

# Lubrication basics

Elearning course transcript.

## Summary

Welcome to this course, which looks at the basics of lubrication. We hope you will enjoy learning with us, and find the material useful in your daily work.

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## Special notes for iPad users

For iPad users, this course plays in the “Articulate mobile player app”, available free from the App store. The app offers a download option for offline learning, but please note that:

1. An on-line connection is required to use the links on the “resources” tab.
2. If you wish to be able to print your course completion certificate then you need to be on-line when you take the end-of-course test.

To continue, you can click the Home icon on the screen to return to the Welcome page of the course.

### 1. Module 1 – Introduction

#### 1.1. Welcome

##### 1.1.1. Course structure

Welcome to this interactive course which looks at the basics of lubrication. The course comprises four lessons, supported by some additional learning resources.

There’s also a test at the end of the course. If you pass the test then you will be able to download and print your own course completion certificate. Click on the lesson titles here to view the learning objectives for each of the lessons.

### 2. Module 2 - Lessons

#### 2.1. Lesson 1: Basics

##### 2.1.1. Lubrication and bearings

A challenge in today’s world is to take the best advantage of assets available, and bearings are not excluded from this premise.

Unfortunately, many bearings fail prematurely due to several reasons related with poor maintenance practices.

What is your experience of bearing failure in your plant?

##### 2.1.2. Reasons for premature bearing failure

SKF experience suggests that, generally speaking, about half of those premature failures are typically related with poor lubrication or contamination. These figures do vary from industry to industry.

##### 2.1.3. Good lubrication is important

But, what is meant by “poor” lubrication? Poor lubrication practices include:

- Applying an unsuitable lubricant
- inadequate quantities of lubricant
- Failure to follow the required relubrication intervals.

Moreover, bear in mind that often, once the bearing has been properly installed and sealed, the only contact that it will have with the exterior will be by means of any lubricant that may be added from time to time.

Therefore, providing clean and cool lubricant is another key element of a maintenance program, when if the life span of a machine component is to be maximised.

Improper relubrication practices can also destroy seals, allowing the ingress of external contaminants. Based on these facts, and on the data presented on the previous slide, we could therefore say that with a proper lubrication program in place, we could help to control about half of premature bearing failures!

Our elearning course “Introduction to Lubrication Management” offers more information about what a good lubrication management program should encompass.

##### 2.1.4. Friction

Friction can be defined as the force resisting the relative motion of two bodies.

Many parts of a machine actually rely on friction for their operation, for example brakes, clutches, belt drives, and even fasteners such as the nuts and bolts which hold the machine together.

In many other machinery parts, however, friction is undesirable since it can create heat, wear, and increased energy consumption.

##### 2.1.5. Bearings and lubrication

Minimising friction between moving parts is a primary function of a bearing.

However, in order to achieve longer life and lower energy consumption, friction within the bearing has to be minimised

This is the main objective of a bearing lubricant, thereby minimising wear.

### 2.1.6. Lubrication

Additional functions of lubricants are:

- Protection against corrosion,
- Sealing against external media, and
- Cooling (as in the case of oils)

### 2.1.7. Viscosity:

A lubricant can be considered as a stack of layers which will slide as a relative movement between the surfaces takes place. Viscosity is a measure of the internal friction between these layers.

Viscosity is often thought of as the resistance of a given fluid to flow. This is easily understood by comparing, for example, what happens when we try to pour honey with what happens when we try to pour wine.

### 2.1.8. Dynamic and kinematic viscosity

Dynamic viscosity is determined by measuring the resistance to flow. The measurement unit for dynamic viscosity is the Poise (P), named after scientist Jean Poiseuille. It is more commonly expressed in terms of centipoise (cP), this being equal to the SI multiple milliPascal seconds (mPa·s).

By dividing the dynamic viscosity of a fluid by the density of the fluid, the kinematic viscosity value is found. This is the measurement that is used for commercial purposes, in order to characterize a lubricant. The measurement unit for kinematic viscosity is the stokes (St), named after George Gabriel Stokes. It is more commonly expressed in terms of centistokes (cSt) or in terms of mm<sup>2</sup>/s (1 cSt = 1mm<sup>2</sup>/s).

### 2.1.9. Viscosity classification: ISO3448

ISO has defined a series of standard ranges for viscosity as defined in the table shown here.

An ISO VG (viscosity grade) is defined by a mid point with a possible deviation of 10%

For example, ISO VG 100 denotes an oil that has a kinematic viscosity of 100 cSt, plus/minus 10%, @ 40°C i.e. the viscosity is in the range 90cSt to 100 cSt.

Notice that an oil of (for example) 85 cSt may exist but there is no ISO classification for such a lubricant.

As a general rule, low viscosities are used for high speeds, low temperatures and low pressures while high viscosities applied for opposed conditions

From an application point of view, lighter oils (normally up to VG 22) are used for pneumatic applications, higher viscosities (traditionally between VG 32 and VG 68) for hydraulic systems.

ISO VG 100 and 150 are commonly found in circulation systems, while viscosities between VG 220 and VG 680 are found in gear applications.

Heavier viscosities can be found in, for example, open gear applications.

### 2.1.10. Viscosity classification: Other classification scales

Although ISO aims to provide a standard scale for viscosity measurement, several other scales are also used, and this table presents a comparison between some of them.

Notably, SAE scales are specially meant for automotive applications while AGMA ones have been designed for gear applications.

Click on the download icon to obtain a copy of the comparison chart for future reference.

