4 Dryer section

Dryer section

When the web has left the press section and enters the dryer section it has water content of 50–65%. Drying is completed in the dryer section so that the paper has an ambient moisture content level of 5–10%.

Drying is normally accomplished by moving the web along an S-shaped path over a double row of heated drying cylinders.

When starting up the machine, or when the web breaks, a strip of paper about 200 mm wide is pulled through the dryer section by means of two ropes running at the front side through pulleys and grooves in the cylinders. Compressed air is used in modern high-speed machines to blow the strip between the cylinders.

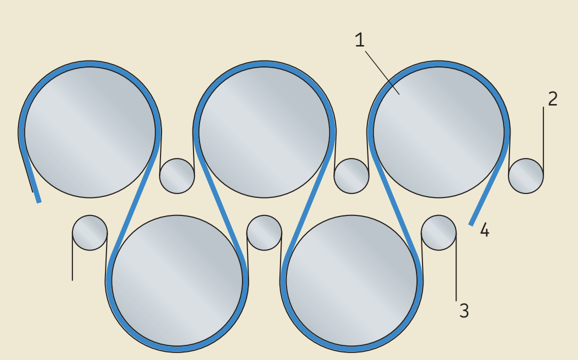
In modern paper machines, the whole of the dryer section is encased in an enveloping dryer hood and the ambient temperature inside the hood is 80–100 °C.

The felt run

The felt run consists of a double or a single (serpentine) felt. With the double felt, a top felt is used for the top row of cylinders and a bottom felt for the bottom row of cylinders (→ **fig. 1**). At high speeds, double felt runs can cause web flutter and currently a single felt run (→ **fig. 2**), where the web is supported the whole time by the felt, is used for high-speed machines.

Double felt run
1 Drying cylinder
2 Top felt
3 Bottom felt
4 Paper web

Fig. 1



Single felt run
1 Drying cylinder
2 Felt
3 Paper web

Fig. 2

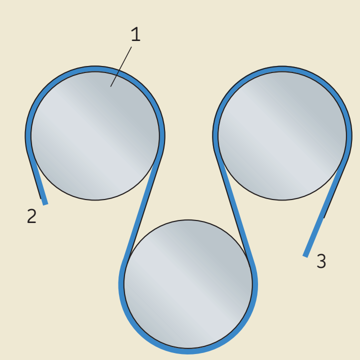
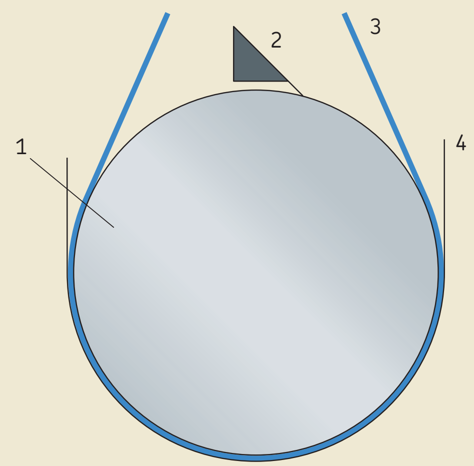


Fig. 3



Drying cylinder with doctor
1 Drying cylinder
2 Doctor
3 Paper web
4 Felt

Doctors

Drying cylinders are kept clean by means of doctors (→ **fig. 3**) which, in the event of web breakage, also stop the paper from getting wrapped around the cylinder. To prevent uneven wear of the cylinder surface by the doctor blade, the doctor oscillates axially by some 10–20 mm.

In the case of tissue paper, doctors are also used to crepe the paper.

Drying cylinders

The drying cylinders (→ **fig. 4**) are heated by steam. The temperature of the steam can vary between 125 and 210 °C, depending on the thickness of the paper, the speed of the machine and the size of the dryer section. The steam condenses into water when it comes into contact with the cooler surface of the cylinder. The water, together with steam, is extracted from the cylinder via a siphon pipe.

A dryer section may contain 40 to 100 drying cylinders, 1,5, to 2,2 m in diameter. A newsprint machine usually has 40 to 50 drying cylinders and a board machine 90 to 100 such cylinders.

A traditional dryer section is split up into drive groups (→ **fig. 5**). The paper speed for each drive group is individually adjustable to compensate for the contraction of the web as it dries.

A feature of modern drying sections is that the gear drive of each drying cylinder is replaced by a felt drive. Normally, the drying cylinder has a gear drive built into the machine frame at the drive side. However, the strength of the felts has increased greatly over the years. This has enabled application of felt drives where the drying cylinders are driven via the felt and felt rolls. When this type of drive system is employed, most of the drying cylinders have ordinary bearing housings at both sides.

Vacuum rolls

In modern dryer sections, vented steel rolls, known as vacuum or Vac rolls have replaced some of the drying cylinders. These rolls are connected to a vacuum pump and are used with single (serpentine) felt runs in positions where the web passes outside the felt. The partial vacuum in these rolls prevents the web stretching and perhaps folding under the influence of the centrifugal force. Vac rolls are placed in both bottom and top positions so that the paper web is treated equally on both sides.

Drying cylinder arrangement
1 Drying cylinder
2 Steam joint
3 Steam inlet
4 Siphon
5 Condensation
6 Journal insulation
7 Drive side bearing
8 Front side bearing
9 Gear drive

