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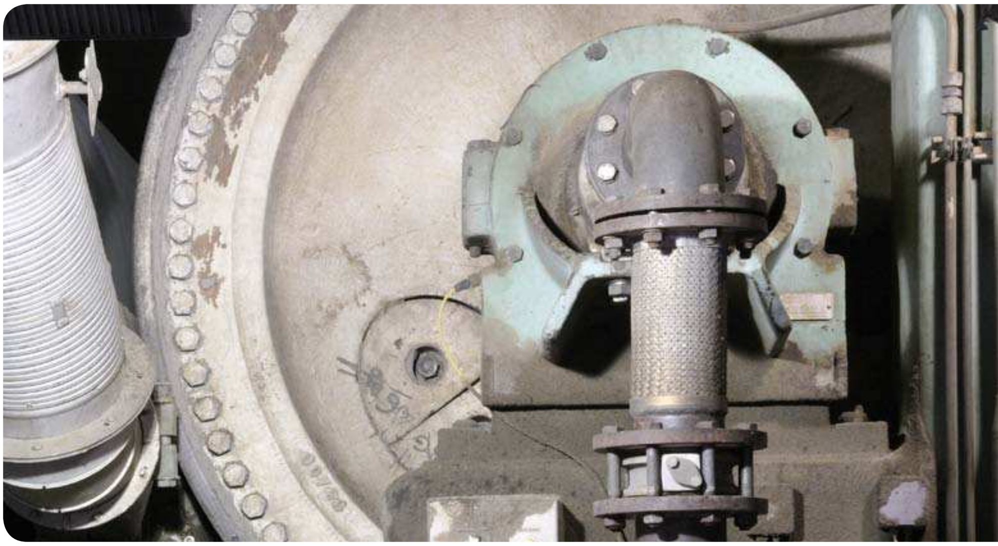
SKF Pulp & Paper Practices



I do not want to be called an "expert"

"After 22 years of working as an SKF engineer with the paper industry, I'm still in learning mode. That said I have developed some principles during this time that help me with both my professional and personal life".

My first principle is that 'just because it has always done that way doesn't mean it is a good way to do it.' My second is based on a quote from Gandhi: "An error does not become truth by reason of multiplied propagation, nor does truth become error because nobody sees it." My third and final principle is that 'by illuminating the past, the present becomes clearer.'

Years ago, I remember having to supervise the mounting of some drying cylinder bearings. The fitters were from an outsourced maintenance company. Some of them had been bakers the week before! In charge of the team was an older man who they all called "boss". The boss explained to his team how to use feeler gauges to check bearing clearance and how to mount bearings on tapered seats. He told them to reduce the bearing clearance to the minimum permissible residual clearance value.

Not wanting to contradict the boss in front of his team, I waited until we were alone to explain that he shouldn't aim for minimum permissible residual clearance as it could lead to premature failures – even maybe leading to cracked inner rings – especially for drying cylinder bearings with C4 or C5 clearance class.

The boss explained to me that he had worked for more than 20 years for a crane manufacturer, that he had always mounted spherical roller bearings in this way and that he had never had any complaints. He had little time for the young SKF engineer, fresh out of college, who told him that crane bearings weren't C4 clearance and the risk was much lower of getting too tight a fit.

The boss later retired. He became a bearing mounting trainer and taught people his way of doing things. The bearing catalogue didn't warn readers about minimum permissible radial clearance and that it could be easily misunderstood. So, error became truth for a while.

These days, you won't find information about minimum permissible radial clearance in new SKF bearing catalogues. We learned and we've taken it away. Nevertheless, ever since that day I'm never entirely comfortable when a colleague introduces me as an expert.

Regards,
Philippe Gachet
Senior technical consultant
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Drying and Yankee cylinder bearings and their lubrication (Part II)

In this edition of SKF Pulp & Paper Practices I will continue my coverage of drying and Yankee cylinder bearings that I started in the previous issue. Given this, I recommend that you read issue six again to refresh your memory.

As promised last time, I'll address a number of important topics in this issue: bearing steel and heat treatment, bearing clearance class, oil selection and oil flow rates.

Bearing steel and heat treatment

As we saw in the previous issue, the inner rings of bearings in drying and Yankee cylinder applications have to withstand high hoop stress especially during machine start-up. This can crack them though the risk is higher with certain steel types and heat treatment methods than with others.

