SKF Solutions for drying cylinders

– A better solution with CARB toroidal roller bearings on the front side

SKF – the knowledge engineering company

From one simple but inspired solution to a misalignment problem in a textile mill in Sweden, and fifteen employees in 1907, SKF has grown to become a global industrial knowledge leader. Over the years we have built on our expertise in bearings, extending it to seals, mechatronics, services and lubrication systems. Our knowledge network includes 46 000 employees, 15 000 distributor partners, offices in more than 130 countries, and a growing number of SKF Solution Factory sites around the world.

Research and development

We have hands-on experience in over forty industries, based on our employees' knowledge of real life conditions. In addition our world-leading experts and university partners who pioneer advanced theoretical research and development in areas including tribology, condition monitoring, asset management and bearing life theory. Our ongoing commitment to research and development helps us keep our customers at the forefront of their industries.

Meeting the toughest challenges

Our network of knowledge and experience along with our understanding of how our core technologies can be combined helps us create innovative solutions that meet the toughest of challenges. We work closely with our customers throughout the asset life cycle, helping them to profitably and responsibly grow their businesses.

Working for a sustainable future

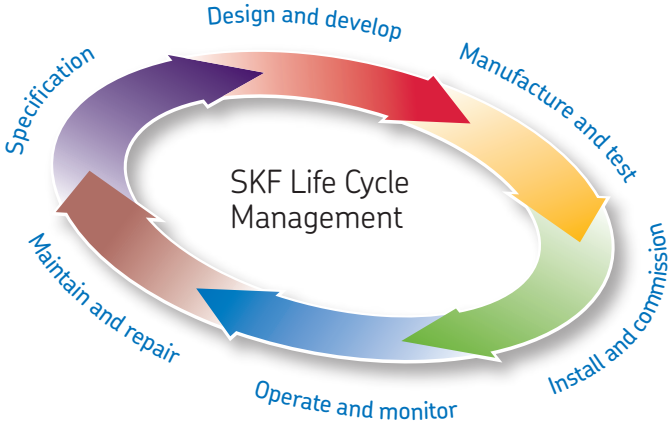
Since 2005, SKF has worked to reduce the negative environmental impact from our own operations and those of our suppliers. Our continuing technology development introduced the SKF BeyondZero portfolio of products and services which improve efficiency and reduce energy losses, as well as enable new technologies harnessing wind, solar and ocean power. This combined approach helps reduce the environmental impact both in our own operations and in our customers'.

SKF Solution Factory makes SKF knowledge and manufacturing expertise available locally, to provide unique solutions and services to our customers.

Working with SKF IT and logistics systems and application experts, SKF Authorized Distributors deliver a valuable mix of product and application knowledge to customers worldwide.

Our knowledge – your success

SKF Life Cycle Management is how we combine our technology platforms and advanced services, and apply them at each stage of the asset life cycle, to help our customers to be more successful, sustainable and profitable.



Working closely with you

Our objective is to help our customers improve productivity, minimize maintenance, achieve higher energy and resource efficiency, and optimize designs for long service life and reliability.

Innovative solutions

Whether the application is linear or rotary or a combination of the two, SKF engineers can work with you at each stage of the asset life cycle to improve machine performance by looking at the entire application. This approach doesn't just focus on individual components like bearings or seals. It looks at the whole application to see how each component interacts with the next.

Design optimization and verification

SKF can work with you to optimize current or new designs with proprietary 3-D modeling software that can also be used as a virtual test rig to confirm the integrity of the design.

Bearings
SKF is the world leader in the design, development and manufacture of high performance rolling bearings, plain bearings, bearing units and housings.

Machinery maintenance
Condition monitoring technologies and maintenance services from SKF can help minimize unplanned downtime, improve operational efficiency and reduce maintenance costs.

Sealing solutions
SKF offers standard seals and custom engineered sealing solutions to increase uptime, improve machine reliability, reduce friction and power losses, and extend lubricant life.

Mechatronics
SKF fly-by-wire systems for aircraft and drive-by-wire systems for off-road, agricultural and forklift applications replace heavy, grease or oil consuming mechanical and hydraulic systems.

Lubrication solutions
From specialized lubricants to state-of-the-art lubrication systems and lubrication management services, lubrication solutions from SKF can help to reduce lubrication related downtime and lubricant consumption.

Actuation and motion control
With a wide assortment of products – from actuators and ball screws to profile rail guides – SKF can work with you to solve your most pressing linear system challenges.

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CARB toroidal roller bearings make the difference

CARB bearings are the only rolling bearings that accomodate angular misalignment and axial shaft displacement with virtually no influence on performance. In addition, they have very high radial load carrying capacity to match those of corresponding SKF Explorer spherical roller bearings.

Translated to drying cylinder conditions, this means that CARB bearings can accommodate cylinder elongation, shaft and housing misalignment, heavier loads, higher speeds and high journal temperatures better than any other solution. From a maintenance point of view this means fewer planned and unplanned stops. From a performance perspective, CARB bearings provide the opportunity to increase the loads or to select a smaller bearing and the possibility to increase the speed with an equal or decreased vibration level.

Demanding environment

Drying cylinders

Drying cylinders are heated by steam. The steam temperature can vary between 130 and 200 °C *(270 – 390 °F)*, depending on the paper grade. A dryer section may contain 35 to 100 drying cylinders.

The bearing housing on the drive side is, in most cases, an integral part of the machine frame where the circulating oil drains into the gear casing. On the drive side the drying cylinder is supported by a spherical roller bearing.

The design of the front side of the drying cylinder depends mainly upon the wire width. For wire widths less than 4,5 m, a fixed housing is typically used. For wire widths greater than 4,5 m, the housing is usually mounted on rockers.

The front side bearing arrangement has to be non-locating in order to accommodate the expansion of the cylinder due to the high operating temperature. The steam heating through the shaft also produces high thermal stresses in the bearing inner ring. Furthermore, the bearings are often subjected to misalignment caused by deflection, low accuracy of housing alignment and settling of foundations.

Summary of operating conditions:

- Large axial displacement due to thermal expansion of the shaft – up to some 10 mm.
- High thermal inner ring stresses due to temperature differences.
- Separate housings, sometimes more than 10 metres apart, require bearings which can accommodate substantial misalignment.

Yankee cylinders

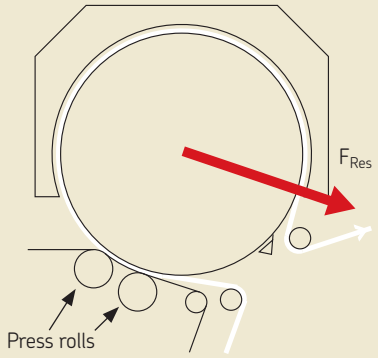
Most of the information in this brochure regarding drying cylinders is also valid for Yankee cylinders. Bearings in Yankee cylinders have approximately the same operating conditions as those in drying cylinders, including operating temperature and expansion of the cylinder. In relation to bearing size, also speeds and loads are in the same order of magnitude.

The design of the bearing arrangement for Yankee cylinders is similar to that of drying cylinders. The major difference is that the Yankee press rolls cause a resultant bearing load (→ **fig. 1**), which might even be directed upwards. For rocker housings this is taken care of by means of “hooks” in combination with additional rockers or linear bearings. Still, the press loads are a source of problems.