Fig. 4

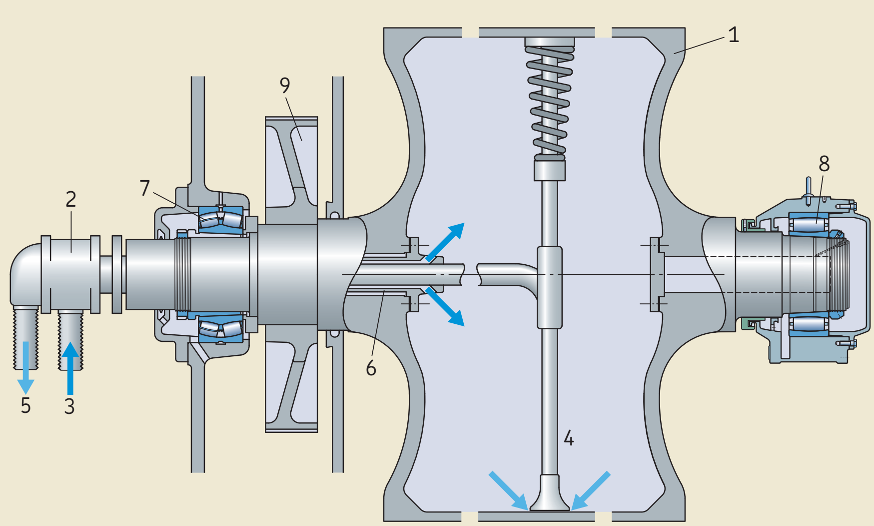
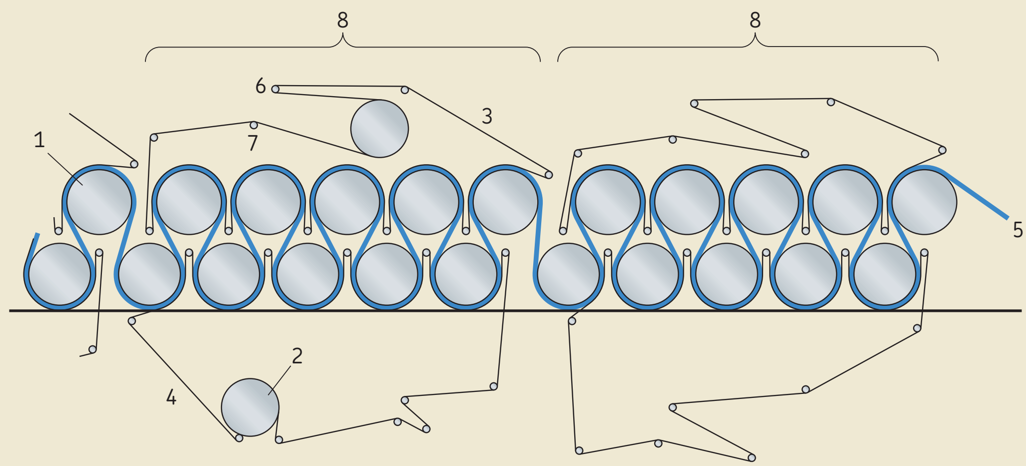


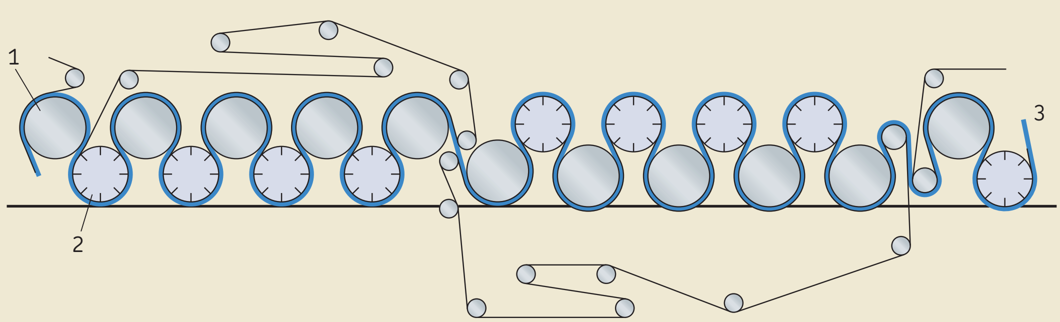
Fig. 5



Traditional dryer section
1 Drying cylinder
2 Felt drying cylinder
3 Top felt
4 Bottom felt
5 Paper web
6 Felt stretch roll
7 Felt guide roll
8 Drive group

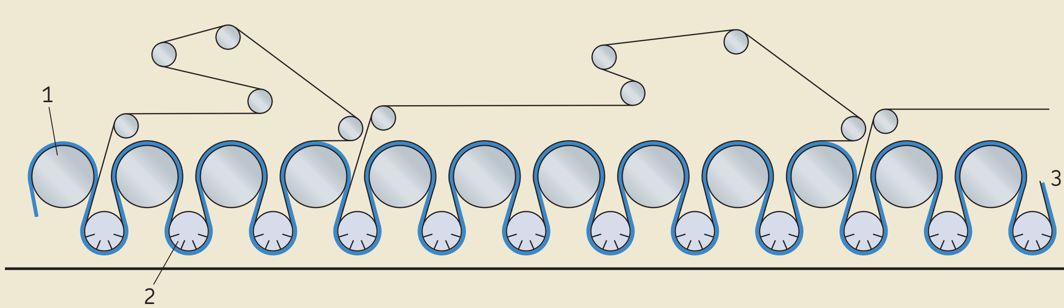
4

Fig. 6



Dryer section with Vac rolls, Metso
1 Drying cylinder
2 Vac roll
3 Paper web

Fig. 7



Voith Paper TopDuoRun dryer section
1 Drying cylinder
2 Vacuum roll
3 Paper web

Breaker stack
1 Drying cylinder
2 Guide roll
3 Solid press roll
3a Deflection-compensating press roll
4 Doctor
5 Felt
6 Paper web

Fig. 8

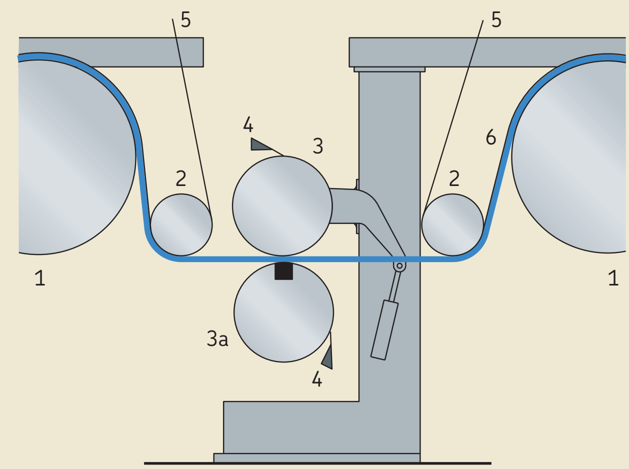


Fig. 6, shows a Metso dryer section with Vac rolls and **fig. 7**, **page 3**, the Voith Paper TopDuoRun dryer section.

New drying processes for drying section

There is an ongoing trend to shorten the drying section. This can be achieved by using

- some cylinders with extra high temperature
- belt drying systems, e.g. Condebelt from Metso
- air drying systems.

Breaker stack

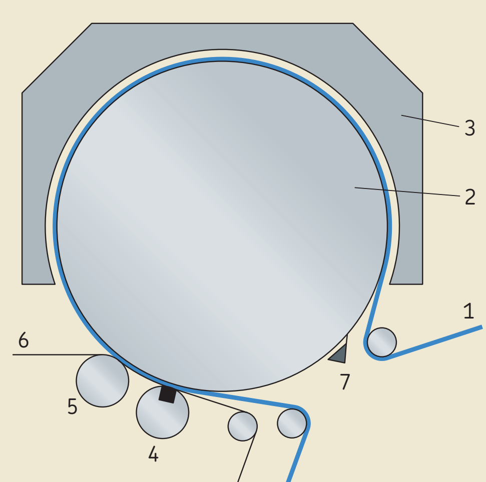
The breaker stack (→ **fig. 8**) is positioned in the dryer section and consists of two driven steel rolls, one of which may be a deflection-compensating roll. The stack is used to achieve a smoother paper than can be obtained solely by the machine calendering process. It is also assumed that the breaker stack presses the water from the interior to the outer layer of the web and, by so doing, facilitates subsequent drying.