### 2.1.11. Viscosity index

Viscosity is affected by several factors, like load, ageing or stress. However, for practical applications, the most relevant variable is temperature.

The degree by which viscosity reduces as the temperature rises is assessed by means of the viscosity index (VI). This is calculated by means of measuring the viscosity at 40°C and 100°C.

In the example shown here, two ISO VG 100 oils with different viscosity index are compared. Although at 40°C the viscosity is the same, at 100°C, the oil with a viscosity index of 135 reports a higher value compared with the oil having a viscosity index of 95.

### 2.1.12. Types of friction

To understand the characteristics of friction in a little more details, consider what happens as a plain bearing starts from standstill and gradually increases in speed. The graph shown is commonly known as a “Stribeck curve” and illustrates the types of friction present on that plain bearing as it increases in speed.

On the vertical axis, the friction value is represented in a logarithmic scale, while on the horizontal axis, a parameter that combines speed, viscosity and pressure is shown

With a given viscosity and pressure, as the speed increases, the friction starts at a high value in a condition known as “boundary friction” which is characterized by the entwining of the asperities of the surfaces in contact.

Rather quickly though, the surfaces start to separate from each other by means of the lubricant, creating a condition known as “mixed friction”

Later on, when the two surfaces are completely separated, the minimum friction value is achieved. This is the start of a condition known as “fluid friction”. Under such condition, the surfaces are no longer in contact.

However, a given amount of friction arises from the internal resistance of the fluid separating the surfaces

Such resistance could be identified with what we know as “viscosity”.

The ideal working condition would be somewhere after the minimum friction point.

The reason for choosing such point is simply to provide additional protection to the surfaces in case of e.g. overload, in order to avoid “falling back” into the mixed friction zone.

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### 2.1.14. Kappa value (K):

Still thinking of the Stribeck curve, consider now what happens if speed and pressure remain constant, but the viscosity varies.

At a given speed, the viscosity required to achieve the minimum friction point (i.e. provide complete surface separation) is known as the “required viscosity”. This is normally identified as  $V_1$ .

The ratio between the actual viscosity ( $V$ ) and the required viscosity ( $V_1$ ) is known as the Kappa value.

General rules state that the Kappa value should fall in the range of 1 and up to 4

Values higher than 4 provide no extra benefit and could rather generate high temperature due to the excess of fluid friction inside the lubricant.

Some applications, normally related with slow rotation or oscillating movements, can not always achieve a kappa value over 1.

Under such conditions, the formulation of the grease and its additive package are crucial to ensure a proper lubrication condition.

### 2.1.15. Lubrication mechanism in rolling bearings

Lubrication mechanism in rolling bearings is slightly different from plain bearings. Consider what happens in a ball bearing when a ball reaches the load zone. Both the element and the race get deformed, creating an elliptical area of contact.

As the surfaces flatten, a high pressure zone is created where the lubricant is compressed.

What effect do you think this compression has on the viscosity of the lubricant?

### 2.1.16. Elastohydrodynamic lubrication

The lubricant is compressed in the pressure zone created as the surfaces flatten.

This dramatically increases the viscosity of the lubricant. Given the elastic deformation that it created, this phenomenon is called Elastohydrodynamic lubrication

### 2.1.17. Recap

Let’s take a moment to review some of the things that we covered so far. Try to complete the following exercises without referring back to the previous pages.

### 2.1.18. Lubricant types

Let’s now move on and take a look at the different types of lubricants available. Click the buttons above to learn more about each type.

### 2.1.19. Lubricant types: Liquid

The most common liquid lubricants are oils, which are primarily sourced from petroleum. These are known as mineral oils.

Some formulations can be modified in a laboratory, creating what we know as synthetic oils.

Additionally, some animal and vegetable oils are used specially in food processing industry.

Finally, additional liquid lubricants can be formed by means of dispersions or emulsions; most common examples are dispersions of graphite in water or emulsions of silicone.

#### 2.1.20. Lubricant types: Semi-solid

When we add some structure to wrap the oil and keep it in place, the result is a semi solid lubricant.

The first form is a wax which is basically a by-product of the petroleum refining process that remains solid at ambient temperature

Another typical example is bees wax.

A grease is made by the addition of a thickener to an oil in a proportion that can be up to 30%

Greases are the most common way of lubricating bearings due mainly to its ability to stay in place.

Unlike a grease, a paste has normally little oil but high amounts of solid lubricants and it is designed for the lubrication of surfaces that will have very small movements or will be subjected to high temperatures or corrosive environments.

Mounting pastes like SKF LGAF 3E are used in order to avoid fretting when mounting e.g. a bearing in a housing and might be applied on the surface of the outer ring in order to avoid wear when axial movements take place given temperature expansion

Other types of pastes, normally called anti seize pastes use metallic particles like copper or nickel in order to avoid thermal seizure e.g. in threaded unions subjected to extreme temperatures up to 1000°C

#### 2.1.21. Lubricant types: Solid

Solid lubricants are normally used as additives in liquid or semi solid lubricants, but they are sometimes applied, in the form of powder or resins, to surfaces typically exposed to sliding movements. A classic example is the graphite powder that is typically applied to a door's lock.

#### 2.1.22. Lubricant types: Gaseous

Finally, some mechanisms can be lubricated by means of compress air, creating a "cushion" around the shaft

#### 2.1.23. Additives

An oil has a base that can be normally either mineral or synthetic and then an additive package that can include several types of additives. Click on the tabs to learn more about the most common types of additives.

#### 2.1.24. Detergents / dispersants

Detergents and dispersants are most commonly found in engine oils.