Consider first martensitic through-hardened steel. The vast majority of bearings that are made use this as it provides adequate hardness at comparatively low cost. Unfortunately, there are residual tensile stresses near the surface in such steel. This is because the structure of steel changes during the heat treatment and its volume increases as it cools, but the surface cools quicker than the core. This leads to a situation where the core needs to increase in volume while the surface is already hard and cannot deform. This creates tensile stresses near the surface where micro cracks can develop due to classic fatigue or surface-initiated fatigue. If there is a very tight fit of the bearing on its seat or – like in drying cylinder applications – the seat is much hotter than the inner ring, tensile stress near the surface is increased.

Take the example of a drying cylinder bearing made from martensitic steel with a residual tensile stress near the surface of 80 Mpa (11 600 psi). Assume that a tight fit leads to a hoop stress of 50 MPa (7250 psi) and that thermal radial shaft expansion due to the steam adds another 50 MPa (7 250 psi) stress in the ring. This adds up to 180 MPa (26 100 psi) total tensile stress which is slightly above the 175 MPa (25 375 psi) maximum that we recommend for through-hardened rings. While 175 MPa (25 375 psi) is not an absolute maximum since new bearings without any surface damage can withstand more, it is a practical maximum based on field experience where, as we know, rings don't stay in brand new condition for ever.

Compare the example above with bainitic through-hardened or case-hardened steel which have residual compressive stresses near the surface after heat treatment. With premium bainite bearing steel, for instance, with compressive stresses of say 125 MPa (18 125 psi), the total stress – assuming the same conditions – is 25 MPa (3 625 psi) compressive. This is why micro cracks in the subsurface propagate more slowly in such steels and why they are more crack resistant.

Be aware, however, that not all bainitic steel is created equal. Take, for example, the last two generations of SKF bainitic through-hardened steel used in our spherical roller bearings, CARB and spherical roller thrust bearings. While the residual compressive stresses are more or less the same, the latest generation has four times more grains per unit of area and a finer structure. As such, the crack resistance is much higher than with the previous generation. You can read more about this, if you're interested, in issue four of SKF Pulp & Paper Practices.

Case-hardened steels, because they have a soft core, are difficult - though not impossible - to crack. While I have never come across an SKF case-hardened spherical roller bearing mounted on a Yankee or drying cylinder with a cracked inner ring, I have seen it on bearings from some other manufacturers. Another thing worth remembering about case-hardened bearings is that they do not necessarily reduce the risk of surface damage or subsurface fatigue. In fact, some have lower fatigue resistance than modern through-hardened bainite steels.

Another important issue is heat stabilization. The SKF bearings used in Yankee and drying cylinder applications are heat stabilized to 200°C (392°F). This does not mean that there will not be any dimensional changes due to temperature. Rather it means that such changes are limited and acceptable. Acceptable to SKF means changes within the following boundaries:

Metric:
0 to +10 µm/100 mm with 150 °C stabilisation at 150 °C during 2,500 hours
–15 to +5 µm/100 mm with 200 °C stabilisation at 200 °C during 2 500 hours

Imperial:
0 to +0.0254 in /10 in with 302 °F stabilisation at 302 °F during 2 500 hours
–0.0381 in to +0.0127 in /10 in with 392 °F stabilisation at 392 °F during 2 500 hours

Martensitic steel bearings with low (100–120 °C or 212–248 °F) heat stabilization will expand after a relatively short time running at 120 °C (248 °F). Years ago, when such bearings used to be mounted on drying cylinders, many lost their inner ring tight fit and sometimes rotated on the journal leading to wear. This led to maintenance staff increasing the drive-up along the taper seat to achieve a tighter fit thereby increasing the tensile stress and the incidence of cracked inner rings.

Let's consider the example of a spherical roller bearing, 23052 CCK/CW33, on a drying cylinder with no insulation and a steam temperature of 130 °C (266 °F). Inner ring dimensional changes will vary significantly depending on the steel used and the level of heat stabilization (see **figure 1**)

Considering residual stress, crack resistance and dimensional stability, you could conclude that bearings for drying and Yankee cylinder applications should be stabilized to 200°C (392°F) and case-hardened. In reality, things are not that clear cut.

60 years ago, SKF in Sweden proposed bainitic through-hardened bearings – heat stabilised to 200 °C (392°F) – for drying and Yankee cylinder applications. They became standard for this duty and later for all SKF spherical roller bearings made in Sweden. In contrast, SKF in the USA kept martensitic through-hardened bearings as standard and offered bearings with case-hardened inner rings for dryers and Yankees.

