

DESIGN AND SELECTION OF BEARINGS AND HOUSINGS USED IN MATERIAL HANDLING APPLICATIONS

SPHERICAL ROLLER BEARINGS

Spherical roller bearings (figure 1) generally provide the best solution for material handling applications. These bearings have very high carrying capacities and can take up both radial and axial forces. They are easy to handle when mounting and dismounting and are able to accept misalignment caused either by shaft deflection or inaccurate positioning.

OPTIMISATION OF THE DESIGN OF SPHERICAL ROLLER BEARINGS

The internal design of spherical roller bearings differs markedly from bearing manufacture to bearing manufacturer. By choosing a spherical roller bearing of a particular design, we will show how a simple solution can be provided to a problem which, initially appears to be complex. To illustrate how the design of spherical roller bearings differ, we will first study the development of the spherical roller bearing at SKF.

ORIGINAL DESIGN

The first spherical roller bearing; invented by SKF in 1919, had asymmetrical rollers and a central integral flange (figure 2). Due to their asymmetry, the rollers were effectively guided. These bearings performed satisfactorily and soon became popular, but certain disadvantages occasionally became apparent. The sliding contact between the roller ends and the flange is critical with regard to effective lubrication. Under axial load, the resultant roller load is displaced towards the small end of the roller (figure 3). This increase the force on the flange and may cause flange fracture; also rolling contact end stresses can arise which reduce raceway life.

Grinding reliefs adjacent to the flanges reduce the effective roller length and thus the load rating of the bearing is decreased. These grinding reliefs are, in practice, often appreciably wider than the roller end chamfer. These disadvantages are inherent in all spherical roller bearings with a central integral flange and grinding reliefs, irrespective of whether they have symmetrical or asymmetrical rollers.

THE C-DESIGN BEARING

A further important stage in spherical roller bearing development was reached in 1948, when SKF introduced the C-design bearing (figure 4) which had symmetrical rollers and a loose central guide ring. The advantage of symmetrical rollers is that they endeavour to attain an equilibrium axial position characterised by the coincidence of their largest diameter with a line joining the centres of curvature of inner and outer ring raceways (points A and B in the figure). A symmetrical load distribution along the roller with the best possible utilisation of its length is achieved. This, together with the absence of grinding reliefs, enables the bearing to be designed to provide maximum possible load carrying capacity.

The width of the guide ring is equal to the space between the roller rows, so if the rollers run correctly aligned there are no forces acting between the roller ends and guide ring. Only if a roller is misaligned is a correcting force needed to re-align the roller. When an axial load acts on the bearing and one ring is displaced relative to the other ring, the rollers move a distance of half the displacement of the bearing ring to maintain the equilibrium condition (figure 5). As the rollers in both rows move through an equal distance, the guide ring is still ideally positioned.

The C-design bearing became the most commonly used spherical roller bearing because the rollers were free to adopt their correct geometrical position. It was found, however, that the bearings ran at different operating temperatures under the same operating conditions and this was found to depend on the direction and magnitude of roller skew. The skew may be defined as positive or negative (figure 6). The running temperature is of a minimum when the skew is positive.

To begin with, this was solely a matter of observation and it was not possible to explain why the rollers skewed in a particular direction. It was assumed that roller skew was restricted by the guide ring or cage pocket.

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However, with computer aid, it proved possible to study theoretically what happened to rollers in contact with raceways under load. It was established that the magnitude and direction of the skew angle were determined by the extent of the surface pressure and the frictional forces in the rolling contact area. There was no need to rely on the cage pocket for this purpose if the bearing had been correctly designed. The theoretical background may be summarised as follows:

When the rolling elements of a bearing have a curved profile, a degree of sliding movement always occurs along the greater part of the contact surface simultaneously with the rolling motion. In the case of a spherical roller bearing, this is illustrated by figure 7. True rolling only occurs at the points where the rolling cone lines A and B intersect the roller contact. Sliding occurs in one direction between the points of intersection and in the opposite direction inboard and outboard of these points.

Sliding gives rise to friction forces in the direction of sliding (figure 8). Note that for instance the forces B balance the forces C about the skewing axis A-A. The remaining forces (figure 9) give rise to a skewing moment relative to the skewing axis A-A.

From figure 9, it can be seen that the outer raceway forces try to skew the roller positively and the inner raceway forces try to skew it negatively. Computer simulations show that the roller tends to find an equilibrium skew angle, but often a negative one. It can be made more positive, however, by reducing friction at D and E or increasing it at F and G.

THE CC-DESIGN BEARING

Figure 10 shows the variation of bearing friction plotted against the skew angle β . The skew angle is defined as positive when the axially directed friction forces oppose the external axial load (figure 11). As expected, friction increases with increasing angle of skew, as seen from the curve of a radially loaded bearing. Under axial load, however, a zero angle does not give the lowest friction, this is attained with a slightly positive. The reason for this is that the axially directed frictional forces assist in carrying the external load (figure 11), thus reducing the load acting on the rollers.