Detergents are intended to remove the soot particles created by the combustion process. The purpose of dispersants is to keep those particles separated in order to avoid the formation of larger size particles that would have tougher impact on lubrication films and which could clog filters more easily.

#### 2.1.25. Friction modifiers

Friction modifiers are a series of additives designed to minimize the contact of surfaces. They normally have a polar head and an oil-soluble tail. The "heads" of such compounds chemically react with the surface while the tails create a kind of "carpet" that protects the surface. A typical anti wear additive is the ZDDP (Zinc dialkyldithiophosphate).

When the contact load expected is higher, then Extreme Pressure (EP) additives are used. These ones are normally made of sulphur and phosphorus compounds and require a higher reaction energy. Bear in mind that the formation of a protection film means that such layer will be sacrificed, therefore these type of additives should only be used if needed. A typical industry practice is to use EP lubricants for applications not subjected to such conditions, and therefore unnecessary wear can be created by means of those additives. Solid lubricants like MoS<sub>2</sub> or Graphite are another way of create surface separation, specially under very high loads and very low speeds.

#### 2.1.26. Foam inhibitors

Foam inhibitors are normally silicon compounds that aim to alter the surface tension of the oil, thus helping to burst the bubbles.

#### 2.1.27. Corrosion inhibitors

In the context of lubrication, the term corrosion refers to the degradation process that takes place on the component to be lubricated, caused by the environment which surrounds it. Corrosion is typically produced by the effect of air or water. The purpose of corrosion inhibitors is therefore to prevent contact of water with the surface in a manner similar to the friction modifiers. Typical compounds used for such purpose are amine succinates and alkaline earth sulfonates.

#### 2.1.28. Oxidation inhibitors

Just like corrosion takes place on the component being lubricated, oxidation may occurs in the bulk of the oil. Therefore compounds like Zinc dithiophosphates, hindered phenols and diphenyl amines are used in order to decompose the peroxides under formation and to inhibit the formation of free radicals that otherwise would lead to varnish formation.

#### 2.1.29. Adhesion improvers

The purpose of adhesion improvers intend to make sure that the oil stays in place. This property is crucial, for example in chain oils

#### 2.1.30. VI Improvers

Typically Polymers and copolymers of olefins, methacrylates, dienes or styrenes, they intend to

minimise the impact of temperature in the change of viscosity of an oil. They do this by “uncurling” themselves like a spiral thus physically increasing the viscosity of a given oil

#### 2.1.31. Pour point depressants

The pour point of a liquid is the temperature at which it becomes semi solid and loses its flow characteristics. At low temperature, crystals of wax begin to form inside an oil. These additives intend to avoid such phenomenon and are usually based on Polymethacrylate (PMA) and Styrene Ester compounds.

#### 2.1.32. Emulsifiers and demulsifiers

Emulsifiers cause water to be entrained in the oil, whilst demulsifiers cause water to be separated from the oil. They are based on surfactants, glycols, alcohols or soaps.

Emulsifiers are used when small quantities of water are expected, while the demulsifiers are used when large amounts of water are present.

#### 2.1.33. Grease: Thickened oil

A grease is normally defined as a “thickened oil” and is generally compared with a sponge that releases oil while it is being pressed. This concept might come from the appearance of a Lithium soap. However, not all the greases have the same structure and in fact, the thickener used is dictated to a large extent by the intended application.

While Lithium greases are used for general applications, lithium complex greases are used to provide extended relubrication intervals.

Polyurea is typically used for high temperature and high speed applications (for example electric motors) while Calcium sulphonate complex is becoming widely used for heavy applications with vibration and where water contamination is a concern.

In general terms, a grease comprises a large portion of oil (up to 95%), thickener (up to 30%) and additives (up to 10%).

#### 2.1.34. Grease: Consistency

Just as viscosity defines an oil, consistency defines a grease.

Similar to the way in which has defined viscosity grades, the National Lubricating Greases Institute (NLGI) has defined a consistency scale.

Consistency is measured by letting a cone fall into a sample at 25°C and measuring how deep it goes in tenths of a millimeter.

An NLGI 2 consistency means that, in such a test, the cone fell between 265 and 295 tenths of a millimeter. While bearings normally use NLGI 1,2 or 3, low consistencies are typically used for centralised

lubrication systems or gearboxes, and higher consistencies are applied for sealing purposes, for example in valves.

#### 2.1.35. Grease or oil?

While grease is the most common type of lubricant applied to bearings, given the ease of installation and its natural capability to remain in place and seal the application, oil becomes the choice when high temperatures or high speeds are in place. Additionally, oil allows the possibility to install a filtration system in order to remove contamination particles. However, grease is still to be preferred when frequent start/stop conditions are present.

## 2.2. Lesson 2: Performance tests

### 2.2.1. Grease production

Grease production is a delicate business. The image shows two greases that, although having used identical formulations, had different production conditions, leading to completely different products.

While one process generated an NLGI 2 grease, the other one led to an NLGI 00.

Likewise, other properties like corrosion protection or relubrication intervals are affected depending on the raw materials and process used.

The conclusion is clear: although two greases might report similar formulations, their performance is not necessarily the same; how then to decide between two different greases that look alike?

### 2.2.2. Grease characteristics

When choosing a grease for a bearing application it is very important to select a grease which has characteristics appropriate to the operating conditions to which the grease will be subjected.

Greases can be characterised in a number of ways, some of which are shown here. Click each icon to learn more about each of these, and how these properties are assessed.