For more detailed information concerning Yankee cylinder bearing arrangements, please contact SKF application engineering service.

Drying cylinder
Drying cylinders can be up to 12 metres wide and have a diameter of up to 2,2 metres.

Fig. 1



Yankee cylinder
The major difference for the bearings in Yankee cylinders compared to those in drying cylinders is the resultant bearing load, F_{Res}, caused by the Yankee press rolls.

Table 1

	Drying cylinder	Yankee cylinder
Shaft diameter	180 – 320 mm	340 – 710 mm
Cylinder diameter	1 500 – 2 200 mm	3 000 – 6 500 mm
Cylinder length	2,5 –12 m	2 – 7 m
Cylinder mass	5 – 30 tonnes	50 – 170 tonnes
Paper speed	up to 1 900 m/min	up to 2 200 m/min (tissue) up to 700 m/min (board)
Steam temperature	130 – 200 °C *(270 – 390 °F)*	140 – 190 °C *(280 – 370 °F)*

Fig. 2

Solutions – before the CARB bearing

Spherical roller bearings with axially free outer ring

With an arrangement according to **fig. 1** the axial displacement is accommodated between outer ring and housing. There is a risk that the axial friction forces in this contact can become excessive due, for example, to fretting corrosion, unsuitable fit or ovality of the housings.

In unfavourable cases the friction between outer ring and housing may cause axial forces which are roughly 10–20% 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. The general guideline is thus not to use this bearing arrangement for wire widths above 4,5 m.

Example: An induced axial force of 15% reduces the basic rating life of a spherical roller bearing 23052 by 70% .

Cylindrical roller bearings

Cylindrical roller bearings accommodate axial displacement within the bearing (→ **fig. 2**). The load carrying capacity is substantially lower than for spherical roller bearings. However, the major disadvantage with this arrangement is that misalignment causes edge stresses on rollers and raceways. To align the housings as accurately as is required for cylindrical roller bearings is time-consuming. Still misalignment may occur again at any time due, for example, to settling of the foundations.

Accordingly cylindrical roller bearings are not recommended for drying cylinders, see also **fig. 1**, **page 10**.

Example: The allowed misalignment on a cylindrical roller bearing with logarithmic profile is limited to 3–4 min of arc which is much below the typical misalignments of 0.3° in drying cylinders.

Self-aligning double row cylindrical roller bearings

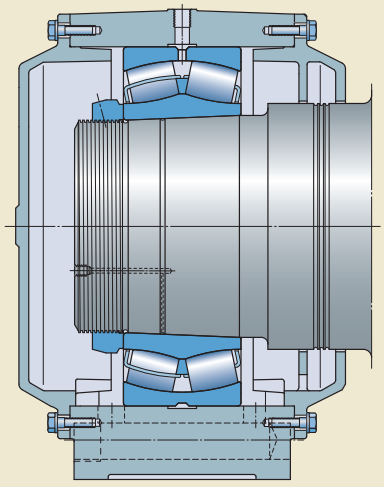
With this special cylindrical roller bearing design, the axial displacement is accommodated between outer and inner ring and the misalignment by the sphered mating surfaces of the two outer ring parts (→ **fig. 3**). The reason why this solution is so uncommon is that the bearing design is complicated and gives a reduced load carrying capacity, resulting in short bearing life.

There is also a risk of fretting corrosion between the two outer ring parts. Fretting corrosion in this contact eliminates the ability of the bearing to cope with misalignment. The result is edge stresses and further reduction of bearing life.

Example: 30% lower load carrying capacity reduces basic rating bearing life by about 70%.

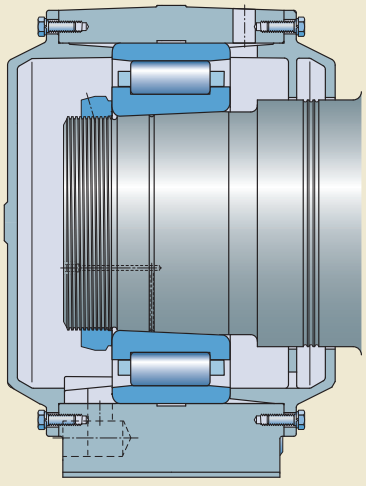
Friction between bearing outer ring and housing results in axial loads on bearing and machine frame.

Fig. 1



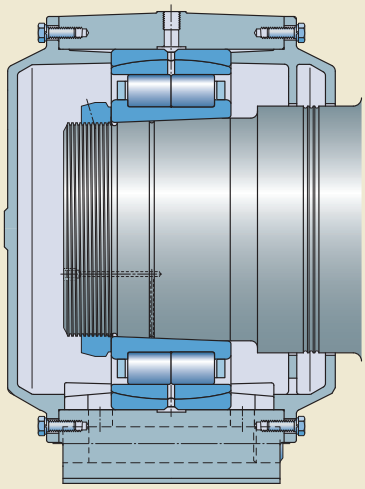
Misalignment causes edge stresses on rollers and raceways.

Fig. 2



The outer ring design gives low load carrying capacity.

Fig. 3



Spherical roller bearings in housing mounted on rockers

When the housing is mounted on rockers, the axial displacement is accommodated by a slight tilting of the rockers (→ **fig. 4**). Due to the shape of the rockers this gives a pure axial displacement with no displacement in the vertical direction.

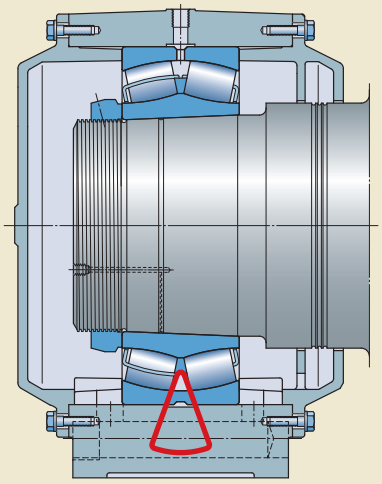
This was previously the best solution and accordingly recommended by SKF for machines with a wire width above 4,5 m. However, this housing arrangement is rather unstable and does not damp vibrations as well as solid housings which may be a problem when upgrading to higher speeds. This arrangement is 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 solution 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.

Spherical roller bearing in a rocker housing. Note that the red triangle indicates the rocker. Vibration and tilting forces may cause problems in such arrangements.

Fig. 4



A better solution with CARB bearings

In 1995 SKF introduced a new bearing – the CARB bearing. It was a major breakthrough in bearing technology – the greatest in over 50 years since SKF introduced the spherical roller thrust bearing in 1939.

This bearing is in accordance with the increasing demand for high load carrying capacity, robustness and low friction. Like a spherical roller bearing, CARB bearings can accommodate misalignment and heavy radial loads, but they are also able to accommodate axial displacement like a cylindrical roller bearing. Similar to the needle roller bearing, a CARB bearing has the potential of a compact design.

CARB bearings provide a unique combination of accommodating misalignment and axial displacement (→ **fig. 1**).

This was the main reason why the front side of drying cylinders was one of the main applications considered when developing the CARB bearing. Tests made at a number of paper mills have proved that one CARB bearing mounted in a fixed housing is an excellent bearing arrangement for this application.

The design

The rollers are long and barrel-shaped with a profile radius much larger than that of rollers in spherical roller bearings.