The linear load is usually 10–20 N/mm.

Yankee cylinders

A Yankee (MG) cylinder is used for drying the web in the manufacture of tissue and board. The Yankee cylinder is normally 4–6 m in diameter but can be as much as 9 m. It is designed for steam pressures up to 1 100 kPa (11 bar). The steam temperature can be more than 200 °C. One or two press rolls, positioned below the Yankee cylinder, press the web against the cylinder. The paper

Fig. 9



Yankee cylinder for board
1 Paper web
2 Yankee cylinder
3 Hood
4 Deflection-compensating press roll
5 Press roll
6 Felt
7 Doctor

adheres to the heated cylinder and it is dried by the heat from the cylinder and by hot air being blown at high speed on to the outside of the web.

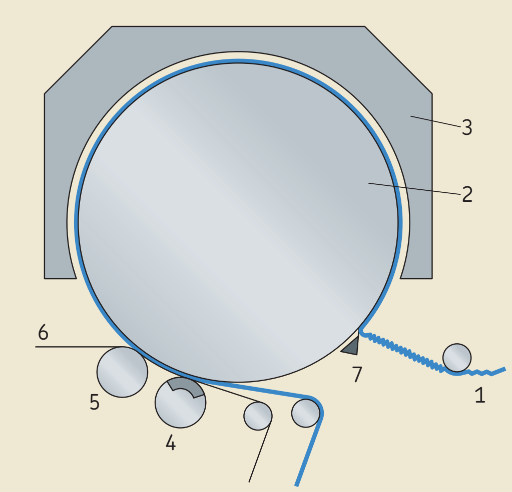
In the case of board, the contacting side of the paper takes on a fine-glazed shiny surface. When the board has reached a certain dryness level, the surface tension is released and the board can then easily leave the cylinder (→ **fig. 9**). Additional drying of board is carried out using ordinary drying cylinders.

The drying in tissue machines is performed only by a Yankee cylinder. The first press roll is usually a suction press roll in order to obtain efficient dewatering. Tissue paper does not come away from the cylinder shell automatically and has to be doctored off by means of a special crepe blade, which gives a softer paper (→ **fig. 10**).

New drying processes for Yankee cylinders

There is an ongoing trend to produce tissue of higher quality, e.g. there is the TAD (through air drying) concept giving higher softness, strength and absorbency properties. Another possibility is to use a shoe press directly against the Yankee cylinder.

Fig. 10



Yankee cylinder for tissue
1 *Paper web*
2 *Yankee cylinder*
3 *Hood*
4 *Suction press roll*
5 *Press roll*
6 *Felt*
7 *Doctor*

Bearing arrangements

Bearings in the dryer section are exposed to very high temperatures over long periods of time. Unfavourable lubrication conditions are quite common and short starting-up periods cause very high thermal stresses in the bearings. As such, the operating conditions for these bearings are quite severe. Over the years, the demands made on the bearings have also increased due to larger machines, higher speeds and higher steam temperatures. Production stops have become very costly, particularly unplanned stops caused by bearing failure in the dryer section. The performance and reliability of the bearings for these applications are consequently of the utmost importance.

Several factors have to be taken into consideration when choosing the bearings for high-temperature applications, e.g. drying and Yankee cylinders. This is also valid for other high temperature bearing applications such as calenders. The selection of material and heat treatment has to be based on some estimates as well as on several known parameters and serves to minimize the risk of cracked bearing inner rings. The following parameters should be taken into account:

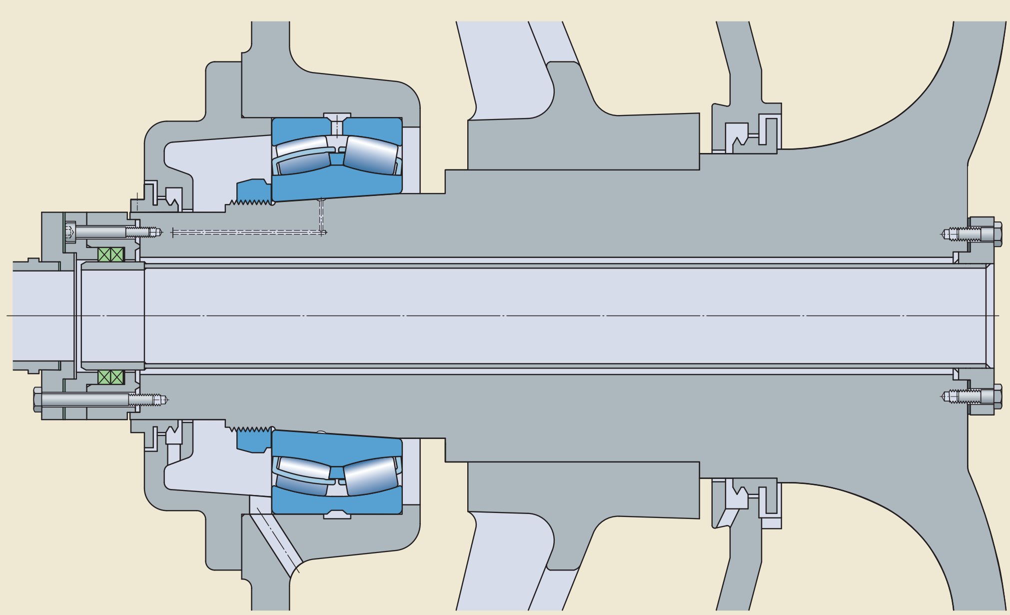
- **The maximum total stress in the inner ring**
  This occurs when the machine is started up as the temperature of the journal is then much higher than that of the inner ring, i.e. the inner ring is subjected to tensile stress in addition to the compressive stresses resulting from the loading of the bearing. The stress level also depends on the heat treatment method used for the inner ring.

- **The maximum difference between the temperatures of the journal and inner ring**
  This depends mainly on the heating-up time during the starting-up period and whether or not the journal is provided with efficient insulation.

- **The drive-up of the bearing**
  The drive-up has to be selected so that the actual operational inner ring-to-journal interference does not exceed the permissible interference for an unheated journal.

- **The initial radial internal clearance of the bearing**
  The bearing may become preloaded during start-up if the radial internal clearance is inadequate for such conditions.

Fig. 11



Insulation of drying cylinder, drive side

- **The ability to rapidly detect damage to the inner ring and take action to prevent cracking**
  Since a bearing inner ring will not crack until some time after initial damage has occurred, effective condition monitoring, in combination with remedial action, can prevent such cracking.