### 2.2.3. Mechanical stability: Definition and test

Mechanical stability is the structural stiffness of a grease when submitted to load and impact. The consistency of a grease will change when the grease starts to work. If the consistency doesn't change much when working then the grease is said to have a good mechanical stability.

A basic test performed to measure this is the “prolonged penetration test” in which a grease sample is subjected to 100,000 double strokes in a device called a “grease worker” and then its consistency is measured again.

The lower the change, the more “mechanically stable” is the grease. This characteristic is crucial when selecting greases for many applications, e.g. vibrating machinery. SKF performs additional tests to assess the characteristics of the grease in order to ensure its suitability for a given application.

#### 2.2.4. Mechanical stability: Additional tests

SKF performs additional tests to assess the characteristics of the grease in order to ensure its suitability for a given application. Two additional tests performed to assess the mechanical stability of a grease are:

1. Roll stability test: In this test, a grease sample is placed in a cylinder with a roller inside. Standard ASTM D 1403 requires that the test is performed for 2 hours at room temperature. However, SKF modified the standard procedure making the cylinder roll at 165 rpm during 72 or 100 hours at 80 or 100 °C. At the end of the test, the cylinder is cooled down at room temperature, consistency is measured and the variation is indicated in tenths of mm.
2. V2F: A railway grease box is submitted to 1 HZ vibration shocks produced by a 50Kg hammer, reaching an acceleration level of 12–15 g. After 72 hours at 500 rpm, the grease that has leaked from the support through the labyrinth seal is gathered on a tray. If this grease weighs less than 50 g, it gets a score of “m”; if not, it’s considered a “fail”. Then, the test goes on for another 72 hours at 1,000 rpm. If there’s a leak of less than 150 g, it gets a score of “M”, showing the suitability of the grease for highly loaded and vibrating applications

#### 2.2.5. Protection against corrosion: SKF Emcor test

Lubricating greases should protect metal surfaces from corrosive attack in service. The corrosion protection properties of rolling bearing greases are evaluated using the SKF Emcor method, which is standardised under ISO 11007.

Under this test method a mixture of lubricating grease and distilled water is present in the bearing.

The bearing alternates during a defined test cycle between standstill and rotation at 80 rpm.

At the end of the test cycle the degree of corrosion is evaluated according to a scale between 0 (no corrosion) and 5 (very severe corrosion).

A more severe test method is to follow the standard test procedure, but to replace the distilled water with salt water.

In addition the variation shown in the slide, called “water washout test” is carried out by continuously

allowing water to flow or wash through the bearing arrangement during the test cycle.

#### 2.2.6. Protection against corrosion: Test results

This corrosion test is a useful guide to the protection provided by a lubricating grease in the event of a bearing becoming constantly contaminated with water and normally leads to the failure of greases formulated with water-soluble corrosion inhibitors.

The results of water wash out are believed to be significant with respect to service performance.

#### 2.2.7. Grease lubrication capacity

In this test, the lubrication capacity of the grease under variable load, temperature and speed conditions is evaluated.

Two specially designated Spherical Roller Bearings (22312 EWMA/C3P VQ420) are submitted to specific load, temperature and speed conditions.

- Test A: After the first 24 hours at room temperature wear is measured.
- Test B: If < 25 mg of wear is measured in the rollers and < 100 mg in the cages, test continues at higher temperature (normally 120°C) until completing 20 days. An approval means that the grease is adequate for use with large bearings at high temperatures keeping the same wear limits.

#### 2.2.8. Grease lifespan

The SKF ROF grease test machine determines the maximum operating speed, load, grease life and high temperature performance limit for a particular grease. Ten deep groove ball bearings are fitted into 5 housings and filled with a given quantity of grease.

Speed, temperature and both axial and radial load can be adjusted and those conditions are applied to the bearings until they fail.

The time to failure is recorded in hours and a Weibull life calculation is made at the end of the test period to establish the grease life.

The longer the number of running hours in the test unit, the more effectively the grease lubricates under those conditions.

This information can then be used in the determination of relubrication intervals in an application.

#### 2.2.9. Load capacity

This test gives an indication of the load capacity of the grease sample. The device has 3 balls held in a cup over which a third one is placed, with the lubricant to be tested in between. Two tests can then be performed : The 4 ball weld load test. This method evaluates the EP (Extreme Pressure) performance of a lubricating grease. This test method is standardized under DIN 51 350/4.

Three steel balls are held in a cup and another fourth ball is rotated against the three balls at a given speed. A starting load is applied and increased at predetermined intervals until the rotating ball seizes and welds to the three stationary balls. The test indicates the point at which the extreme pressure limit of the grease is exceeded. Greases can be considered as EP greases when the weld load is higher than 2600 N.

**The 4 ball wear scar test** This test is performed with the same rig used in the 4ball weld load test. 1400 N are applied on the fourth ball for a period of 1 minute. Then the wear on the three balls is measured. The industry standard test uses a load of 400 N. However, SKF uses an increased load of 1400 N in order to make the test relevant for bearing applications.

#### 2.2.10. Typical grease data sheet

In this lesson we learned how SKF has developed a series of performance tests in order to simulate real working conditions and to assess the capabilities of a given grease.

These results, along with additional industry standards, are reported in the technical data sheets of SKF Greases.

### 2.3. Lesson 3: Grease selection

#### 2.3.1. A four step process

In order to select a grease, 4 main steps have to be considered:

1. Determine the temperature range under which the grease is required to work.
2. Based on the speed, bearing geometry and temperature, define the required viscosity of the lubricant.
3. Based on the load conditions select the additional characteristics required of the lubricant.
4. Based on the working conditions and environment, verify compatibilities and any additional characteristic required from the grease.