This means that the centre of curvature of the outer ring raceway is not located on the bearing axis as is the case for spherical roller bearings (→ **fig. 2**).

Raceway profile radii are optimized to achieve favourable load distribution and minimum friction. Roller self-guidance is obtained by well-matched roller and ring raceway geometries, long rollers and zero contact angle.

Load rating

The radial load rating of CARB bearings is high due to the long rollers. This can be achieved within a low sectional height. The dynamic load rating C given in catalogues is usually used as a basis for the selection of type and size of bearing. However, the ability of most bearing types to carry load and still reach expected life can be reduced if there is misalignment involved.

Misalignment can occur around two axes in drying cylinders (→ **fig. 3**). When mounting the bearing housing it should be well aligned around the vertical axis. CARB bearings accommodate 0,5° misalignment around this axis considering a vertical load, but in most cases the misalignment is only about 0,1° and is not likely to change over time. It's influence therefore ignored here.

Misalignment around the horizontal axis is often substantial as the bearings are mounted in separate housings, sometimes more than 10 metres apart, the misalignment is often substantial. Due to deflection and settling of the foundations this misalignment may increase over time and accordingly up to 0,3° misalignment is common for drying cylinder bearings. Alignment can easily be checked by measuring with a feeler gauge between shaft and housing cover.

Fig. 1

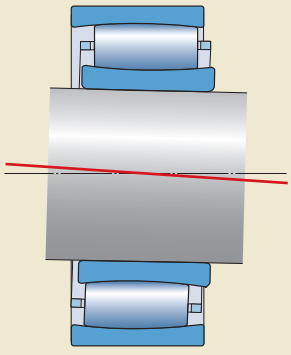


Diagram 1 shows a comparison between CARB bearings, spherical roller bearings and cylindrical roller bearings.

Their ability to accommodate high loads, misalignment and axial displacement without inducing external axial loads are characteristics of a CARB bearing's design. These properties can either be used for downsizing, that is selection of a smaller bearing size, or for increased reliability depending on which is considered more valuable.

Friction

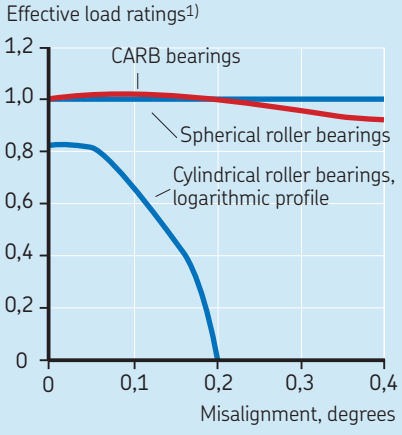
CARB bearings have about the same friction as cylindrical roller bearings and double row spherical roller bearings. The friction depends on the misalignment as the rollers adjust their axial position to avoid edge load.

The friction increase in CARB bearings is negligible up to a misalignment of 0.5°. As mentioned before, misalignment up to 0,3° is common for drying cylinder bearings.

Measurements in cases where a CARB bearing in a fixed housing has replaced a spherical roller bearing in a housing on rockers have shown that the bearing temperature has decreased substantially.

Diagram 1

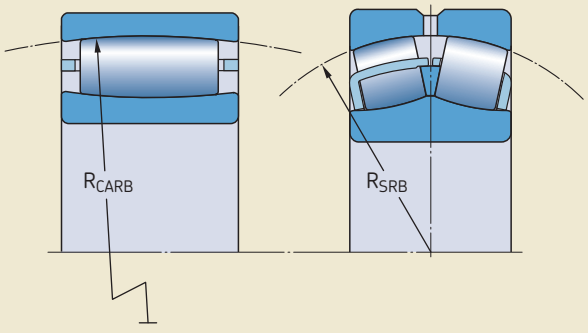
The CARB bearing has the same high load carrying capacity and is practically as insensitive to misalignment around the horizontal axis (→ Fig. 3) as a spherical roller bearings.



1) Calculated based on the reduced life due to misalignment .

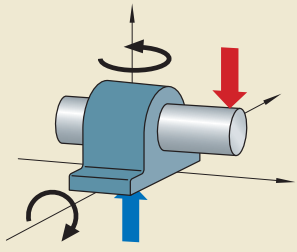
The raceway profile radius of a CARB bearing is much larger than that of a spherical roller bearing $R_{CARB} >> R_{SRB}$

Fig. 2



Misalignment can occur – around a vertical axis or around a horizontal axis.

Fig. 3



Axial displacement

The relation between radial clearance and axial displacement allowance from a central position is shown in **diagram 2**.

Axial displacement and radial clearance are given in relation to bearing width (B). This makes the diagram valid for all CARB bearings.

Example: Bearing C 3044 K/C4 with bearing width B = 90 mm (from table on page 20).

Assume that the operational radial clearance during start-up is 0,1 mm. That is 0,11% of the bearing width.

The diagram then shows (dotted line) that the bearing can be axially displaced up to 11% of bearing width, which is 0,11 × 90 = 9,9 mm from the centre.

During start-up a typical operational radial clearance at moderate steam temperature and without journal insulation can be 0,1% of the bearing width. This corresponds to a possible axial displacement from the centre of 10% of the bearing width. In **diagram 3** the available axial displacement of a CARB bearing is compared with the corresponding displacement of cylindrical and spherical roller bearings. Just as for a CARB bearing, the available axial displacement of spherical roller bearings in the bearing itself, depends on the radial clearance. For cylindrical roller bearings the available axial displacement is independent of the radial clearance but is limited by the width of the raceways.

Diagram 2

Allowed axial displacement depends on radial clearance. Rollers may protrude from the ring raceway at axial displacements above 20% of the bearing width.

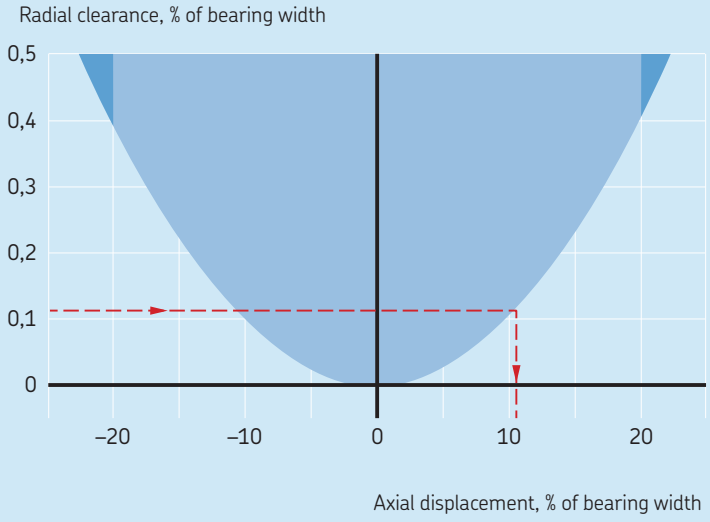
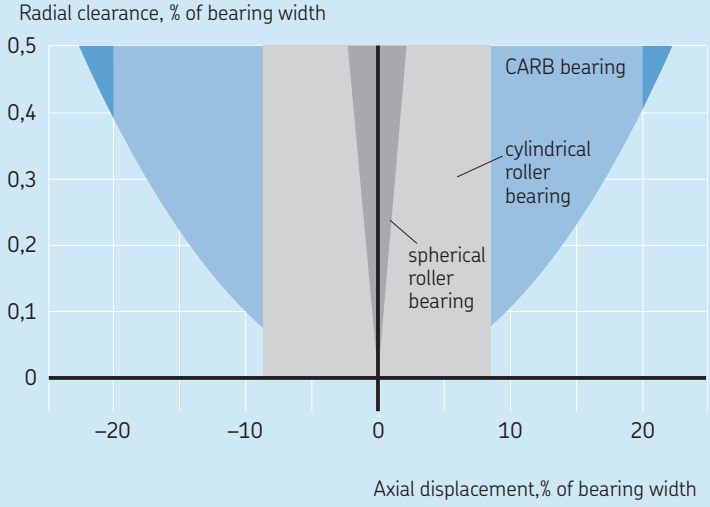