For drying and Yankee cylinders, SKF recommends the use of SKF XBite steel or case carburized steel inner rings. SKF XBite is a patented hardening method giving better performances than normal bainite through hardening It gives better crack, wear and fatigue resistance. All SKF spherical roller bearings and sizes of CARB toroidal roller bearings in the drying and Yankee cylinder range have their rings made of X-Bite steel as standard. SKF XBite bearings are the normal SKF recommendation for modern high performance paper machines. In cases where journals are not insulated and have steam temperatures above 170 °C, SKF recommends HA3 bearings. These HA3 bearings have case hardened inner rings.

In all cases, martentisitic steel bearing rings should be avoided in such applications.

Journal insulation

With the steam temperatures employed in modern machines, effective insulation is essential as the temperatures of the bearings would otherwise be too high. **Fig. 11** shows a common design of such insulation in the bore of the journal of a drying cylinder bearing arrangement. The same design in principle is also used for Yankee cylinder applications. This type of journal insulation can reduce the bearing temperature by as much as 35 °C.

It is worthwhile for the steam joint to be effectively insulated from the end face of the journal. This is often disregarded, but can easily be accomplished with an air gap, as in **fig. 11**, or with a 5 mm insulating washer having a thermal conductivity of 0,25 W/(m K) (less than 0,005 of that of steel). With this end face insulation, the bearing temperature can be brought down another 5–6 °C, which is of great value.

Special bearing housings

The ambient temperature in the dryer section is rather high. Consequently, all the cylinders will expand considerably during the heating-up period. This in turn makes high demands on the non-locating bearing arrangement. This is one reason why SKF has developed special bearing housings for different rolls and cylinders in the dryer section (→ *Chapter 1*, *General requirements and recommendations*, **pages 10–13**).

Felt rolls

Mounting the bearings on sleeves was the usual practice in the past but today mounting them directly on the journals is more common. **Fig. 12** shows SKF special housings for felt rolls in the dryer section where a spherical roller bearing and a CARB toroidal roller bearing are mounted directly on a tapered journal and are locked by an SKF KMT nut. The journal should have oil injection grooves when the bearing is mounted directly on it to facilitate its dismounting.

In cases where more efficient seals are required, the housings can be provided with a reinforced sealing arrangement.

Bearing types

SKF recommends the use of spherical roller bearings of series 223 and 232 and CARB toroidal roller bearings of series C 23 and C 32, but spherical roller bearings of series 222 and CARB toroidal roller bearings of series C 22 can also be used. Both spherical roller bearings of series 222 and cylindrical roller bearings of series NUB 2, with wide inner ring, can be used as the support bearings for wire stretch and guide rolls (→ *Chapter 2*, *Forming section*, **figs. 7** and **8**, **pages 4–5**). The main bearings, as well as the support bearings, should have C3 radial internal clearance.

Selection of bearing size

Bearings for felt rolls in the dryer section are calculated in the same way as shown for felt roll bearings in *chapter 3*, *Press section*, **pages 5–6**. The only difference is the recommended L_{10h} and L_{10ah} lives. These are 200 000 hours in the dryer section.

Journal and housing tolerances for felt rolls

Shell supporting bearings:

Journal	Mounting on a sleeve		h9 (IT5/2)
	Direct mounting on a cylindrical journal		
	(65) to 100 mm		m6
	(100) to 140 mm		n6
	Mounting on a tapered journal, see *chapter 1*, **pages 14–16**		
	Support bearing seating		
	Cylindrical roller bearing	Spherical roller bearing	
	(40) to 100 mm	(40) to 65 mm	m5
	(65) to 100 mm		m6
Housing			G7

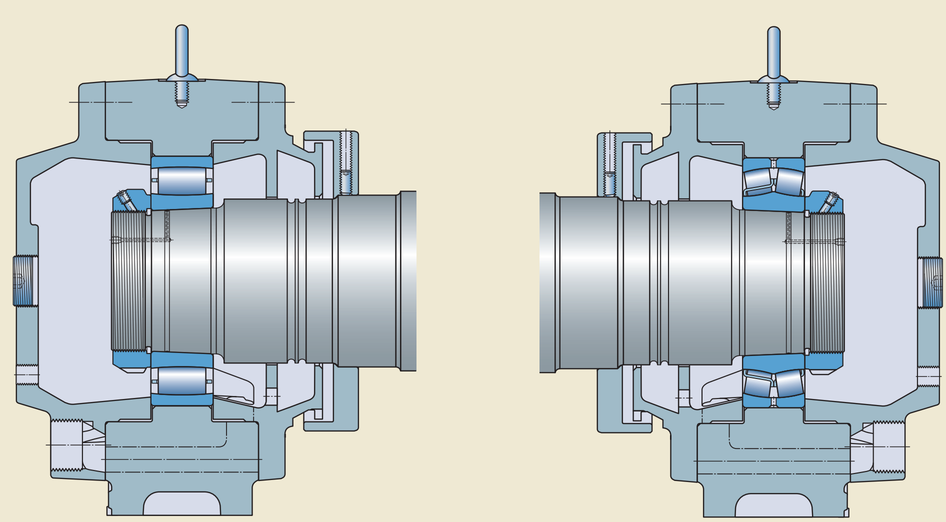
See also *chapter 1*, *General requirements and recommendations*, *Tolerances*, **pages 14–16**

Lubrication

The felt roll bearings in the dryer section are lubricated by circulating oil from the same oil system as the drying cylinder bearings. **Fig. 12** shows a typical arrangement for oil circulation lubrication of spherical roller bearings and CARB toroidal roller bearings.

Requirements on the lubricating oil for the dryer section are dictated by the drying cylinders (→ *Chapter 7*, *Lubrication*, *General notes on lubrication*, **pages 3–7** and *examples 12* and *13* in *chapter 8*, *Lubrication examples*, **pages 24–27**).

Fig. 12



SKF felt roll bearing housings for dryer section with oil circulation lubrication

Drying cylinders

The bearing housing on the drive side can be an integral part of the machine frame where the circulating oil drains into the gear casing, as shown in **fig. 4**, **page 2**. These integrated gears are often supported by spherical roller bearings. **Fig. 11**, **page 6**, also shows how to arrange for suitable journal insulation which is always recommended.

In modern machines, the cylinders are driven via the felt and felt rolls. In such machines, most of the drying cylinders have ordinary bearing housings on both sides (**figs. 13**, **14** and **15**).

The bearings may be mounted directly on tapered journals, or on adapter or withdrawal sleeves. If the bearings are to be mounted on a tapered seating, the journal should be provided with oil injection grooves to facilitate dismounting. If an adapter sleeve (with abutment spacer) is to be incorporated, it is recommended that an annular groove be machined in the journal outside the sleeve position. This groove can then be used to take a backing ring when a hydraulic nut (HMV) is employed to dismount the bearing. Where the bearings are to be mounted on withdrawal sleeves, the journal would have to be threaded to take a lock nut.