#### 2.3.2. Step 1: Temperature – Effect on grease performance

A given grease has an ideal working temperature range that depends on its formulation and production process. In general, at low temperatures greases tend to become stiffer and therefore the oil released might become insufficient and the friction increases. This phenomenon is called “starvation”.

Conversely, at high temperatures the oil bleeding will be increased and the oxidation process of the lubricant will be accelerated.

#### 2.3.3. Step 1: Temperature – Traffic light concept

SKF has developed this “traffic light” concept to illustrate the behaviour of grease throughout the temperature range.

The extreme temperature limits, low and high, are well-defined.

- The low temperature limit (LTL), the lowest temperature at which a grease enables the bearing to be started up without difficulty, is largely determined by the base oil and its viscosity.
- The high temperature limit (HTL) is determined by the type of thickener and its dropping point. The dropping point is the temperature at which a grease loses its consistency and becomes a fluid.

The temperature range for reliable operation is indicated by the SKF values for the following limits:

- low temperature performance limit (LTPL)
- high temperature performance limit (HTPL)

Within these two limits, which is indicated by the green zone, the grease fulfils its function reliably and the relubrication interval or grease life can be determined accurately.

Since the definition of the high temperature performance limit is not standardized internationally, care must be taken when interpreting supplier data.

#### 2.3.4. Step 1: Temperature – Grease life

SKF does not recommend using a grease above or below its temperature limits (in the red zones) to lubricate bearings.

At temperatures above the high temperature performance limit (HTPL), grease degrades with increasing rapidity and the byproducts of oxidation have a detrimental effect on the lubricant. Therefore, temperatures in the amber zone, between the high temperature performance limit (HTPL) and the high temperature limit (HTL), should only be allowed to occur for very short periods and not longer than a few hours.

An amber zone also exists for low temperatures. With decreasing temperature, the consistency (stiffness) of grease increases and the tendency of grease to bleed decreases. This ultimately leads to an insufficient supply of lubricant reaching the contact surfaces of the rolling elements and raceways. This temperature limit is indicated by the low temperature performance limit (LTPL). Values for the low temperature performance limit are different for roller bearings than for ball bearings. Since ball bearings are easier to lubricate than roller bearings, the low temperature performance limit is less important for ball bearings. For roller bearings, however, serious damage can result when the bearings are operated continuously below this limit.

Short periods in this zone, such as during a cold start, are not harmful because the heat caused by friction brings the bearing temperature into the green zone.

### 2.3.5. Step 1: Temperature – SKF greases; temperature range

In this table, taken from SKF publication 10000 “Rolling bearings”, the temperature ranges for several SKF greases can be found.

Bear in mind that when consulting a product data sheet, the operating temperature range will be defined by LTL and HTPL.

Peak temperatures (upper yellow zone) are indicated separately.

### 2.3.6. Step 2: Speed - speed factor

The next step is to establish the speed conditions. The “speed factor” (usually referred to as “A”) is calculated by multiplying the rotational speed of the bearing times the mean diameter of the bearing. The mean diameter is calculated as shown.

This calculation provides a value among 0 and about 1.2 millions for rolling bearing applications

A given value can be classified as low, or high, depending on whether we’re referring to ball or roller bearings according with the table shown.

Notice that ranges are lower for roller bearings. For example a speed factor of 300,000 would be considered “high speed” for a roller bearing, but only “medium speed” for a ball bearing.

### 2.3.7. Step 2: Speed – Exercise

Consider this bearing, type 61868 running at 500 rpm. Within which speed range would this fall? Refer back to the table on the previous slide if necessary.

### 2.3.8. Step 2: Speed – Required viscosity

Let’s continue now with the same example; A bearing type 61868 running at 500 rpm, and we will assume an operating temperature of 70 degrees Celsius.

The next step is to calculate the minimum grease viscosity required that will be needed to properly separate the bearing surfaces.

In the previous exercise we established that the mean diameter (Dm) for this bearing is 380mm.

By applying this mean diameter and the rotational speed to this chart, we can see from the vertical axis a rated viscosity ( $V_1$ ) of approximately 11 cSt. This value ( $V_1$ ) represents the minimum viscosity required at the operating temperature.

### 2.3.9. Step 2: Speed – ISO Viscosity Grade

We saw earlier that technical specifications for lubricants typically provide viscosity data in terms of the ISO VG classification. The next step is to determine the

ISO Viscosity Grade (ISO VG) that we need, to provide this required viscosity ( $V_1$ ) at our operating temperature of 70°C. We must now remember that ISO grades are defined at a temperature of 40°C, and so a further calculation is needed to allow for the higher operating temperature.

Locate the  $V_1$  value (11cSt) from the previous slide on the vertical axis of this chart, then project that value until it crosses the operating temperature (70°C) from the horizontal.

The point found lies between the curves of ISO VG 22 and 32.

Note that the chart shown is only valid for mineral oils with viscosity index of 95.

### 2.3.10. Step 2: Speed – Kappa values

In the “basics lesson” we learned about the “kappa value”, which you may remember is the ratio between the actual viscosity (V) and the required viscosity ( $V_1$ ). We just established that, for our sample application, the  $V_1$  value is 11 cSt.

Using the data from this chart we can see that, if we use a lubricant with a mineral oil having a viscosity index of 95, and an ISO viscosity grade 22, then we will get 9 cSt at the operating temperature of 70°C., providing a kappa value of 0.8.