As a consequence, for several decades most European-designed paper machines used spherical roller bearings made from bainitic steel while those designed in the USA used martensitic bearings and case-hardened bearings for heated cylinders in the dryer section. To further complicate matters, some Beloit machines were designed by European subsidiaries and used bainitic steel bearings plus SKF Sweden had the capability to offer case-hardened bearings if requested by the customer.

For consistency, and because European machines were often sold to markets that favoured case-hardened bearings, SKF began recommending bearings with case-hardened inner rings for heated cylinders in the early 1990s. Many customers were satisfied with the standard bainitic steel and didn't change over, but some did.

So much for the history lesson, but times and technology move on. Based on our latest heat treatment developments and the installed base of paper machines with SKF standard bearings in their dryer sections, we updated our recommendations at the end of 2010.

So, what are SKF's current recommendations? Quite simply:

1 If the journals are insulated, bearings with case-hardened inner rings are not needed and standard SKF spherical roller bearings and CARB can be used.

2 If the journals are not insulated, standard SKF spherical roller bearings and CARB can be used if steam temperatures are below 170 °C (8.35 bars) or 338 °F (121 PSI). Otherwise, bearings with case-hardened inners ring should be fitted.

In SKF, spherical roller bearings and CARB bearings with case hardened inner ring are denoted by the suffix HA3. The exception is for SKF spherical roller bearings made in the USA which have the prefix ECB.

Example of 23040 bearing with a tapered bore and C4 clearance class:

- 23040 CCK/C4W33 (standard bainitic through-hardened steel)
- 23040 CCK/HA3C4W33 or ECB 23040 CCK/C4W33 (bearing with case-hardened inner ring)

One final word of warning - be careful if you speed up your old, uninsulated drying cylinders and increase the steam temperature above 170 °C at the same time. This could lead to problems unless you have suitable bearings mounted.

Fig. 1 – Inner ring dimensional expansion in µm/100 mm (inch/10 inch).

Operating time	Martensitic steel dimensionally stabilised at 120°C (248°F)	Martensitic steel dimensionally stabilised at 200°C (392°F)	SQS Salt Quench Martensitic steel dimensionally stabilised at 200°C (392°F)	SKF bainitic new steel dimensionally stabilised at 200°C (392°F)
10 000 hours	17 (0.0432)	5 (0.0127)	0,07 (0.0002)	0,05 (0.0001)
100 000 hours	70 (0.1778)	13 (0.0330)	0,31 (0.0008)	0,35 (0.0009)

Clearance class

If we disassemble a drying cylinder bearing and look at the operating marks on the outer ring raceway, we can see that the load zone is often around one-third of the circumference. This shows that the bearing has operated with more clearance than needed and that the load distribution is not optimised for the longest fatigue life. As we know, a slight preload is better if we want to achieve that (see **figure 2**)

The clearance needs, however, to be sufficient to avoid excessive preload during start up from cold when, because of the steam passing through the journal bore, there is a large difference between the temperature of the bearing inner ring and outer ring and a subsequent clearance reduction. The consequence is a smaller loaded zone once the machine has reached its steady state operating temperature.

Theoretically, a small preload is not a concern as it increases the fatigue life, but we should not forget that friction rises and consequently preload can increase - sometimes in an uncontrolled way - with a risk of jammed bearings. Furthermore, other things need to be considered:

1 Possible form errors of the housing and the journal
2 The mounting method used to get the right fit

The feeler gauge method is still widely used for mounting which can lead to a wide range of clearance reduction. In addition, incorrect mounting is relatively common with fitters trying to reach the minimum residual recommended clearance shown in old bearing catalogues. For drying cylinders, this results in too much clearance reduction.

All things considered, it is not a problem to play it safe and have more operating clearance than is needed in these applications because drying and Yankee cylinders are generally oversized.