Diagram 3

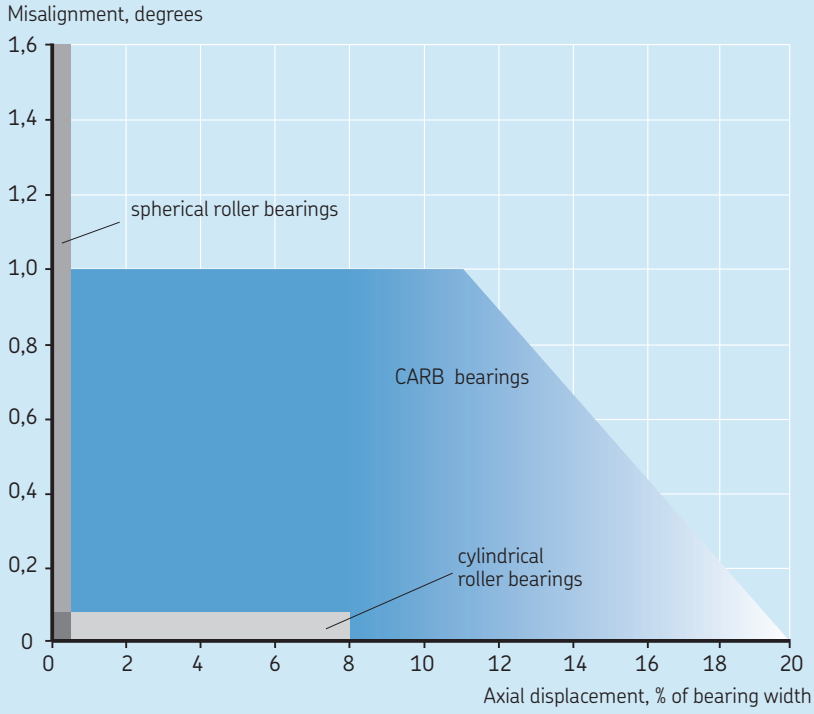
Allowed axial displacement of CARB bearings, cylindrical roller bearings and spherical roller bearings.



Because of their ability to accommodate misalignment and axial displacement, CARB bearings have a much greater "working area" than spherical roller bearings or cylindrical roller bearings. Within the dark blue area (axial displacement up to 8% of bearing width) for CARB bearings in the diagram the risk of radial preload occurring is less than or equal to that for spherical roller bearings with C4 clearance. The allowable misalignment becomes dependent on the operating clearance when axial displacement exceeds 8% of the bearing width.

Diagram 4

CARB bearings have a much greater "working area" than spherical roller bearings or cylindrical roller bearings. The diagram is valid for misalignments around the horizontal axis. (→ fig. 3, page 11).



Comparison and summary

By using CARB bearings and appropriate housings, the following benefits can be achieved:

- Improved reliability
- Improved service life
- Higher output
- Higher speeds
- Improved paper quality
- Fewer unplanned stops

A safer, more reliable bearing arrangement is a much more economical solution.

Bearing arrangement can accommodate	Cylindrical roller bearings	Self-aligning double-row cylindrical roller bearings	Spherical roller bearings with axially free outer ring	Spherical roller bearings in rocker housing	CARB bearings
Axial displacement	Yes	Yes	Sometimes	Yes	Yes
Misalignment	No	Sometimes	Yes	Yes	Yes
Vibrations	Yes	Yes	Yes	No	Yes
High radial load	Sometimes	No	Yes	Yes	Yes
Fretting corrosion	Yes	No	No	Yes	Yes
Tilting forces	Yes	Yes	Yes	Sometimes	Yes

Application

Bearing life and reliability

A typical bearing arrangement incorporating a CARB bearing is shown in **fig 1**.The requirements for journal and housing tolerances as well as the requirements on the calculated bearing lives L_{10h} and L_{10mh} are the same as for other bearing types (→ SKF publication *Rolling bearings in paper machines)*. As the load carrying capacity for CARB bearings is somewhat higher than for spherical roller bearings and substantially higher than for other bearing types used in this application (→ **fig. 2** and **3**, **page 8**), the calculated bearing life will be up to three times higher for CARB bearings. Compared to solutions with spherical roller bearings (→ **fig. 1** and **4**, **pages 8** and **9**), the major increase in calculated bearing life is due to the avoidance of axial loads from the steam joint, malfunctioning housing rockers, and, in the case of a fixed housing, friction between outer ring and housing. Operating conditions may change over time, for example increased misalignment due to settling of the foundations. This means that the increase in real service life for a CARB bearing compared to other solutions may be higher than the calculated one. Even more important than a long bearing service life is to avoid unplanned stops. The standard steel used for CARB bearings is characterized by an extremely homogenious structure, high hardness and excellent toughness providing outstanding resistance to ring cracking.

On request, SKF can deliver bearings with case hardened inner rings (denoted by suffix HA3 in the designation). This is recommended for journals without insulation and steam temperatures above 170 °C *(340 °F)*. In all other cases, the SKF standard steel for CARB bearings and spherical roller bearings is the appropriate choice.

Lock nuts

To secure the bearing in the right position on the shaft, an appropriate locking device is needed.

SKF has designed a wide selection of lock nuts which can be used in paper machines.

Not all lock nuts are adequate in combination with a CARB bearing due to their outer diameter. For additional information, contact the SKF application engineering service.

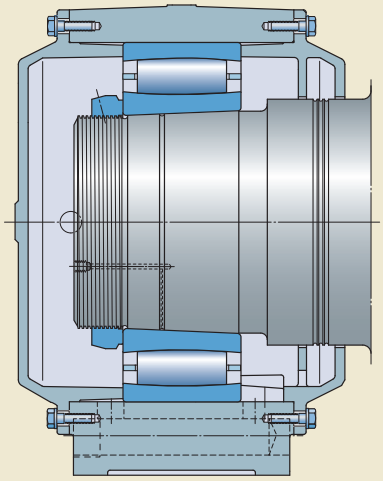
Housings

Historically all paper machines have been equipped with specially designed bearing housings. The manufacturer has designed a special housing for more or less every individual machine which has involved a lot of cost of pattern equipment and design time. Specially made housings have also been very difficult to find when a replacement has been required at the paper mill.