Similarly, we see that using an ISO VG 32 lubricant we get a kappa value of 1.2.

In the basics lesson we learned that the kappa value should ideally be between 1 and 4.

Values below 1 will require additional additives in order to provide effective surface protection, while values over 4 will not provide extra benefits and on the contrary, it can only add fluid friction, which might increase the application temperature, specially at high speeds.

A key parameter in identifying the most suitable kappa value is the load condition, which takes us to the next step in our process.

### 2.3.11. Step 3: Load – Load ratio

In order to define the “load ratio” we have to identify two values:

1. The basic dynamic load rating (C) of the bearing
2. The equivalent dynamic bearing load (P), = the real load applied to the bearing.

The bearing’s basic dynamic load rating can be obtained from the technical information, for our example 178 kN. The actual bearing load is normally a design parameter and is not always easy to determine accurately in the field. However, the application conditions can give us an indication of the type of load applied. For example, high speed applications like electric motors, or some fans, are normally subjected to low to medium loads. Low

speed applications (for example crushers or mills) are typically related to high loads. Coming back to the kappa value, we would choose higher values for heavier loads and lower values for lighter loads.

### 2.3.12. Step 3: Load – EP additives

Finally, some additional recommendations are:

- Use EP additives when
  - C/P <5
  - Shock loads are present
  - The application has frequent start/stop conditions
- Pay attention to mechanical stability (i.e. the change of consistency with the work) when high vibrations. We'll come back to this latter
- Solid lubricants are normally advised when speed factor falls below 30.000

### 2.3.13. Step 3: Load – Recap

So far, we have identified that for the bearing considered, we would need about an ISO VG 32 in order to provide effective separation of the bearing surfaces. From this point on the selection process will be largely directed by the load, environmental and working conditions of the application.

In order to illustrate this aspect of the selection process we will compare four SKF greases:

LGMT 2, which is a general purpose grease

LGWA 2, which is a wide temperature grease

LGFP 2, which is a food grade grease

and

LGLT 2, a high speed, low temperature grease.

Click on the images to download the data sheet for each of these greases. You should print or save these documents; you will need to refer to them in the next part of this lesson.

### 2.3.14. Step 3: Load – SKF Bearing calculator

In order to simplify the comparison process, we will use the SKF Bearing Calculator. This is an easy-to-use, on-line tool for bearing selection and calculation. It is available online at [www.skf.com](http://www.skf.com) under “knowledge-centre/engineering-tools”. It's also available as an “app” for phones and tablets. You can find the app at the [Apple AppStore](#) or [Google Play](#).

We will now see how the tool can provide us with the information that we need for the first of our four greases, LGMT 2. Then you can use the tool yourself to do the calculations for the other greases, LGWA 2, LGFP 2, and LGLT 2.

If you're viewing this course on-line then you can go directly to the tool by clicking on the icon above. When

the page opens in your browser, click the “Open tool” button.

1. Now click the “select bearing” link in the tool's left navigation, and
2. enter the designation of our example bearing into the search.
3. Click “search bearings” and then
4. confirm the result by clicking the 6168MA designation that appears in the “my bearing type” area.
5. Check the box for a “Viscosity” calculation then
6. Click continue.

### 2.3.15. Step 3: Load – SKF Bearing calculator – Application data

1. Enter the speed and operating temperature into the fields provided.
2. Select Viscosity calculation input type = Viscosity input at 40°C and 100°C.
3. Refer to the grease LGMT2 data sheet and enter the base oil viscosity values at 40°C and 100°C.
4. Then click “calculate”

### 2.3.16. Step 3: Load – SKF Bearing calculator – Results

Now make a note of the results for 1-4 as indicated here. Then use the SKF Bearing Calculator to obtain the same data for the other three greases under consideration, LGWA 2, LGLT 2, LGFP 2. Make a note of the results for all of these greases. If you wish you can download and print a worksheet on which you can write the results of the calculations.

### 2.3.17. Comparisons

If you've completed the previous exercise in full then the results of your calculations should look like this.

In summary, LGMT 2 provides a Kappa value of 2.68, LGWA 2 provides 3.98.

LGFP 2 provides a Kappa value of 2.12, and LGLT 2 provides 0.78.

In order to determine the most suitable grease for our example, we now need to consider the application conditions.

- LGMT 2 has shown that it would provide a sufficient film to separate the surfaces under normal conditions and this would be the logical selection if the application was subject to low loads.
- However, for applications subjected to higher loads LGWA 2 would be a more appropriate choice, given its higher base oil viscosity and additization. Grease LGWA 2 would also provide extended relubrication intervals when compared with LGMT 2, an aspect that we will investigate in the next lesson.

- For even more heavily loaded applications, or for applications involving strong vibrations, greases with even stronger additization (for example LGEP 2) might be recommended. Another parameter to consider under such conditions would be the results of mechanical stability tests: prolonged penetration, rolled stability and SKF V2F.
- Grease LGFP 2 would be an appropriate choice for an application subject to low or medium loads, which requires a food grade grease.
- For the application conditions stated in this exercise grease LGLT 2 would provide a kappa value below 1, and would therefore not be recommended, especially if medium loads or vibrations are present.
- However, if the application was running at higher speed, for example 2000 rpm (instead of 500 rpm), then the speed factor would be 4 times higher, falling into the “extremely high” speed range. Under such hypothetical conditions, LGLT 2 would certainly become a highly suitable grease.

#### 2.3.18. Comparisons – Additional grease properties

In a real-world situation there may be several lubricants that fulfil the required specifications.