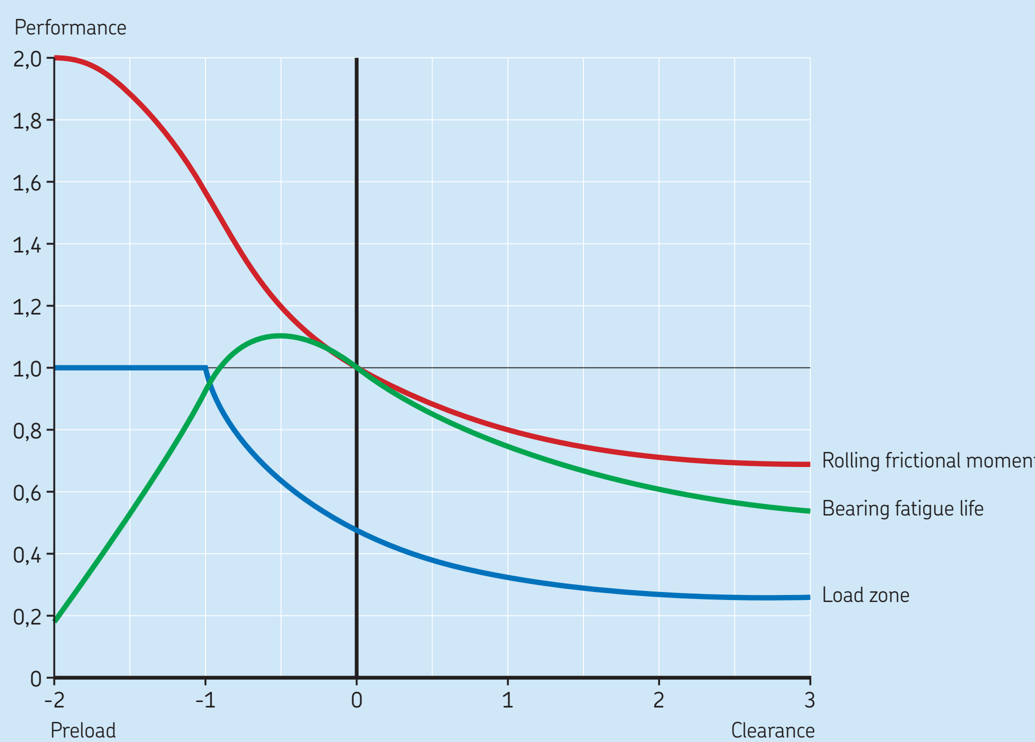
Over the years, C4 clearance class has become industry standard for drying and Yankee cylinders though C3 clearance is optimal in some cases. However, for cases with no journal insulation and steam temperatures greater than 165–170 °C (320–338 °F), we recommend C5 clearance.

Before moving on to talk about lubrication, there are a few things that I need to say about bearing selection. Initially, I didn't want to cover it as there is a lot of confusion about bearing life and because it really needs an article of its own but, on reflection, there are four points that I should make.

One, for the load calculation the mass of the cylinder and press load on the Yankee are always taken into account, but loads created by felt tension and the water inside the cylinder are often forgotten.

Two, it is generally accepted that the basic rating life (L10h), which only takes into account load and rotational speed, should be above 200 000 hours for drying and Yankee cylinder bearings. This is an old guideline and is longer than the bearings in other paper machine applications. It leads to oversized bearings and made sense in the old days to compensate for inadequate lubrica-

Fig. 2 – The influence of internal bearing clearance on fatigue life and friction.



tion and contamination. Today, the SKF rating life (L10mh) - which takes account of solid contamination (oil filter efficiency), surface separation in the rolling contact (the viscosity ratio) and the fatigue load limit of the material – allows a more realistic life to be calculated. However, the industry has not reached agreement on what the SKF rating life should be. Some manufacturers say that above 100 000 hours is fine, but others stick with the old 200 000 hour life. My personal view is that L10mh should be above 100 000 hours and that water content should be kept below 200 ppm with 500 ppm allowable during operation only.

Three, water content in the oil and its influence are not taken into account when calculating rating life. Dissolved water has an influence on bearing life, but different studies show different results. As no consistent results exist, it is not included in any rating life calculation.

Four, calculated rating life is not service life. Calculated rating life is used to choose a bearing for an application whereas the service life is the actual life of a bearing in an application. Individual bearing life can only be calculated statistically and life calculation only refers to a population of bearings with a given degree of reliability. Besides which, bearing failures in drying and Yankee cylinders are not generally the result of normal fatigue, they are mainly due to corrosion and inadequate lubrication.

Lubrication

Grease, oil bath and oil drop lubrication are not recommended for drying and Yankee cylinders. Quite simply, SKF recommends circulating oil lubrication on modern machines to maximize reliability.

In some cases, the same oil is used to lubricate the bearings used in the drying cylinders, the vacuum rolls, the felt rolls and the integrated gears. This is a compromise as suitable oils for gears and drying cylinders have different characteristics. Gears oils need EP additives which we don't recommend for drying cylinder applications.

With regards to Yankee cylinders, SKF recommends separate lubrication systems for the Yankee bearings, the external drive gearbox and the suction press or press roll. These are quite different applications and it is better to lubricate each with oils with suitable properties. Such an approach also prevents cross-contamination. For example, oil lubricating the suction press roll could be contaminated with water and the EP additives needed for gears which accelerate oil ageing and reduce bearing life drastically.

