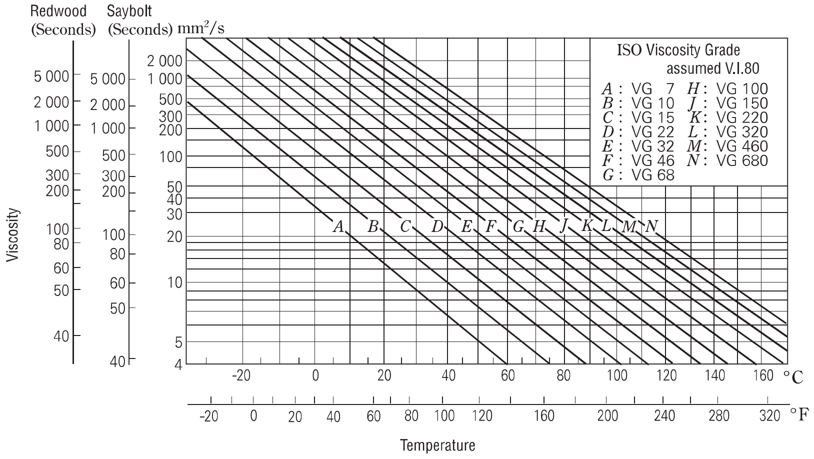


Fig. 11.11 Temperature-Viscosity Chart

Oil Replacement Intervals

Oil replacement intervals depend on the operating conditions and oil quantity.

In those cases where the operating temperature is less than 50°C, and the environmental conditions are good with little dust, the oil should be replaced approximately once a year. However, in cases where the oil temperature is about 100°C, the oil must be changed at least once every three months.

If moisture may enter or if foreign matter may be mixed in the oil, then the oil replacement interval must be shortened.

Mixing different brands of oil must be prevented for the same reason given previously for grease.

Table 11. 5 Examples of Selection Lubricating Oils

Operating Temperature	Speed	Light or normal Load	Heavy or Shock Load
−30 to 0 °C	Less than limiting speed	ISO VG 15, 22, 32 (refrigerating machine oil)	–
0 to 50 °C	Less than 50% of limiting speed	ISO VG 32, 46, 68 (bearing oil, turbine oil)	ISO VG 46, 68, 100 (bearing oil, turbine oil)
	50 to 100% of limiting speed	ISO VG 15, 22, 32 (bearing oil, turbine oil)	ISO VG 22, 32, 46 (bearing oil, turbine oil)
	More than limiting speed	ISO VG 10, 15, 22 (bearing oil)	–
50 to 80 °C	Less than 50% of limiting speed	ISO VG 100, 150, 220 (bearings oil)	ISO VG 150, 220, 320 (bearing oil)
	50 to 100% of limiting speed	ISO VG 46, 68, 100 (bearing oil, turbine oil)	ISO VG 68, 100, 150 (bearing oil, turbine oil)
	More than limiting speed	ISO VG 32, 46, 68 (bearing oil, turbine oil)	–
80 to 110 °C	Less than 50% of limiting speed	ISO VG 320, 460 (bearing oil)	ISO VG 460, 680 (bearing oil, gear oil)
	50 to 100% of limiting speed	ISO VG 150, 220 (bearing oil)	ISO VG 220, 320 (bearing oil)
	More than limiting speed	ISO VG 68, 100 (bearing oil, turbine oil)	–

Remarks
1. For the limiting speed, use the values listed in the bearing tables.
2. Refer to Refrigerating Machine Oils (JIS K 2211), Bearing Oils (JIS K 2239), Turbine Oils (JIS K 2213), Gear Oils (JIS K 2219).
3. If the operating temperature is near the high end of the temperature range listed in the left column, select a high viscosity oil.
4. If the operating temperature is lower than -30°C or higher than 110°C , it is advisable to consult NSK.