In order to make the most appropriate final selection a number of additional characteristics must be taken into account. Explore the images above to learn more about some of these.

1. Temperature: Similar greases may provide different relubrication intervals, depending on the temperature range of the grease. Be sure to take the dropping point of the grease into account.
2. Viscosity index: If the application will be subject to wide temperature variations then selecting an oil with a higher viscosity index would be advantageous.
3. Pumpability: Not all the greases perform the same when automatic lubrication systems are in place. Some might be too difficult to pump. In other cases the pressure of the system may cause separation of the oil from the thickener, thus forming blockages of thickener in the pipework.
4. Mechanical stability is a key parameter when selecting a grease that must endure high loads and vibrations. Reported values of tests like prolonged penetration, rolled stability and SKF V2F are of value in such applications.
5. Corrosion protection: Applications exposed to high water contamination or any other corrosive environment will require special properties from the grease. Results from tests such as the SKF Emcor test are crucial for this purpose.

6. Lubrication ability: Tests like SKF R2F provide valuable information regarding the performance of a grease under specific conditions and temperature ranges.
7. Relubrication interval: The relubrication intervals provided by a given grease are closely tied to its formulation and quality. Tests like SKF ROF provide comparison parameters to enable appropriate grease selection.
8. Food grade: The food processing industry requires lubricants with special certifications such as NSF H1, which allows incidental contact of the lubricant with the foodstuff being processed.
9. Biodegradability: Forestry or agriculture related applications should be lubricated with biodegradable substances where risk exists of environmental contamination.
10. Compatibility: It is advisable to verify the compatibility of the lubricant to be used with previous lubricants that may have been used. Also check for compatibility with sealing materials or even bearing materials.

#### 2.3.19. Step 4: Compatibility

A selection of compatibility charts is offered here; click the tabs to view them. Tables like these indicate the compatibility of different thickeners and base oils with each other. This is especially important when replacing an existing grease with a new one.

The compatibility of sealing materials with different base oils must also be checked when new lubricants are to be introduced.

You should also bear in mind that some EP additives might be harmful for brass or polyamide cages, especially above 100°C.

Contact your SKF representative for help in verifying the compatibility of an SKF lubricant for your application.

#### 2.3.20. SKF Grease selection chart

The SKF Maintenance products catalogue provides a selection chart like this along with additional technical information about SKF lubricants. This publication, used with the approach demonstrated in this lesson, can help you to make an appropriate grease selection for a basic application.

If you need more assistance, or if your application involves factors not covered in this training, then please contact your local SKF representative.

## 2.4. Lesson 4: Relubrication

### 2.4.1. Relubrication

Rolling bearings have to be relubricated if the service life of the grease is shorter than the expected service life of the bearing. Relubrication should always occur while the existing Lubricant is still satisfactory.

### 2.4.2. Relubrication: Why is it necessary?

As grease works in a given application, a degradation process will take place. In order to keep proper lubrication conditions, fresh grease should be applied on a regular basis.

The relubrication intervals will depend on the working conditions and the properties of the grease. This aspect of grease performance should always be considered when comparing the purchase price of different greases. While a given grease might have a higher purchase price, the relubrication intervals might be substantially larger, leading thus to reduced grease consumption. Where manual relubrication is being undertaken it may also lead to reduction in maintenance time and less bearing exposure.

### 2.4.3. Relubrication interval – factors

The time at which the bearing should be relubricated depends on many related factors.

These include:

- bearing type and size
- speed
- operating temperature
- grease type
- space around the bearing
- bearing environment

It is only possible to base recommendations on statistical rules. The SKF relubrication intervals are defined as the time period, at the end of which 99% of the bearings are still reliably lubricated. This represents the L1 grease life.

The SKF handbook “Rolling bearings” provides these statistical rules in the form of some tables that we will be referring to in this lesson. You can download a copy of these tables by clicking the image on this page.

### 2.4.4. Relubrication interval calculation – Speed factor

One of the things that we discussed in the “grease selection” lesson was the “speed factor (A)” of a bearing. We will need this information to help determine the relubrication interval.

Can you remember how this was calculated?

### 2.4.5. Relubrication interval calculation – Example application data

For the purposes of this lesson we will continue with the same application example that we used for the “grease selection” exercises; the application details are repeated here, and you may remember that we calculated the bearing’s speed factor (A) to be 190,000.

In the “grease selection” lesson we also discussed the “load ratio” of a bearing; you may recall that this is the ratio of the bearing’s dynamic load rating (C) and the actual bearing load (P).

### 2.4.6. Relubrication interval calculation – Bearing factor

First step in calculating the relubrication interval is to compare the applicable speed factor with the speed limits shown in this table, taking into account the bearing type and load ratio.

If the speed factor A exceeds 70% of the recommended limits, this is normally an indication that the heat generation might not be properly dissipated by the application and oil lubrication might be required. Please contact the SKF application engineering service for assistance with such applications.

If speed factor for the application is less than 70% of the recommended limits, multiply the Bearing factor found times the speed factor.

Our example is based on a deep groove ball bearing, and so the bearing factor is 1.

The speed factor of our 61868MA bearing is 190,000; this is less than 70% of the speed limits given for all of the load conditions for a deep groove ball bearing.