SKF stepped into the lead position in the 1990s by introducing a standard range of bearing housings for the felt rolls in the dryer section, drying cylinders and Yankee cylinders. Another step was taken in the early

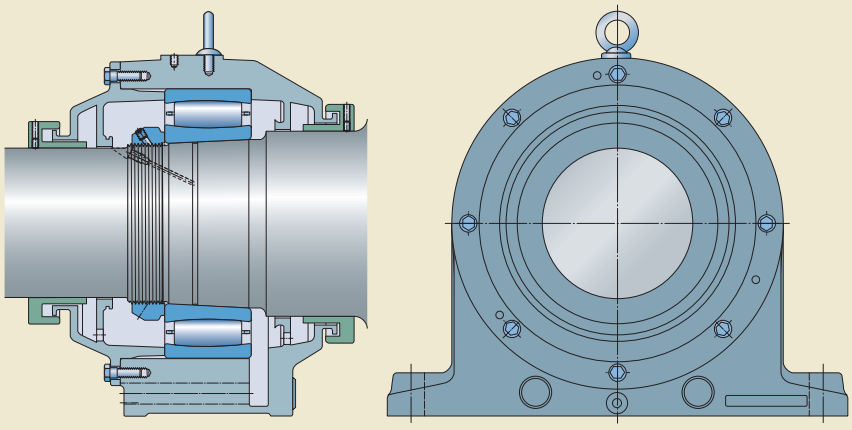
Bearing arrangement for CARB bearing.

Fig. 1



CARB bearings can be mounted in latest generation one-piece, fixed SBPN housings from SKF which eliminate the need for rocker housings and reduces drastically the risk of water ingress.

Fig. 2



2000s with the introduction of SBPN housings that enable higher oil flow rates and much better protection against water ingress especially when high pressure water cleaning is used. (→ **fig. 2**) .These housings have a compact and optimized design for the pulp and paper industry that gives advantages for both the manufacturers and the paper mills.

Today paper mills worldwide wish to increase production, for example by speeding up the paper machine. In many cases, that requires an increased oil flow to maintain good lubrication. The SKF range of housings is designed for high flow circulating oil lubrication.

CARB bearings eliminate the need for rocker housing, as the bearing accomodates thermal elongation of the cylinder. Instead the bearing can be mounted in a more robust and rigid, fixed housing (→ **fig. 2**, **page 15**). This gives a more stable arrangement and reduced vibration which is especially important at increased speeds. Lower vibration levels also means less risk of component wear.

Steam joint on front side

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

As the CARB bearing is mounted in a fixed housing, the axial elongation of the cylinder will be taken up within 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 elongation inside the joint. This is no problem if the expansion sleeve can accommodate this displacement with regard to space and spring preload (→ **fig. 3**). 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 during regular maintenance intervals. The total distance the sleeve moves axially due to wear of the washer is roughly 5 mm. To accommodate both expansion and washer wear, the sleeve may have to be extended.

Different manufacturers of steam joints have of course their own solution or design. As the CARB bearing arrangement is more rigid and stable than a rocker housing arrangement, it is much easier to adjust the siphon in a correct position. When a CARB 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 elongates.

Multi-parameter monitoring

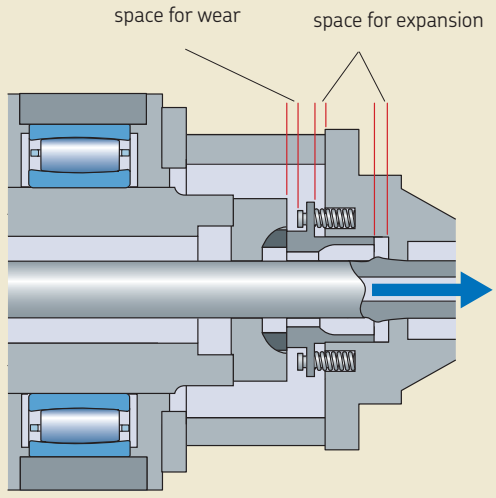
Developed jointly by SKF Condition Monitoring and the SKF Engineering & Research Centre in the Netherlands, multi-parameter monitoring is the most comprehensive, reliable and accurate approach to machinery monitoring and analysis. Collecting and analyzing multiple measurement parameters greatly increases the capability to accurately and readily identify bearing faults and other machinery problems.

By measuring a number of machinery parameters – from vibration acceleration, velocity and displacement to process parameters like speed, temperature, current, pressure and flow – users gain essential insights into a machine's condition. Advanced analysis techniques, like acceleration enveloping, enable analysts to take the guesswork out of maintenance by supplying the information needed to take action toward preventing unscheduled downtime. When rebuilding from a rocker housing arrangement to a CARB bearing arrangement with fixed housing, the vibration level will most probably be reduced. Condition monitoring measurements have shown that the axial vibrations can be reduced by up to 85% (→ **diagram 1**).

SKF provides a complete condition monitoring programme. The product range includes everything from handheld vibration pens to advanced online systems for con-

Basic layout of a front side steam joint. Make sure that there is room for axial cylinder expansion inside the steam joint.

Fig. 3



tinuous monitoring, all prepared for multi-parameter monitoring.

The instruments are supported by a full range software platform for administration and analysis of measurement data. Training and support can be given by SKF local representatives.

SKF housings designed to be combined with CARB bearing arrangements for the dryer section can be supplied to special order already prepared for multi-parameter monitoring. The measurement points can be provided with everything from a quick connector to a complete sensor arrangement fitted to the housing. Different solutions are available depending on the position in the dryer section.

SKF condition monitoring systems are operating with CARB bearing arrangements in the dryer section of papermaking machines, with very good results. Defect frequencies of CARB bearings are shown in **table 1**.

Please contact SKF for references and for more information.

Lubrication

Concerning lubrication of CARB bearings for drying cylinders, the same guidelines can be used as for spherical roller bearings (SKF publication *Rolling bearings in paper machines*). As a CARB bearing has only one roller row it is lubricated from the bearing side face on the outer side (away from the cylinder) (→ **fig. 4**).

In most cases when cylindrical roller bearings are used for drying cylinders the oil inlet is on the inner side (towards the cylinder) of the bearing(→ **fig. 2**, **page 8**). If the shaft diameter on this side of the bearing is very large, this may result in a lower maximum oil flow compared to a design according to **fig 4**. However, the pressed steel cage used in CARB bearings allows higher oil flows than the brass cage usually used in cylindrical roller bearings.