Let's move on to look at lubrication in more depth, but please note that what follows is applicable to drying and Yankee cylinder bearings only.

Oil flow and oil viscosity

Clearly, a certain oil flow rate is needed to cool dryer section bearings and ensure that the oil in the rolling contact has sufficient viscosity to create an adequate film thickness.

SKF uses the κ value (kappa) as an indicator of the surface separation in the rolling contact. It is a viscosity ratio.

$\kappa = \nu/\nu_1$

With
κ = viscosity ratio
ν = real operating viscosity of the oil, in mm²/s, at the bearing operating temperature
ν_1 = rated viscosity depending on the bearing mean diameter and rotational speed, in mm ²/s.

The SKF General Catalogue shows that the rated viscosity is the minimum viscosity with adequate lubrication in the rolling contact and also how to calculate it. The higher the value of κ, the better the surface separation. For κ above 4, the surfaces are completely separated.

As general guideline for paper machines, SKF recommends a κ value between 2 and 4. In the case of drying and Yankee cylinders, due to the high operating temperature and the relative low rotational speed of the bearings, most drying and Yankee cylinder bearings operate with κ below 1. Sometimes it can even be below 0.2 which results in boundary lubrication with surface distress and/or abrasive wear. This is especially true for old machines where the journals are not insulated. These old machines often run above design speed with increased steam temperature. For machines with uninsulated journals, old circulating oil systems and steam temperatures above 170 °C (338 °C) it's not uncommon for mills to complain about low bearing service life, cooked oil and oil leakage above certain oil flow rates.

The oil flow and oil viscosity will be chosen based on a κ calculation. SKF uses proprietary software called Drycyl to do this. Comparisons between calculations and measurements done by a leading paper machine manufacturer showed a high level accuracy with it.

As bearing temperature is mainly influenced by the steam temperature, the influence of the load can be ignored. The information needed is:

1. Bearing reference
2. Rotational speed
3. Steam temperature
4. Oil inlet temperature
5. The degree of insulation i.e. no insulation, bore only insulated or bore and journal end face insulated.
6. Whether saturated steam or superheated steam is used in for cases where there is no insulation.

Let's take an example:

- Bearing: 23148 CCK/C4W33
- Speed: 200 rpm
- Steam temperature (saturated): 177 °C (350 °F)
- Oil inlet temperature: 55 °C (130 °F)
- Oil: ISO VG 220 (the most common oil viscosity class in dryer sections)

Firstly, for a journal with no insulation, it can be seen that the κ value is below one even with high flow rates (see **figure 3**).

The first improvement could be to decrease the oil inlet temperature, but this means risking condensation in the bearing housing. Also, when the journal isn't insulated, decreasing the oil inlet temperature by 5 to 10 °C (9 to 18 °F) only has a small influence on the bearing temperature. Alternatively, we could try increasing the oil viscosity class from ISO VG 220 to a ISO VG 460 for instance (see **figure 4**).

The higher viscosity means there will be more friction in the bearing and its temperature will increase. Even if we selected oil with twice the viscosity, the increased viscosity at bearing operating temperature is less than 40% in this case. Furthermore, the risks of leakage due to flow resistance in the return ducts and pipes are increased which may mean the oil circulating system would have to be modified. So, let's try keeping the ISO VG 220 oil and good insulation on the bore and end face of the journal instead (see **figure 5**)

As you can see, just by good journal insulation we can achieve the κ value recommendations from the SKF General Catalogue with an oil flow just above 3 l/min (0.79 US gal/min).

That said, experience shows that many drying and Yankee cylinder bearing operate with κ values below 1 even if it doesn't follow SKF's general recommendations. So, based on field experience, SKF created a κ_{min} concept which is only valid for paper machines. κ_{min} is the minimum κ value above which experience shows that service life was still satisfactory.

κ_{min} = n.dm/80000

n = bearing rotational speed
d_m = bearing mean diameter (bore diameter + outer diameter, then divided by two).

If the formula gives a value below 0.25, then κ_{min} = 0.25.

In our example:

- Bore diameter of the bearing: 240 mm
- Outer diameter: 400 mm
- Speed: 200 rpm

κ_{min} = [200 x (240+400)/2]/80000 = 0.80

In this case, the journal needs to be insulated to reach a κ above 0.80. I would recommend, for this example, an oil flow between 3 and 3.5 l/min (0.79 and 0.92 USgal/min) with an alarm if the oil flow drops below 2 l/min (0.53 US gal/min). Another SKF engineer

Fig. 3 – Journal with no insulation (1 litre = 0.2642 US gallon).