Traditional solutions for the front side

Spherical roller bearing with axially free outer ring

With an arrangement as shown in **fig. 13** the axial displacement is accommodated between outer ring and housing.

Journal and housing tolerances for drying cylinders

Journal	Mounting on a sleeve Mounting on a tapered journal, see *chapter 1*, **pages 14–16**	h9 (IT5/2)
Housing		G7

See also *chapter 1*, *General requirements and recommendations*, *Tolerances*, **pages 14–16**

The friction between outer ring and housing may cause axial forces which are roughly 15% of the radial bearing load, perhaps even more. This results in a considerable reduction of bearing life. Furthermore, at least for wide machines, the frame is mainly designed for radial loads. Therefore, the general guideline is not to use this bearing arrangement for wire widths above 4 500 mm.

Example: An induced axial load of 15% of the radial load on bearing 23052 reduces calculated bearing life by 70%.

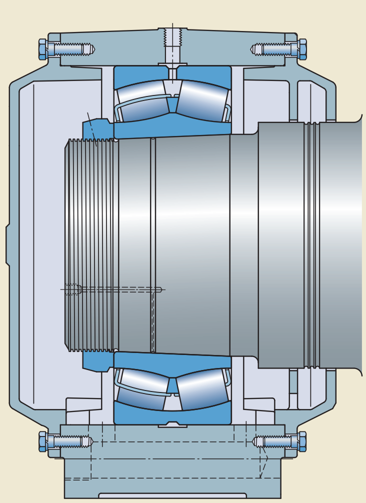
Spherical roller bearing in a housing mounted on rockers

When the housing is mounted on rockers, the axial displacement is accommodated by a slight tilting of the rockers (**fig. 14**). Due to the shape of the rockers, this gives a pure axial displacement with no displacement in the vertical direction.

In the past, this was the best solution and accordingly recommended by SKF for machines with a wire width above 4 500 mm.

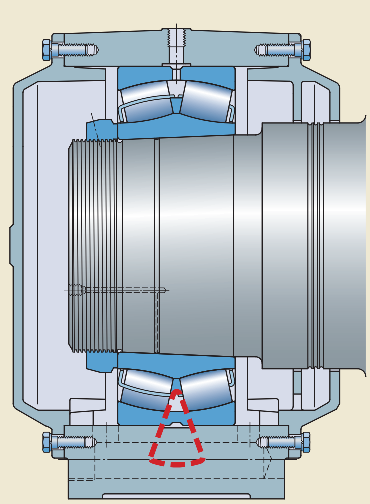
Bearing arrangement for front side with a spherical roller bearing with axially free outer ring

Fig. 13



Bearing arrangement for front side with a spherical roller bearing in a housing mounted on rockers

Fig. 14

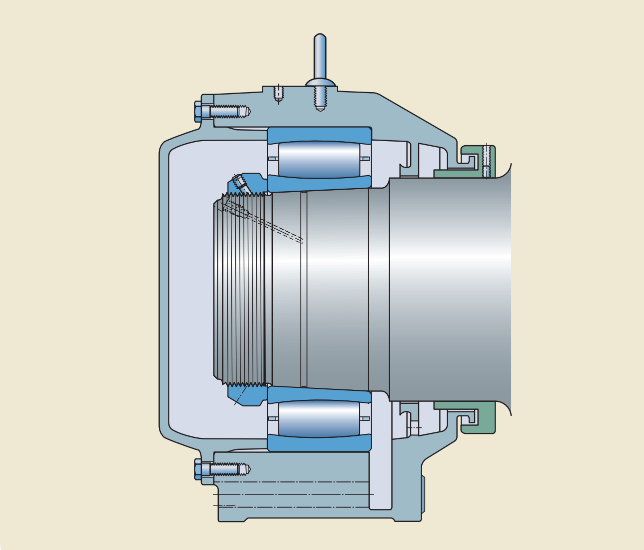


However, this housing arrangement is rather unstable and does not damp vibrations as well as solid housings, which may be a problem when upgrading to higher speeds. This arrangement is also sensitive to tilting forces, from rope sheaves and steam joints fastened on the housing for example.

Maintenance costs due to wear of the rocker arrangement may also be high as malfunctioning rockers produce axial loads.

To sum up, with this arrangement, there is a risk of axial forces and increased maintenance costs caused by malfunctioning rockers as well as restrictions in the speed capability of the machine because of too high vibration levels.

Fig. 15



Bearing arrangement for front side with a CARB toroidal roller bearing in a fixed housing

Front side bearing application with CARB toroidal roller bearing

Bearing life and reliability

A typical bearing arrangement for CARB toroidal roller bearings is shown in **fig. 15**. The requirements for journal and housing tolerances as well as selection of bearing size are the same as for other bearing types.

Compared to solutions with spherical roller bearings (→ **fig. 13** and **14**, **page 9**), the calculated bearing lives are increased due to the elimination of axial loads from the steam joint, malfunctioning housing rockers and, in the case of a fixed housing, friction between outer ring and housing.

Housings

CARB toroidal roller bearing eliminates the need for rocker housing as the bearing itself will take up the thermal expansion of the cylinder. Instead, the bearing can be mounted in a more robust and rigid, fixed housing (→ **fig. 16**). This gives a more stable arrangement and reduced vibration level, which is especially important at increased speeds. Lower vibration level also means less risk of component wear.

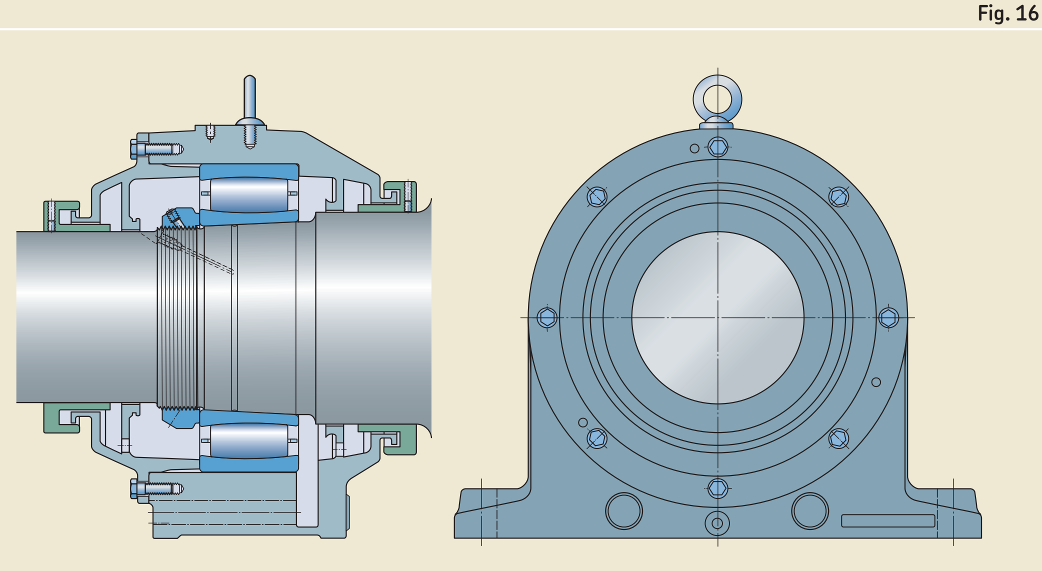
For more information about the housings, see *chapter 1*, *General requirements and recommendations*, **pages 10–13**.