Table 1

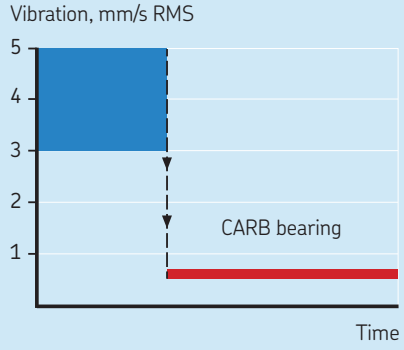
Defect frequencies for CARB bearings when inner ring rotational frequency = 1 Hz = 60 r/min

Bearing size	Frequencies BPFI	BPFO	BSF	FTF
–	Hz			
C 2234	10,33	7,67	3,30	0,43
C 3036	13,80	11,20	4,75	0,45
C 3136	11,35	8,65	3,63	0,43
C 3038	14,82	12,18	5,07	0,45
C 2238	9,82	7,18	3,14	0,42
C 3040	13,29	10,71	4,59	0,45
C 3140	11,84	9,16	3,86	0,44
C 3044	13,29	10,71	4,60	0,45
C 3144	11,81	9,19	3,95	0,44
C 2244	9,31	6,69	2,98	0,42
C 3048	13,76	11,24	4,91	0,45
C 3148	11,35	8,65	3,62	0,43
C 3052	13,80	11,20	4,75	0,45
C 3152	11,30	8,70	3,78	0,44
C 3056	14,82	12,18	5,07	0,45
C 3156	12,35	9,66	4,03	0,44
C 3160	11,81	9,19	3,95	0,44
C 3164	10,84	8,16	3,46	0,43
C 3168	10,84	8,16	3,46	0,43
C 3172	11,35	8,65	3,63	0,43
C 3084	14,35	11,65	4,75	0,45
C 3184	12,27	9,73	4,27	0,44
C 3092	15,76	13,24	5,71	0,46
C 3192	12,83	10,17	4,27	0,44
C 3096	16,27	13,73	5,87	0,46
C 30/500	17,32	14,68	6,04	0,46
C 31/500	12,32	9,68	4,11	0,44
C 30/530	14,74	12,26	5,39	0,45
C 31/530	11,76	9,24	4,10	0,44
C 30/560	16,81	14,19	5,87	0,46
C 30/600	15,76	13,24	5,71	0,46
C 30/630	15,29	12,71	5,40	0,45
C 30/670	15,80	13,21	5,55	0,46
C 30/710	15,83	13,17	5,39	0,45

BPFI = Inner ring defect frequency
BPFO = Outer ring defect frequency
BSF = Roller rotational frequency
FTF = Cage rotational frequency

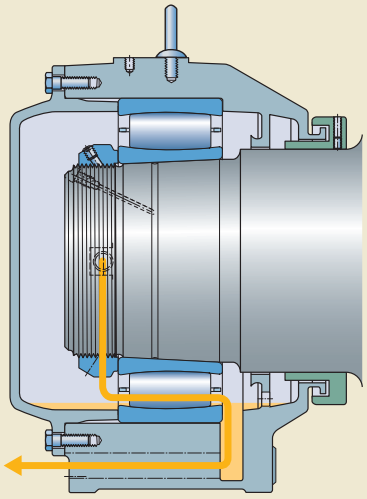
Diagram 1

Measured axial vibrations before and after rebuild from rocker housing arrangement to CARB bearing in a fixed housing.



A CARB bearing lubricated from the side.

Fig. 4



Mounting

When mounting CARB bearings the use of the SKF Drive-up Method is recommended. This is a more precise and less subjective method than measuring clearance reduction with a feeler gauge.

SKF can supply suitable tools (→ **fig. 5**) and mounting instructions for general applications as well as specific applications like drying and Yankee cylinders. SKF can also supply the software program for the "SKF Drive-up Method" making it possible to do your own calculations. Note that the drive-up values obtained are only valid for SKF bearings.

The most precise, reliable and also the simplest way to mount larger bearings with a tapered bore is the SKF SensorMount method.

The system comprises a bearing with a sensor and a hand-held indicator (→ **fig. 6**). The indicator reads the actual radial expansion and therefore no calculations or drive-up tables are needed to achieve the proper drive-up distance.

For detailed information about the SKF Drive-up Method and SensorMount please contact your local SKF sales unit. Additional information can be found:

- in the handbook *Rolling bearings in paper machines*,
- in the online catalogue available on skf.com
- online at skf.com/mount.

Axial mounting position

In **diagram 2**, **page 12**, the axial clearance was shown in relation to the radial clearance. However, the operating radial clearance depends on the temperature distribution in the bearing arrangement, which in turn depends on the design and the operating conditions.

Diagram 2 shows the axial to radial clearance relation estimated for bearing C 3052 K/C4 and 150 – 160 °C (300 – 320 F) steam temperature without journal insulation. The dotted lines in **diagram 2** show what happens to the available clearance during start-up with or without initial displacement. Remember that available clearance has its minimum at start-up when the temperature difference between inner and outer ring is at it's maximum. The available clearance increases when all parts are warmed up, shown in the diagram as "running".

A Without initial axial displacement position A is reached at start-up. In this position the axial clearance is 3 mm outwards (from the cylinder) and 17 mm inwards.

B With 10 mm initial axial displacement position B is reached at start-up. In this position the axial clearance is 13 mm outwards (from the cylinder) and 7 mm inwards.

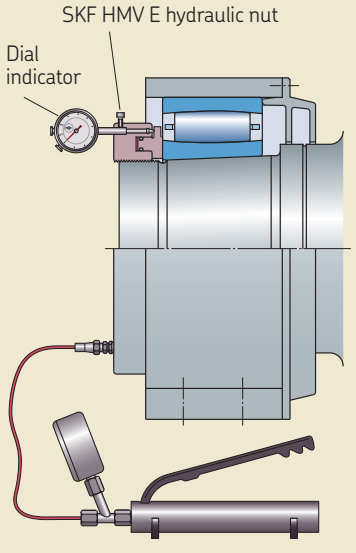
SKF experience shows that the cylinder thermal elongation is about one millimetre per metre cylinder length at a steam temperature of 150 °C (300F). To compensate for this elongation it is possible to displace the housing outwards from the cylinder (→ **fig. 7**).

To achieve an equal or higher safety margin against preload as for spherical roller bearings with C4 clearance, the axial mounting positions shown in **table 2** are recommended (valid for cold machine).

In many cases, especially for insulated journals with negligible risk of steam leakage, these values for initial axial displacement of the housing may be reduced. In such cases please consult SKF.

Mounting tools used with the SKF Drive-up Method.

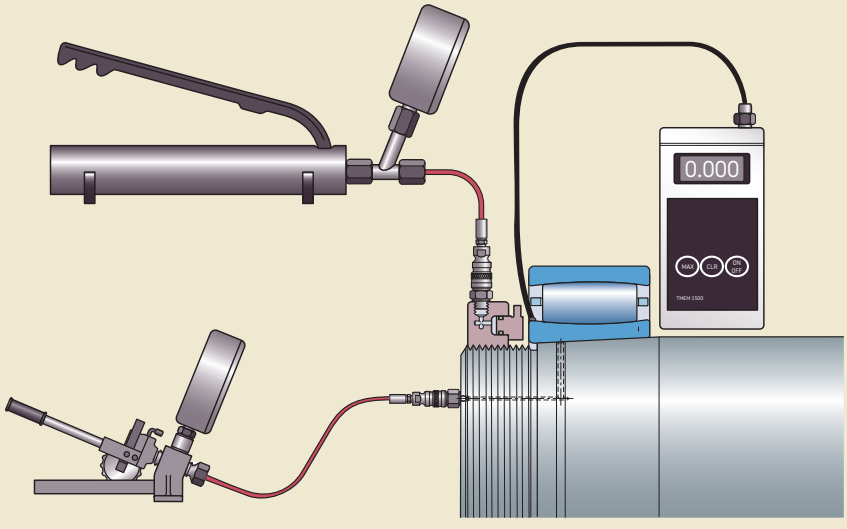
Fig. 5



SKF 729124 SRB (for nuts ≤ HMV 54 E)
SKF TMJL 100 SRB (for nuts ≤ HMV 92 E)
SKF TMJL 50 SRB (for nuts ≤ HMV 200 E)

Mounting tools used with the SKF SensorMount method.