Result

Oil flow l/ min	**Viscosity ratio kappa**	**Viscosity** mm ^{2}/s	**Bearing temperature** °C
0,5	0,27	8,2	136
1,0	0,31	9,3	130
2,0	0,35	10,8	123
3,0	0,38	11,5	120
5,0	0,40	12,0	118
10	0,41	12,3	117

Fig. 4 – Journal with no insulation and increased oil viscosity (1 litre = 0.2642 US gallon)

Result

Oil flow l/ min	**Viscosity ratio kappa**	**Viscosity** mm ^{2}/s	**Bearing temperature** °C
0,5	0,37	11,2	141
1,0	0,42	12,7	135
2,0	0,48	14,6	128
3,0	0,52	15,7	126
5,0	0,54	16,4	124
10,0	0,55	16,8	123

Fig. 5 – Journal with insulation (1 litre = 0.2642 US gallon)

Result

Oil flow l/ min	**Viscosity ratio kappa**	**Viscosity** mm ^{2}/s	**Bearing temperature** °C
0,5	0,67	20,4	98
1 ,0	0,81	24,7	91
2,0	0,95	28,8	87
3,0	0,99	30,2	85
5,0	1,03	31,3	84
10,0	1,03	31,3	84

could give slightly different recommendations based on the above calculations

A question that I'm often asked by mills experiencing oil leakage through housing seals due to flow resistance in the ducts and return pipes is to what extent oil flow can be reduced. One point to consider is that as the κ value drops when the oil flow is reduced, so the limit would be when the oil flow reaches the κ_{min} value. Another point is the limit under which there isn't enough oil in the bearing. This limit isn't very well documented and depends on many things. So, to make it simple and conservative, you can use the rule of thumb below.

Minimum oil flow = 0.00002 DB.
D = bearing outside diameter (mm)
B = bearing width (mm)

For a 23148 CCK/C4W33 bearing the minimum oil flow would be 0,00002 x 400 x 128 = 1,02 l/min. So, in the example, an oil flow giving the κ_{min} is just below 1 l/min (see **figure 5**) and the minimum oil flow is just above 1 l/min. So giving 1 l/min as lower limit seems adequate, but it doesn't change my recommendation for the above example.

If a customer has oil leakage at 1.5 l/min (0.40 USgal/min) and there is a need to have 3 l/min (0.79 US gal/min) to be above κ_{min} there is a problem. Either the oil return pipes were not dimensioned for 3 l/min (0.79 US gal/min) at that oil viscosity (which happens with old machines when the steam temperature is increased) or they got contaminated by aged black oil sludge. This reminds me of a customer who tried to use diesel engine oil as a lubricant hoping that the detergent additives would clean his circulating oil system. Also of another customer who made a mixture of white spirit and trichloroethylene and circulated it through his system during a shutdown. In most cases, the really effective solution is to change the oil return pipes.

Another issue is the oil flow when a machine starts. Cold oil or heated oil cooled by passing through cold inlet pipes has too high viscosity. Please take another look at John Yolton's story is SKF Pulp & Paper Practices 2 as there is a solution to this issue.

Note that the lower is the κ value, the more important the filtration efficiency.

- Filter rating β12=75 is a minimum
- Filter rating β6=200 is average today on paper machines, it was considered a very good filtration efficiency more than 20 years ago when I started at SKF.
- Filter rating β3=1000 is state of the art.

Which oil?

Well, let me start by saying that SKF does not recommend a specific brand or oil and that we used to simply leave the customers and the oil suppliers to choose lubricants. This changed after a spate of drying and Yankee cylinder bearing failures in the 1980s that studies indicated were related to inadequate oil formulations.

SKF and a leading European paper machine manufacturer worked closely to solve the issue and in 1988 SKF proposed a set of tests to validate oils for paper machine dryer sections. For practicality, only simple and/or well known tests that could be performed in a standard laboratory were chosen. Many oils that were marketed for paper machine dryer sections failed.

As a result, SKF concluded that the important properties for dryer section oils are:

- Thermal and chemical stability
- Stable viscosity
- Corrosion protection
- Water separation ability
- Cleanliness

***Fig. 6** SKF roller test (new rollers on the left). Rollers are placed in oil and put in an oven for 8 weeks. This test gives information on chemical corrosion and deposit formation. The oils tested are suitable in the case of the two middle rollers, but unsuitable for the two on the right.*

Thermal and chemical stability tests are critical. Oil for the dryer section has to prevent or reduce deposit formation in oil circulation, oil supply systems and rolling bearings. Even after long thermal stressing, the lubricating oil or the ageing products that are formed must not corrode rolling bearing parts chemically. Incipient etching, deposits or incrustation (crack products) interfere with lubrication and will ultimately damage the surface of the rolling contact.