### 2.4.7. Relubrication interval calculation A.Bf

By referring to this chart, and drawing a vertical line representing the A.bf value we establish the different relubrication intervals applicable to various load conditions. Note that the vertical scale is logarithmic. For light load conditions the relubrication interval could reach 10,000 hours. For very high loads the interval would be reduced to only 2,000 hours, in which case an alternative grease might be considered, having better properties than the mineral oil + Lithium thickener to which this chart refers. Referring back to our “grease selection” lesson, this would be a situation when LGWA 2 would likely be chosen instead of LGMT 2 grease. A detailed discussion regarding the influence of lubricant viscosity on the speed factor is outside the scope of this course. The SKF publication “Rolling bearings” (Pub 10000) provides more information on this topic.

### 2.4.8. What do you think?

How do you think an increased operating temperature would affect the lubrication interval?

#### 2.4.9. Relubrication interval: Temperature impact

To account for the accelerated ageing of grease with increasing temperature, SKF recommends halving the obtained intervals

for every 15 °C (27 °F) increase in operating temperature above 70 °C (160 °F). The high temperature performance limit HTPL for the grease should not be exceeded.

The relubrication interval may be extended at temperatures below 70 °C (160 °F) if the temperature is not close to the lower temperature performance limit LTPL. SKF does not recommend extending the relubrication interval by more than a factor of two.

Do not extend the obtained values for full complement bearings or thrust roller bearings. Moreover, it is not advisable to use relubrication intervals in excess of 30,000 hours.

#### 2.4.10. SKF automatic lubricators

SKF has used its lubrication expertise to develop suitable lubrication systems that properly feed lubrication points, thereby creating synergy between SKF lubricants and SKF lubrication systems.

The SKF lubrication systems portfolio provides a comprehensive range of products from user friendly and cost-effective single point automatic lubricators (like those shown here) to complete centralised lubrication systems engineered for specific application(s).

This screen shows SKF System 24 units, which are supplied ready-to-use straight from the box and filled with a wide range of high performance SKF lubricants. Tool-free activation and time-setting allow easy and accurate adjustment of lubrication flow.

#### 2.4.11. SKF DialSet

SKF DialSet has been designed to help you to set up SKF automatic lubricators, and also provides a quick and simple tool for relubrication intervals and quantity calculations. After selecting the criteria and grease appropriate for your application, the program provides you with the correct settings for your SKF automatic lubricators.

The stand-alone version of DialSet can be downloaded from SKF.com and is available in 11 languages: English, French, German, Italian, Spanish, Swedish, Portuguese, Russian, Chinese, Japanese and Thai. The program is suitable for PC's working with MS Windows XP and later. Download it from [skf.com/lubrication](http://skf.com/lubrication) DialSet is also available online from SKF.com, in the English language.

For smartphones, apps are available in English for iPhone and Android. simple tool for relubrication intervals and quantity calculations.

#### 2.4.12. SKF DialSet: Example application data

In this screenshot of DialSet online, we we have entered the details of our example application.

Notice that moderate contamination, moderate load, no shock loads, average ambient temperature, horizontal shaft, replenishment from the side of the bearing and rotating inner ring have been selected.

In this case, under "Grease" we have selected "unspecified" which means that: "A grease with mineral oil and a lithium base thickener that can perform adequately when the operating temperature is 70 °C " is considered.

Dialset provides two values for the relubrication interval: The first value indicates the maximum feasible relubrication interval, under ideal conditions, for this example 10,300 hours.

The "corrected value" represents the recommended interval taking into account the real operating conditions. conditions are considered; for the specified operating conditions this is reduced to 3,600 hours.

#### 2.4.13. SKF DialSet: Grease LGWA 2

Now, let's select LGWA 2 gease, instead of LGMT 2. Notice that some greases can not be selected. This is because those greases are not suitable under the selected parameters.

When selecting LGWA 2 for the same operating conditions, the corrected relubrication interval is adjusted to 5400 hours

Which means an extension of 50%!

Let's consider for a moment the benefits of this:

- Reduced grease consumption
- Fewer relubrication tasks, which translates to a reduction in maintenance time plus less risk of contamination
- Reduced disposal costs
- Less environmental impact
- Overall = lower total cost!

#### 2.4.14. Lubrication feature - W33 suffix bearings

Some series of SKF bearings are equipped with a groove and holes in their outer ring to facilitate easier relubrication.

These bearings are identified by the suffix W33 in their designation. The illustration here shows a cutaway of a 23268\_CA\_W33 bearing.

While relubrication intervals depend on many factors, relubrication quantities depend only on bearing dimensions and design". Formulae to calculate these quantities are shown here. It can be seen that this method of relubricating the bearing significantly reduces the amount of lubricant that is required..

#### 2.4.15. Maintenance free units

SKF has developed specific types of bearings that are virtually maintenance free under given conditions.

Examples include:

- SKF Solid Oil bearings; suitable for many food grade applications
- High temperature bearings; designed to work at low speeds and high temperatures
- Sealed spherical roller bearings, providing additional protection against contamination with virtually no relubrication needed.

For details on these (and other) solutions please contact SKF's application engineering service.

#### 2.4.16. Automatic relubrication

Performing manual relubrication tasks can be a major challenge for lubrication technicians if the appropriate tools, practices and knowledge are not employed. Reliability can also be affected by under- or over-greasing and contamination. Automatic lubrication provides small quantities of clean lubricant on a regular basis, thus improving bearing performance. Additional benefits include increased safety and time savings for lubrication technicians.

#### 2.4.17. Range of relubrication systems

The SKF lubrication systems portfolio provides a comprehensive range of products from user friendly and cost-effective single point automatic lubricators to complete centralised lubrication systems engineered for specific applications.

#### 2.4.18. End of course test

Now it's time to see what you learned.

If you pass the test on-line then you'll be able to print your course completion certificate.