Steam joint on front side

Sometimes, drying cylinders are equipped with a steam joint for condensate drainage on the front side. Steam joints are used on both rocker housings and plummer pillow block housings (fixed).

As a CARB toroidal roller bearing is mounted in a fixed housing, the axial expansion of the cylinder will be taken up within

Fig. 16

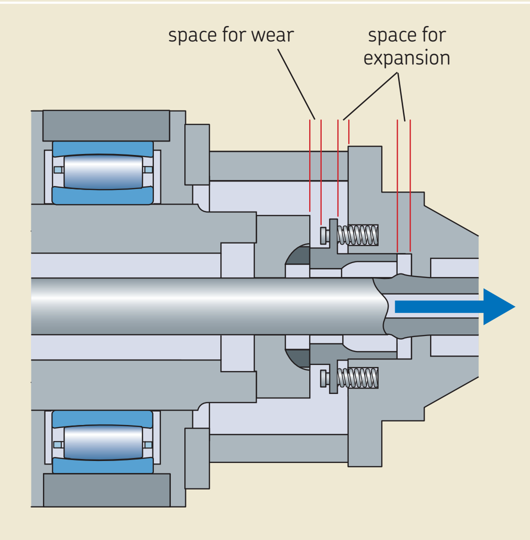


The CARB toroidal roller bearing can be mounted in the SKF one-piece fixed housing, which eliminates the need for rocker housings the bearing. This means that if the steam joint is mounted directly on the cover of the housing, it has to be designed to take up all the axial cylinder expansion internally. This is no problem if the expansion sleeve can accommodate this displacement with regard to space and spring preload (→ **fig 17**). Otherwise, some rework and new springs might be required. The joint is usually equipped with some sort of spherical wear washer. This wear washer is designed to prevent steam leakage and to minimize bending forces. It is normally changed at regular maintenance periods. The total distance the washer moves axially due to wear is roughly 5 mm. To accept both expansion and washer wear, the sleeve may have to be extended.

Different manufacturers of steam joints have their own solutions or designs. As the CARB toroidal roller bearing arrangement is more rigid and stable than a rocker housing arrangement, it is much easier to adjust the siphon into a correct position. When a CARB toroidal roller bearing arrangement is used, it is necessary to check that the siphon has sufficient space in the axial direction inside the cylinder as the cylinder expands.

Basic layout of a front side steam joint. It is important to ensure that there is room for axial cylinder expansion inside the steam joint

Fig. 17



Selection of bearing size

The dryer bearings will be affected by the mass of the cylinder, the felt tension and the water content in the cylinder. The drive side bearing will also be affected by the gear forces. If the front side bearing housing rests on rockers, there is normally no axial force acting on the bearing at that position.

The steam joint, depending on its location and design, may cause one or both of the bearings to be axially loaded.

The recommended L_{10h} and L_{10ah} lives are 200 000 hours. The bearing loads can be estimated with the aid of the following equations

$$G = g\,m$$

$$G_1 = g\,m_1$$

$$K_R = G + G_1 + 2\,q\,L$$

where
G = cylinder weight, N
G_1 = weight of water inside cylinder, N
g = 9,81 (acceleration of gravity), m/s²
m = cylinder mass, kg
m_1 = mass of water inside cylinder, kg
K_R = resultant roll load, N
q = felt tension, N/mm
L = felt width, mm

Drive side bearing:

$$F_r = 0{,}5\,K_R + F_2$$

$$F_a = F_3 + F_4 + F_5$$

$$F_5 = \mu\,F_r$$

Front side bearing:

$$F_r = 0{,}5\,K_R$$

$$F_a = F_4 + F_5$$

where
F_r = radial bearing load, N
F_a = axial bearing load, N
K_R = resultant roll load, N
F_2 = radial gear force, N
F_3 = axial gear force, N
F_4 = axial force from steam box, N
F_5 = axial bearing load, due to friction between housing and outer ring, N (if no CARB toroidal roller bearing or rocker housing is used at the front side)
μ = coefficient of friction between housing and outer ring (use μ = 0,15 when calculating)

Generally, the felt tension is 3–5 N/mm. In old machines, the cylinder often contains a fairly large amount of water. Modern high-speed machines are usually provided with efficient condensed water drainage and the water content is therefore reduced approximately to a value corresponding to 10–15 mm water film around the circumference.

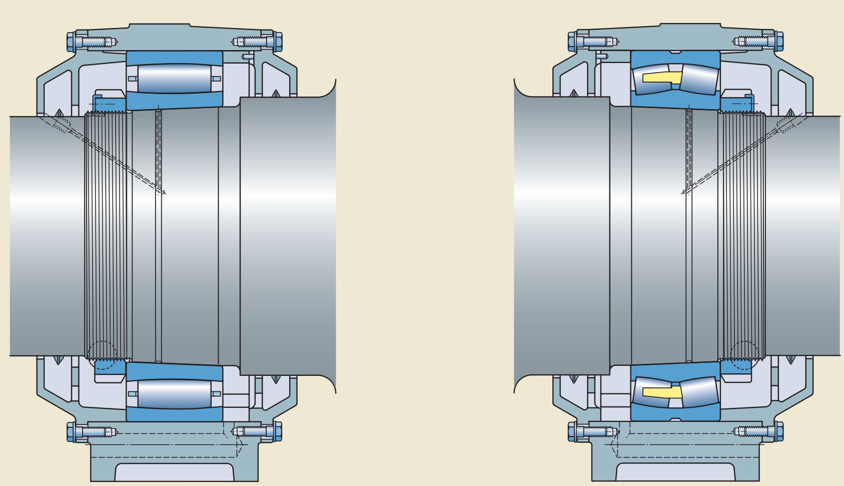
Lubrication

Most problems with drying cylinder bearings are related to the lubrication conditions. The best way to improve the lubrication is to provide the journals with efficient insulation. Circulating oil lubrication is used for all drying cylinder bearings. Owing to high steam and ambient temperatures, large oil quantities of appropriate viscosity must be passed through the bearings to achieve proper lubrication. In modern machines with insulated journals, in most cases, it is possible to cool the bearing to temperatures below 90 °C.