As it ages, oil is darkened by finely suspended matter from oil, coal and cracked products and, as a result, flow meters and flow sight glasses clog or no longer indicate the oil flow correctly. (See **figures 6** and **7**)

Thin oil films must not resinify or form lacquer under thermal stress (see **figure 8**) as this may impair the lubrication system by clogging the oil supply lines or sight glasses. If brass cages are used in the rolling bearings and/or machine parts are made from copper or brass, the oil must not oxidise or corrode these non-ferrous metals.

Fig. 7 Two different mineral oils after 8 weeks at 120 °C (248 °F). The oil on the left is suitable while the one on the right is unsuitable.

Fig. 8 SKF oil ageing test. On the left is synthetic oil after four weeks at 140 °C (284 °F), it has lacquered and the evaporation loss is 93%. On the right is a mineral oil after 4 weeks at 120 °C (248 °F) with an evaporation loss of only 2%.

Thermal and chemical stability tests are undertaken at 120 °C (248 °F) and 140 °C (284 °F). In cases where bearing operating temperature is above 120 °C (248 °F), the results at 140 °C (284 °F) must be taken in account. For example, on a modern machine with insulated journals and where bearing operated at a temperature below 100 °C (212 °F), the results at 140 °C (284 °F) are not critical. Please note that mineral oils are not generally recommended for bearing temperatures above 120 °C (248 °F).

Minor out of tolerances in respect of the property parameters for corrosion protection, wear protection and water separation ability can be accepted under controlled conditions. The requirement in respect of corrosion protection is of minor importance if all free water is removed and water content is always kept near 200 ppm by adequate water/oil separators, for instance.

Going through all the tests and giving explanations would take several issues of SKF Pulp & paper Practices, so I won't do it. Most of the tests are standardised ISO and/or DIN ones. Instead, I will just append a copy of the results for one oil we tested. Please note that the artificial process water used for the EMCOR test and corrosion protection is based on five different process water formulations from different paper machines in Germany. Also, that the FE8 test is optional.

While SKF does not recommend any specific paper machine oil, we can undertake tests on behalf of our customers to determine whether oil is suitable or not. In order to do all the tests, we need 10 litres of fresh new oil. Please note that if the oil is rated as suitable as a result of the tests, this doesn't mean that SKF recommends it for the dryer section. It simply means that the sample tested is suitable. The reason to stress this point is that oil formulations can change without the product being renamed. Consequently, the infrared spectrum included in the test report is very important as it allows us to compare batches of oil simply by redoing this test. As such, I recommend that two litres of new batches of oil are kept as a precaution.

In conclusion, while we have devoted two issues of SKF Pulp & Paper Practices to drying and Yankee cylinder bearings, we could write a lot more. That said, judging by the questions that I get asked by mills at least, the most important issues have been dealt with.

requested by:	Customer
sample:	**1 oil** XYZ

lubricant analysis

Test of oil acc. to SKF requirements for circulating lubricating oils in paper machines

Investigation: acc. to SKF specification “Requirements to be met by circulating lubricating oils for dryer sections of paper machines”

Results: see enclosure 1

Infrared-analysis: see enclosure 2

Evaluation:

XYZ	SKF roller test (roller)	120°C +	140°C +	wear protection (four ball test)	-
	SKF roller test (oil)	-	-	SKF Emcor dist. H_2O artificial process water	 + -
	SKF oil film ageing test	+			
	copper protection	+		water separation ability	+
	FE 8 test	not ordered		cleanliness	-
	seal material compatibility	+		filterability	+

Test passed: +
Test failed: -

Conclusion:
The investigated oil showed poor thermal and chemical stability at 120°C and 140°C, though no incrustation, sludge formation and roller attack occurred; the increase of the viscosity was excessive, therefore the roller test is not passed.
The corrosion protection under the presence of distilled water was excellent, whereas the corrosion protection under the presence of artificial process water was insufficient.
The wear protection was determined with the four ball test and the obtained results were out of specification. Similar results can be excepted when additionally the FE8 test would have been done. This test was not ordered by the customer.
Also the cleanliness class was out of specification and therefore it is recommended to filter the oil during the filling of the paper machine.
All other test results were acceptable.
Due to the viscosity increase during the roller test and the insufficient corrosion protection, the oil can not be recommended for circulating lubrication of bearing in the dryer section of paper machines.