Fig. 6



Dismounting

Usually drying cylinder bearings are mounted in non-split housings.

The best way to release the inner ring from a tapered shaft is to use the oil injection method. Therefore the lock nut needs to be loosened and positioned at a distance from the inner ring side face of about twice the drive-up distance. This is valid also for other bearing types. If the distance is too long there is a risk of damage to the raceways when the inner ring is released from the shaft.

It is often difficult to dismount the bearing from the housing without damaging the raceways. The reason is that it is difficult to apply an axial dismounting force by hand.

Further, a spherical roller bearing sometimes tends to stick in the housing, especially if fretting corrosion has occurred.

Larger CARB bearings which have a loose or a transition fit in the housing can be removed using a tool with hooks that pass between the rollers and grip the outer ring from behind (→ **fig. 8**), so that the withdrawal forces are applied directly to the outer ring and the rollers do not become jammed between the rings.

Diagram 2

Example: C 3052 K/HA3C4 with radial clearances estimated for 150–160 °C *(300–320°F)* steam temperature and no journal insulation. Cylinder thermal expansion 7 mm.

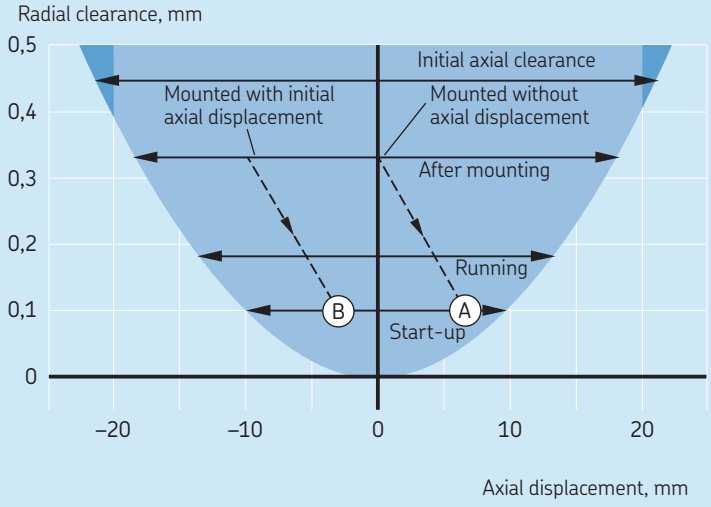


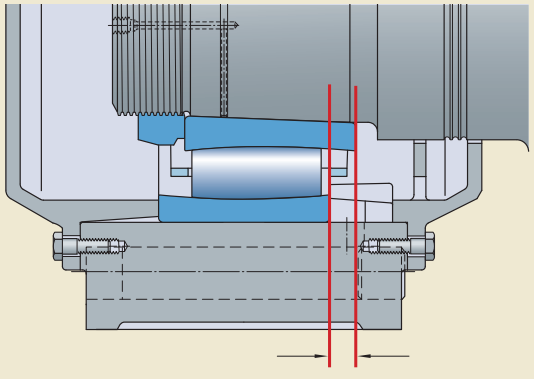
Table 2

Axial housing mounting positions for cold machine (→ diagram 2, page 12). For further information please contact SKF.

Cylinder length over	incl.	Steam temperature		Initial axial displacement
m		°C	°F	mm
0	4	<160	*<320*	0±1
0	4	160–200	*320–390*	2–4
4	7	<160	*<320*	2–4
4	7	160–200	*320–390*	4–6
7	11	<160	*<320*	4–6
7	11	160–200	*320–390*	6–8

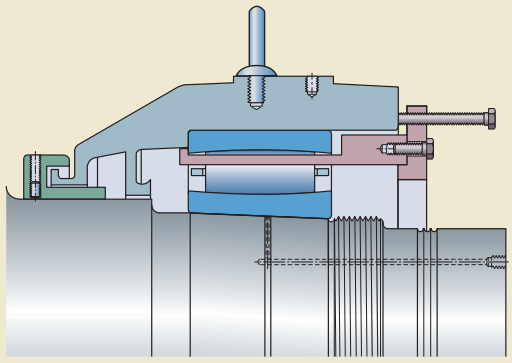
Initial axial housing displacement can be used to increase the available axial clearance for cylinder expansion.

Fig. 7



Schematic sketch of tool for removal of CARB bearings from a non-split housing.

Fig. 8



Rebuild to CARB bearing arrangement

To obtain all the benefits a CARB bearing arrangement can provide, SKF recommends the use of a housing designed for a CARB bearing when rebuilding existing machines. Reworking existing housings may cause additional machine stoppages and this can be as expensive as a new housing.

After many years in operation the bearing seatings of drying cylinder housings may have extensive fretting corrosion and be worn or oval. When converting from a rocker housing, a reworked housing will not be as stable as a new one.

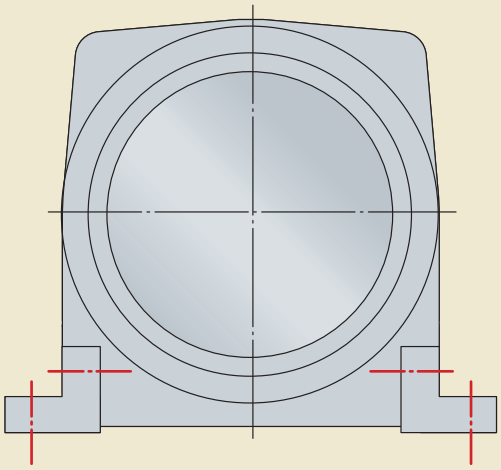
As CARB bearings follow the ISO standard for bearing dimensions, bearing C 3152 has the same boundary dimensions as spherical roller bearing 23152 or cylindrical roller bearing N 3152. If the existing housings are inspected with good result they may in many cases, perhaps somewhat modified, be used for CARB bearings when converting from other bearing types. If however modifications are required, the total cost for a rebuild is often as high as an investment in new housings.

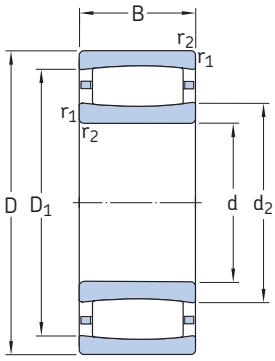
- When a rocker housing is modified to a fixed housing, it must be locked in all directions. This can be achieved by modifying the housing according to **fig. 9**, depending on the design of the original housing.
- When rebuilding from spherical roller bearings with an axially free outer ring, distance sleeves have to be used in order to axially locate the outer ring of the CARB bearing.
- When the existing bearing is lubricated from the side (→ **fig. 2**, **page 8**), it can be replaced by CARB without any changes related to the lubrication, although the oil flow can be somewhat increased due to the open design of CARB bearing.
- If the existing bearing is lubricated through the outer ring (→ **figs. 1**, **3** and **4**, **pages 8** and **9**), the housing lubrication design must be changed when converting to CARB bearings. One way is to displace the oil inlet to the outer side of the bearing as for the SKF housings specifically designed for CARB bearings. However, this requires modifications in order to ensure that no oil drains without passing through the bearing. In some existing housings the diametre of the oil channels connecting the two sides of the bearing is small and should be enlarged to make a high oil flow possible. The other alternative is to displace the oil inlet to the inner side of the bearing and plug the oil channels connecting the two sides. Note that this modification may influence the drainage capacity of the housing.