Many factors influence the calculation of the requisite oil flows, so these must be determined for each individual case. Consideration should be given to bearing size, speed, steam temperature, oil inlet temperature and insulation methods. The influence of bearing load and ambient temperature on the temperature of drying cylinder bearings is small compared with that of the speed, steam temperature and insulation method. SKF can carry out a computer analysis of the lubrication and temperature conditions for drying cylinder bearings on request.

For further information see *chapter 7*, *Lubrication*, and the below examples in *chapter 8*, *Lubrication examples*:
Example 14 (140 °C),
Example 15 (140 °C),
Example 16 (140 °C),
Example 17 (165 °C),
Example 18 (165 °C),
Example 19 (190 °C), and
Example 20 (190 °C) on **pages 28–41**.

Fig. 18



Yankee cylinder bearing arrangement with fixed housings

Yankee cylinders

Yankee cylinder bearings are exposed to very high temperatures over long periods of time. The operating conditions are similar to those of drying cylinders but the rotational speed is usually lower, as is the ambient temperature. It is always recommended that this bearing arrangement be provided with effective journal insulation, similar to that shown in **fig. 11**, **page 6**. In the case of Yankee cylinder journals, the bearing and the steam joint are spaced further apart and end face insulation is not so important.

Yankee cylinders, also called MG cylinders, are carried by spherical roller and CARB toroidal roller bearings mounted directly on tapered journals or on adapter sleeves. If the bearings are to be mounted on tapered seatings, the journals should be provided with oil injection grooves to facilitate dismounting of the bearings.

If an adapter sleeve (with abutment spacer) is to be incorporated, it is recommended that an annular groove be machined in the journal outside the sleeve position. This groove can then be used to take a backing ring when a hydraulic nut (HMV) is used to dismount the bearing.

Split bearing housings with removable covers on both sides are normally used. The split cover at the inside position provides easy inspection, mounting and dismounting of the bearing (→ **fig. 18**).

Before the introduction of CARB toroidal roller bearings, there was a need to have special front side housings for spherical roller bearings. These housings are provided with rockers in order to reduce axial loads on the bearings and the frame caused by thermal expansion. They also have anchoring hooks in order to keep the bearing housing in position when the cylinder is being pressed upwards by the press rolls. It is necessary to equip the front side bearing housing with rockers in the horizontal plane as well if the press rolls are located in such a position that the resultant load (including gravity forces) on the cylinder diverges more than 30° from the vertical downward position (→ **fig. 19**).

Today, SKF recommends the use of CARB toroidal roller bearings on the front side. The CARB toroidal roller bearing eliminates the need for the rocker housings, as the bearing itself will take up the thermal expansion of the cylinder. Instead, the bearing can be mounted in a more robust and rigid, fixed housing (→ **fig. 18**). This gives a more stable arrangement and reduced vibration level which is especially important at increased speeds. Lower vibration level also means less risk of component wear.

For more information about the housings, see *chapter 1*, *General requirements and recommendations*, **page 10–13**.

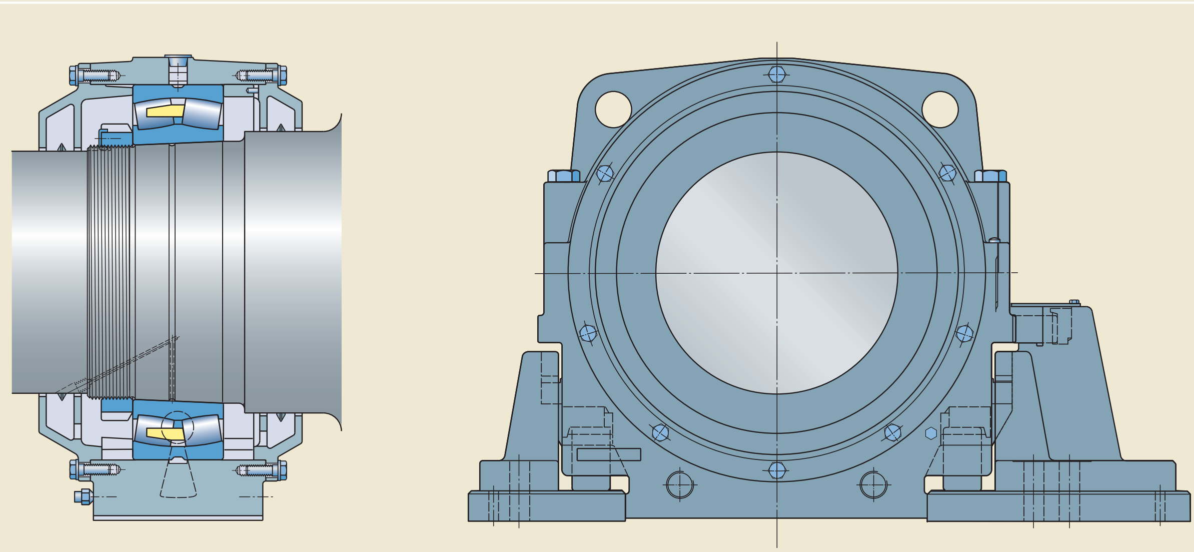
Journal and housing tolerances for Yankee cylinders

Journal	Mounting on a sleeve	h9 (IT5/2)
	Mounting on a tapered journal, see *chapter 1*, **pages 14–16**	
Housing	Bore diameter	
	up to 400 mm	G7
	above 400 mm	F7

See also *chapter 1*, *General requirements and recommendations*, *Tolerances*, **pages 14–16**

Yankee cylinder bearing housing with side rockers, front side

Fig. 19



Bearing types

SKF recommends spherical roller bearings of series 230 and 231 for the drive side. For the front side, SKF recommends CARB toroidal roller bearing from series C 30 and C 31. However, spherical roller bearings in rocker housings can also be used.

As the journals and inner rings will reach a much higher temperature than the outer rings during operation, the bearing must have a radial internal clearance greater than Normal. C4 clearance and C08 (improved) running accuracy are generally recommended.

Selection of bearing size

The radial load acting on the Yankee cylinder bearings depends on the mass of the cylinder, the water content and the position and the press load of the Yankee press rolls. The recommended L_{10h} and L_{10ah} lives are 200 000 hours.