11.4 Technical Data

11. 4. 1 Brands and Properties of Lubricating Greases

Table 11. 6 Brands of Lubricating Greases

Brands	Thickeners	Base Oils	Dropping Point (°C)	Consistency	Working Temperature Range(1)(°C)	Pressure Resistance	Usable Limit Compared to Listed Limiting Speed(Grease)(2)(%)
EA3 GREASE	Urea (3)	Poly-α-olefin oil	≧260	230	−40 to +150	Fair	100
EA5 GREASE	Urea (3)	Poly-α-olefin oil	≧260	251	−40 to +160	Good	60
EA6 GREASE	Urea (3)	Poly-α-olefin oil	≧260	220	−40 to + 160	Fair	70
EA7 GREASE	Urea (3)	Poly-α-olefin oil	≧260	243	−40 to +160	Fair	100
EA9 GREASE	Urea (3)	Poly-α-olefin oil	≧260	314	−40 to +140	Fair	100
ENS GREASE	Urea (3)	Polyol ester oil (4)	≧260	264	−40 to +160	Poor	100
ECE GREASE	Lithium	Poly-α-olefin oil	≧260	235	−10 to +120	Poor	100
DOW CORNING(R) SH 44 M GREASE	Lithium	Silicone oil (5)	210	260	−30 to +130	Poor	60
NS HI-LUBE	Lithium	Ester oil + Diester oil (4)	192	250	−40 to +130	poor	100
LG2 GREASE	Lithium	Poly-α-olefin oil + Mineral oil	201	199	−20 to +70	Poor	100
LGU GREASE	Urea (3)	Poly-α-olefin oil	≧260	201	−40 to +120	Fair	70
EMALUBE 8030	Urea (3)	Mineral oil	≧260	280	0 to +130	Good	60
KP1 GREASE	PTFE	Perfluoropolyether oil	Not applicable	290	−30 to +200	Fair	60
SHELL ALVANIA GREASE S2	Lithium	Mineral oil	181	275	−10 to +110	Fair	70
SHELL ALVANIA GREASE S3	Lithium	Mineral oil	182	242	−10 to +110	Fair	70
SHELL SUNLIGHT GREASE 2	Lithium	Mineral oil	200	274	−10 to +110	Fair	70
WPH GREASE	Urea (3)	Poly-α-olefin oil	259	240	−40 to +150	Fair	70
NIGLUBE RSH	Sodium Complex	Glycol oil	≧260	270	−20 to +140	Fair	60
PALMAX RBG	Lithium Complex	Mineral oil	216	300	−10 to +130	Good	70
MULTEMP PS No.2	Lithium	Poly-α-olefin oil + Diester oil	190	275	−50 to +110	Poor	100
MOLYKOTE(R) FS-3451GREASE	PTFE	Fluorosilicone oil	Not applicable	285	0 to +180	Fair	70
UME GREASE	Urea (3)	Mineral oil	≧260	272	−10 to +130	Fair	70
RW1 GREASE	Urea (3)	Mineral oil	≧260	300	−10 to +130	Fair	70
HA1 GREASE	Urea (3)	Ether oil	≧260	290	−40 to +160	Fair	70
HA2 GREASE	Urea (3)	Ether + Poly-α-olefin oil	≧260	295	−30 to +170	Fair	70
KLUBERSYNTH HB 72-52	Urea (3)	Ester oil	250	295	−30 to +160	Fair	70
NOXLUB KF0921	PTFE	Perfluoropolyether oil	Not applicable	280	−40 to +200	Fair	70
ECH GREASE	Carbon Brack	Perfluoropolyether oil	Not applicable	205	−30 to +260	Fair	60
FWG GREASE	Urea (3)	Mineral oil + Poly-α-olefin oil	≧260	268	−30 to +150	Fair	70
HT1 GREASE	Urea (3)	Poly-α-olefin oil	≧260	236	−40 to +150	Fair	100
ARAPEN RB320	Lithium-Calcium	Mineral oil	177	305	−10 to +80	Fair	70
SHELL GADUSRAIL S4 HIGH SPEED EUFR	Lithium	Mineral oil	188	266	−10 to +110	Fair	100

Notes (1) If grease will be used at the upper or lower limit sufficient of the temperature range or in a special environment such as vacuum, it is advisable to consult NSK.
(2) For short-term operation or when cooling is grease may be used at speeds exceeding the above limits provided the supply of grease is appropriate.
(3) Urea-based grease causes fluorine-based material to deteriorate.
(4) Ester-based grease causes acrylic rubber material to swell.
(5) Silicone-based grease causes silicone-based material to swell.