written by: Ch. Greubel STW4

distributed to: Customer, SKF Pulp & Paper Segment, STW4

enclosure 1

test results

oil designation: C3301/12 XYZ **material:** not known

test			test method	unit	results		requirement
chemical and thermal stability at 120°C	corrosion of rolling bearings	roller attack after 2 weeks 4 weeks 6 weeks 8 weeks	SKF roller test	rating	120°C 1 1 1 1	140°C 1 2 2 2	max. 2
	oil ageing	kinematic viscosity at 40°C after ageing	DIN EN ISO 3 104	mm²/s [% deviation]	245,1 +30,7	265,5 +68,6	max. +/- 20% from fresh oil
		sludge formation	visual	-	none	none	traces
		incrustation	visual	-	none	none	none
		colour after dilution 1:50 with n-Heptan	to VDEW colour chart	dye number	3…4	5…6	max. 6
	oil film stability	evaporation loss after 4 weeks	SKF method (only at 120°C)	[m-%]	7,0		max. 20 at 120°C
		oil film ageing		rating	1		max. 2 at 120°C
	corrosion of brass 120°C	copper strip test 48 h	DIN 51 759	rating number	1		max. 2
kinematic viscosity at		40°C 100°C	DIN 51 562-1	[mm²/s]	187,5 18,6		
corrosion protection; dist. water / artificial process water			SKF EMCOR DIN 51 802	degree of corrosion	0 / 0 2 / 2		max. 1
wear protection under 600 N/hour			DIN 51 350-3	[mm]	2,0		max. 1
water separation ability			DIN ISO 6614	[minutes]	15		max. 20
seal material compatibility			SKF method after 200 h NBR at 120°C FKM at 150°C	changes hardness Shore A weight [%]	hardness: NBR: +5,9 FKM: +2,2 weight: NBR: -4,7 FKM: -0,1		hardness: NBR +/-10Shore FKM +/-10Shore weight: NBR: +/- 10% FKM: +/- 5%
cleanliness		water content fluid contamination class	DIN 51 777-2 ISO 4406	[ppm]	<100 22/21/17		max. 200 max. 18/15/12
filtration			SKF method 12 µm	[minutes]	10		max. 15

evaluation:

requirements	satisfied	conditionally satisfied	not satisfied x
remarks			

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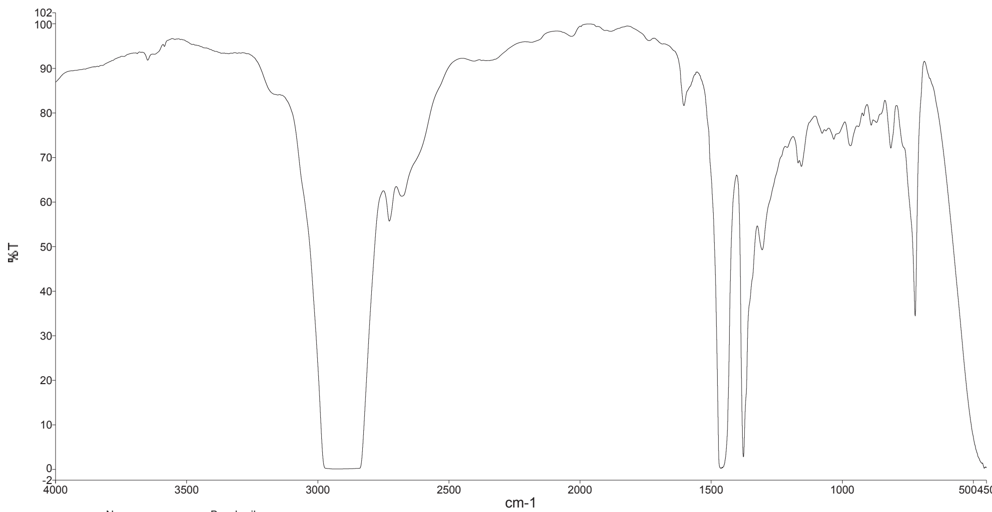
enclosure 2

Infrared analysis



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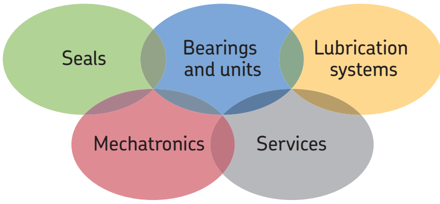

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SKF Global Pulp & Paper Segment

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