In modern machines, the Yankee press rolls can be placed at any suitable position around the periphery of the Yankee cylinder. When calculating the press loads, the following equations should be used

$$G = g\,m$$

$$G_1 = g\,m_1$$

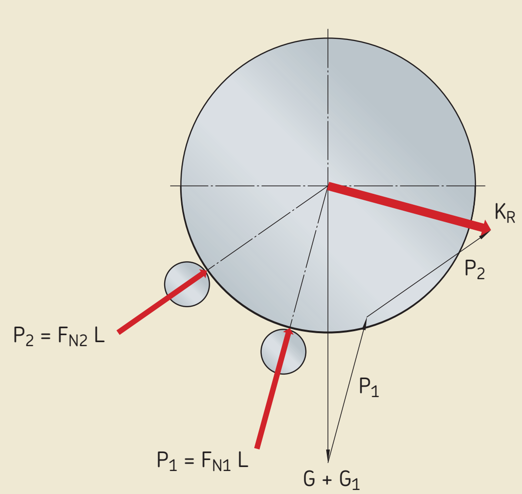
$$P_1 = F_{N1}\,L$$

$$P_2 = F_{N2}\,L$$

where
- G = cylinder weight, N
- G_1 = weight of water inside cylinder, N
- g = 9,81 (acceleration of gravity), m/s^2
- m = cylinder mass, kg
- m_1 = mass of water inside cylinder, kg
- P_1 = press load from the first press nip, N
- P_2 = press load from the second press nip, N
- F_{N1} = linear load of the first press nip, N/mm
- F_{N2} = linear load of the second press nip, N/mm
- L = press nip length, mm

The resultant load K_R on the Yankee cylinder

Fig. 20



When G, G_1, P_1 and P_2 are known, the resultant roll load K_R can be established either graphically (→ **fig. 20**) or by trigonometric calculations. The following equations can be used in the case of shaft riding gear drive

Drive side bearing:

$$F_r = 0,5\,K_R + F_2$$

$$F_a = F_4 + F_5$$

$$F_5 = \mu\,F_r$$

Front side bearing:

$$F_r = 0,5\,K_R$$

$$F_a = F_4 + F_5$$

where
- F_r = radial bearing load, N
- F_a = axial bearing load, N
- K_R = resultant roll load, N,
- F_2 = radial force from gear box, N
- F_4 = axial force from steam box, N
- F_5 = axial bearing load, due to friction between housing and outer ring, N (if no CARB toroidal roller bearing or rocker housing is used at the front side)
- μ = coefficient of friction between housing and outer ring (use μ = 0,15 when calculating)

When a spherical roller bearing is used as a front side bearing, it is normally mounted in a housing with rockers and will therefore not be axially loaded by the cylinder. However, there are still some narrow machines produced where the thermal expansion of the cylinder is taken up via axial movement of the outer ring in the housing. Thrust loads coming from that movement have to be considered. The steam joint, depending on its location and design, may also cause one or both of the bearings to be axially loaded.

Lubrication

A separate circulating oil lubrication system is recommended for the Yankee cylinder bearings. Owing to the high temperature of the steam, large quantities of oil of appropriate viscosity must be passed through the bearings to achieve proper lubrication.

Many factors influence the calculation of the requisite oil flows, so these must be determined for each individual case. Consideration should be given to bearing size, speed, steam temperature, oil inlet temperature and journal insulation method. The influence of bearing load and ambient temperature on the temperature of Yankee cylinder bearings is small compared with that of the speed, steam temperature and insulation method.

SKF can carry out a computer analysis of the lubrication and temperature conditions for Yankee cylinder bearings on request.

For further information see *chapter 7*, *Lubrication*, and the below examples in *chapter 8*, *Lubrication examples*:

Yankee suction press roll:
Example 21 on **pages 42–43**

Yankee cylinder:
Example 22 (140 °C),
Example 23 (140 °C),
Example 24 (140 °C),
Example 25 (165 °C),
Example 26 (165 °C),
Example 27 (190 °C), and
Example 28 (190 °C) on **pages 44–57**.

Breaker stack

The breaker stack is a single-nip press positioned in the dryer section and consists of two driven steel rolls, one of which may be a deflection-compensating roll.

The operating conditions are similar to those of ordinary press rolls except for the ambient temperature which is 80 to 100 °C. The same sealing arrangement as for press roll bearings in the press section may be used in the dryer section, even though bearings in this position are subjected to humidity only.

Bearing types

Spherical roller bearings from series 231 and 232 and CARB toroidal roller bearings from series C 31 and C 32 are recommended. Bearings with C3 radial internal clearance should be selected.

Selection of bearing size

Bearing loads are calculated as for ordinary press rolls but the recommended L_{10h} and L_{10ah} life should reach 200 000 hours if possible.

Lubrication

The lubrication recommendations are basically the same as those for press rolls in the press section. The best lubrication condition is achieved by using AW or EP oil in a separate lubrication system, as in the case of deflection-compensating rolls. When the temperature allows, EP additives should be selected.

For further information, see *chapter 7*, *Lubrication* and the below examples in *chapter 8*, *Lubrication examples*:

Press roll:
Example 9 (grease)
Example 10 (oil) on **pages 18–21**
Paper guide roll:
Example 29 (grease)
Example 30 (oil) on **pages 58–61**

Journal and housing tolerances for breaker stack

Journal	Mounting on a sleeve	h9 (IT5/2)
	Mounting on a tapered journal, see *chapter 1*, **pages 14–16**	
Housing	Bore diameter	
	up to 400 mm	G7
	above 400 mm	F7

See also *chapter 1*, *General requirements and recommendations*, *Tolerances*, **pages 14–16**

Doctors

Specially designed multi-row ball bearings mounted direct on cylindrical journals are recommended for axially oscillating doctors. In some heavily loaded positions, like doctor blades for Yankees, plain bearings can be found (**fig. 22**).

The bearing arrangement depends largely upon how the machine manufacturer has designed and selected the associated components. A typical bearing arrangement is shown in **fig. 21**.

Selection of bearing size

For help with the selection of bearing size, please contact SKF.

Lubrication

Grease lubrication is normally used for the doctor bearings. Relubrication should be carried out every 48 hours. When used in the dryer section, high temperature grease should be selected.

Oil bath lubrication can also be employed, using very high viscosity synthetic oil. The sealing arrangement then has to be modified.

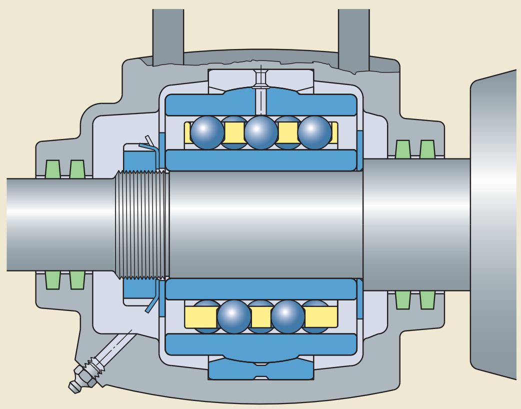
Journal and housing tolerances for doctors

Journal	Mounting on a sleeve	h6)
Housing		J7

See also *chapter 1*, *General requirements and recommendations*, *Tolerances*, **pages 14–16**

Typical doctor bearing arrangement

Fig. 21



Doctor plain bearing arrangement

Fig. 22