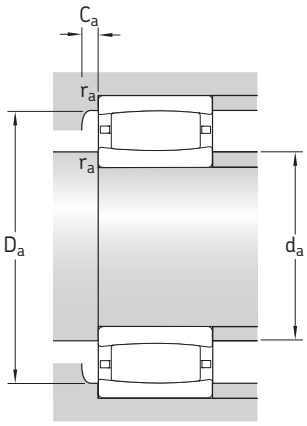
When rebuilding to CARB bearings, please contact SKF in order to optimize the bearing arrangement regarding bearing function and total cost.

Rebuild from rocker housing

Fig. 9







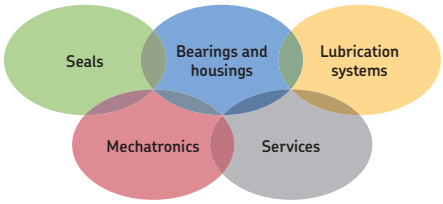
Dimensions						Abutment and fillet dimensions			Basic load ratings dynamic	static	Designation[1]	Designation for bearing with case hardened inner rings[3]
d	D	B	d_2	D_1	$r_{1,2}$ min.	d_a max.	D_a min.	C_a[2] min.	C	C_0		
mm						mm			kN		–	
170	310	86	209	274	4	230	255	3	1 270	1 630	* **C 2234 K/C4**	**C 2234 K/HA3C4**
180	280	74	209	251	2,1	220	240	2	880	1 340	* **C 3036 K/C4**	**C 3036 K/HA3C4**
	300	96	210	266	3	230	255	2,2	1 250	1 730	* **C 3136 K/C4**	**C 3136 K/HA3C4**
190	290	75	225	266	2,1	235	255	1,9	930	1 460	* **C 3038 K/C4**	**C 3038 K/HA3C4**
	340	92	224	296	4	250	275	1,6	1 370	1 730	* **C 2238 K/C4**	**C 2238 K/HA3C4**
200	310	82	235	285	2,1	250	275	2,9	1 120	1 730	* **C 3040 K/C4**	**C 3040 K/HA3C4**
	340	112	245	305	3	260	307	–	1 600	2 320	* **C 3140 K/C4**	**C 3140 K/HA3C4**
220	340	90	257	310	3	270	295	3,1	1 320	2 040	* **C 3044 K/C4**	**C 3044 K/HA3C4**
	370	120	268	333	4	290	315	3,5	1 900	2 900	* **C 3144 K/C4**	**C 3144 K/HA3C4**
	400	108	259	350	4	295	320	1,7	2 000	2 500	* **C 2244 K/C4**	**C 2244 K/HA3C4**
240	360	92	276	329	3	290	315	1,3	1 340	2 160	* **C 3048 K/C4**	**C 3048 K/HA3C4**
	400	128	281	357	4	305	335	3,7	2 320	3 450	* **C 3148 K/C4**	**C 3148 K/HA3C4**
260	400	104	305	367	4	325	350	3,4	1 760	2 850	* **C 3052 K/C4**	**C 3052 K/HA3C4**
	440	144	314	394	4	340	375	4,1	2 650	4 050	* **C 3152 K/C4**	**C 3152 K/HA3C4**
280	420	106	328	389	4	350	375	1,8	1 860	3 100	* **C 3056 K/C4**	**C 3056 K/HA3C4**
	460	146	336	416	5	360	395	4,1	2 850	4 500	* **C 3156 K/C4**	**C 3156 K/HA3C4**
300	500	160	362	448	5	390	425	4,9	3 250	5 200	* **C 3160 K/C4**	**C 3160 K/HA3C4**
320	540	176	372	476	5	410	455	3,9	4 150	6 300	* **C 3164 KM/C4**	**C 3164 KM/HA3C4**
340	580	190	405	517	5	445	490	4,2 4	900	7 500	* **C 3168 KM/C4**	**C 3168 KM/HA3C4**
360	600	192	423	537	5	460	510	3,9	5 000	8 000	* **C 3172 KM/C4**	**C 3172 KM/HA3C4**
420	620	150	475	570	5	510	550	2,2	3 800	6 400	* **C 3084 KM/C4**	**C 3084 KM/HA3C4**
	700	224	508	618	6	540	595	3,8	6 000	10 400	* **C 3184 KM/C4**	**C 3184 KM/HA3C4**
460	680	163	539	624	6	565	605	2,3	4 000	7 500	* **C 3092 KM/C4**	**C 3092 KM/HA3C4**
	760	240	559	679	7,5	570	655	4,2	6 800	12 000	* **C 3192 KM/C4**	**C 3192 KM/HA3C4**
480	700	165	555	640	6	580	625	2,3	4 050	7 800	* **C 3096 KM/C4**	**C 3096 KM/HA3C4**
500	720	167	572	656	6	600	640	2,3	4 250	8 300	* **C 30/500 KM/C4**	**C 30/500 KM/HA3C4**
	830	264	605	738	7,5	655	705	–	7 500	12 700	* **C 31/500 KM/C4**	**C 31/500 KM/HA3C4**
530	780	185	601	704	6	635	685	2,5	5 100	9 500	* **C 30/530 KM/C4**	**C 30/530 KM/HA3C4**
	870	272	635	781	7,5	680	745	4,8	8 800	15 600	* **C 31/530 KM/C4**	**C 31/530 KM/HA3C4**

[1] For sizes not shown, please contact SKF.
[2] Minimum width of free space for bearings with cage in normal position; for a displaced bearing, half the displacement should be added to the table value.
[3] Please check availability before ordering.
* SKF Explorer bearing

Dimensions						Abutment and fillet dimensions			Basic load ratings dynamic	static	Designation[1]	Designation for bearing with case hardened inner rings[3]
d	D	B	d_2	D_1	$r_{1,2}$ min.	d_a max.	D_a min.	C_a,[2] min.	C	C_0		
mm						mm			kN		–	
560	820	195	660	761	6	695	740	2,7	5 600	11 000	* **C 30/560 KM/C4**	**C 30/560 KM/HA3C4**
600	870	200	692	805	6	725	775	2,7	6 300	12 200	* **C 30/600 KM/C4**	**C 30/600 KM/HA3C4**
630	920	212	717	840	7,5	755	810	2,9	6 800	12 900	* **C 30/630 KM/C4**	**C 30/630 KM/HA3C4**
670	980	230	775	904	7,5	820	875	2,9	8 150	16 300	* **C 30/670 KM/C4**	**C 30/670 KM/HA3C4**
710	1 030	236	807	945	7,5	850	910	3,2	8 800	17 300	* **C 30/710 KM/C4**	**C 30/710 KM/HA3C4**

C

[1] For sizes not shown, please contact SKF.
[2] Minimum width of free space for bearings with cage in normal position; for a displaced bearing, half the displacement should be added to the table value.
[3] Please check availability before ordering.
* SKF Explorer bearing



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These competence areas include bearings and units, seals, lubrication systems, mechatronics, and a wide range of services, from 3-D computer modelling to cloud-based condition monitoring and asset management services.

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PUB 72/P2 13390 EN · September 2013

This publication supersedes publication 4410.

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