To ensure that optimum roller guidance is maintained, SKF carried out two important changes to the internal design of spherical roller bearings. One concerns the relationship between roller and raceway profiles (osculation), the other, the raceway surface condition. Even though the refinements may appear superficial, they have justified the granting of several patents. These bearings, introduced in 1979, carry an extra C in the bearing designation, for example 23226C is designated 23226CC.

The CC-design has reduced friction, permitting cooler running temperatures or higher speeds. It also substantially increased axial load-carrying capacity and lubricant life.

A PRACTICAL EXAMPLE USING A CC-DESIGN SPHERICAL ROLLER BEARING IN A MATERIAL HANDLING APPLICATION.

A number of customers have approached SKF South Africa because they have experienced premature failure of, or have had difficulty in selecting bearings used in the footstep housings of vertical belt turnover pulleys.

Figure 12 shows a proposal submitted by a customer for their vertical turnover pulleys. It was suggested that a 23120 spherical roller bearing carry the radial load of 5 000 N and a thrust ball bearing 53215 carry the axial load of 7850N. The rotational speed of the pulley is 242,52 r/min. The required life was 100 000 hours.

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The calculated lives were as follows:-

23120 $7,36 \times 10^7$ hours

53215 43 000 hours

The life of the thrust ball bearing was too low.

We explained to the customer that if an SKF CC-design spherical roller bearing is used, it can accommodate both the radial and axial loads.

Under the above operating conditions, SKF spherical roller bearing 23120 CC/W33 had a calculated life of 186 000 hours which is well in excess of the 100 000 hours required.

The bearing arrangement for these particular turnover pulleys is shown in figure 13.

E-DESIGN SPHERICAL ROLLER BEARING

In 1989 SKF introduced a new and stronger spherical roller bearing designated E. This was a further development of the successful CC-design bearing and will replace it in the small and medium size range.

The pressed steel cages developed for the E-design permit the inclusion of a greater number and/or large diameter rollers of increased length, imparting even higher load carrying capacity to the bearings (figure 14). The guide ring is now positioned towards the outer ring.

Figure 15 provides a good illustration of the way the increased load carrying capacity has step by step, allowed for the downsizing of spherical roller bearings for a certain radial load. The basic dynamic load ratings of all eight SKF bearings are roughly the same.

BEARING HOUSINGS

Standard cast iron plummer block housings are the most commonly used housings used in material handling applications. They are economically and as they are split, inspection is facilitated. They are readily available, therefore the demand for spares can easily be accommodated. A whole range of housings are available and are designated SNH, SD or SDJC housings depending on shaft size.

Plummer block housings are designed for use with self-aligning ball bearings and spherical roller bearings. The bearings may be mounted directly on the shaft but are more commonly mounted on adapter sleeves (figure 16).

The bearing seating in the housing bore is machined to tolerance H8 and designed for non-locating bearing arrangements. It is possible for a bearing to move axially in both directions. Elongation of the shaft as a result of thermal expansion can therefore be compensated for inside the housing.

Locating bearing arrangements (figure 16) are obtained by inserting two locating rings, one at each side of the bearing.

Plummer block housings should be designed to have adequate strength no matter what the direction of loading. Tests have shown that very few housing manufacturers can provide housings which can accommodate high loads in all directions (figure 17).

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To ensure that bearing life is not affected by incorrect seatings, it is necessary that housings indeed conform to tolerance H8. Figure 18 shows that very few housing manufacturers meet this requirement and that often the diameters are too small. Calculations carried out by SKF have shown that these housings with undersized bores can cause life reductions which vary between 30 and more than 90%!

SEALS

Plummer block housings can be provided with various standard seals. Figure 19 summarises the various seal designs available. In the material handling industry, the double-lip split seal and the labyrinth seal are the most popular and normally very effective.

If the operating conditions are very hostile, i.e. dirty, dusty abrasive and wet the standard seals are not suitable and repeated bearing failures occur. It is then recommended that taconite seals are incorporated. Figure 20 shows examples of taconite seals. When greasing the seal, the grease purges through the outboard seal and the contaminants are expelled.

INFLUENCE OF MOUNTING, SEALING AND MAINTENANCE ON BEARING LIFE

Bearing life is to a great extent influenced by the design of the sealing arrangement. To illustrate the effect of sealing, mounting and maintenance on bearing life we will consider a conveyor pulley application.

Pulley	:	Head drive Belt speed 4 m/s
Pulley load	:	1 200 kN
Rotational speed	:	62 r/min
Lubrication	:	EP2 grease with a base oil viscosity of 209 mm ² /s at 40°C
Bearing	:	SKF 23168 CCK/W33 mounted in plummer block SDJC 3168
Environment	:	Dirty and wet

It is possible to calculate the effective service life of the bearings using the SKF New Life Theory. The New Life Theory takes into account the effect of lubrication and contamination.

- CASE 1** : Mounting carried out by a fitter on site. The plummer block has standard labyrinth seals.
- CASE 2** : Mounting carried out by a fitter in a workshop. The plummer block has standard labyrinth seals.
- CASE 3** : Mounting carried out by a fitter in a workshop. The plummer block has a taconite seal. The inner seal is a felt seal and the outer seal a V-ring. The seal is greased once a week.

The calculated lives are as follows:

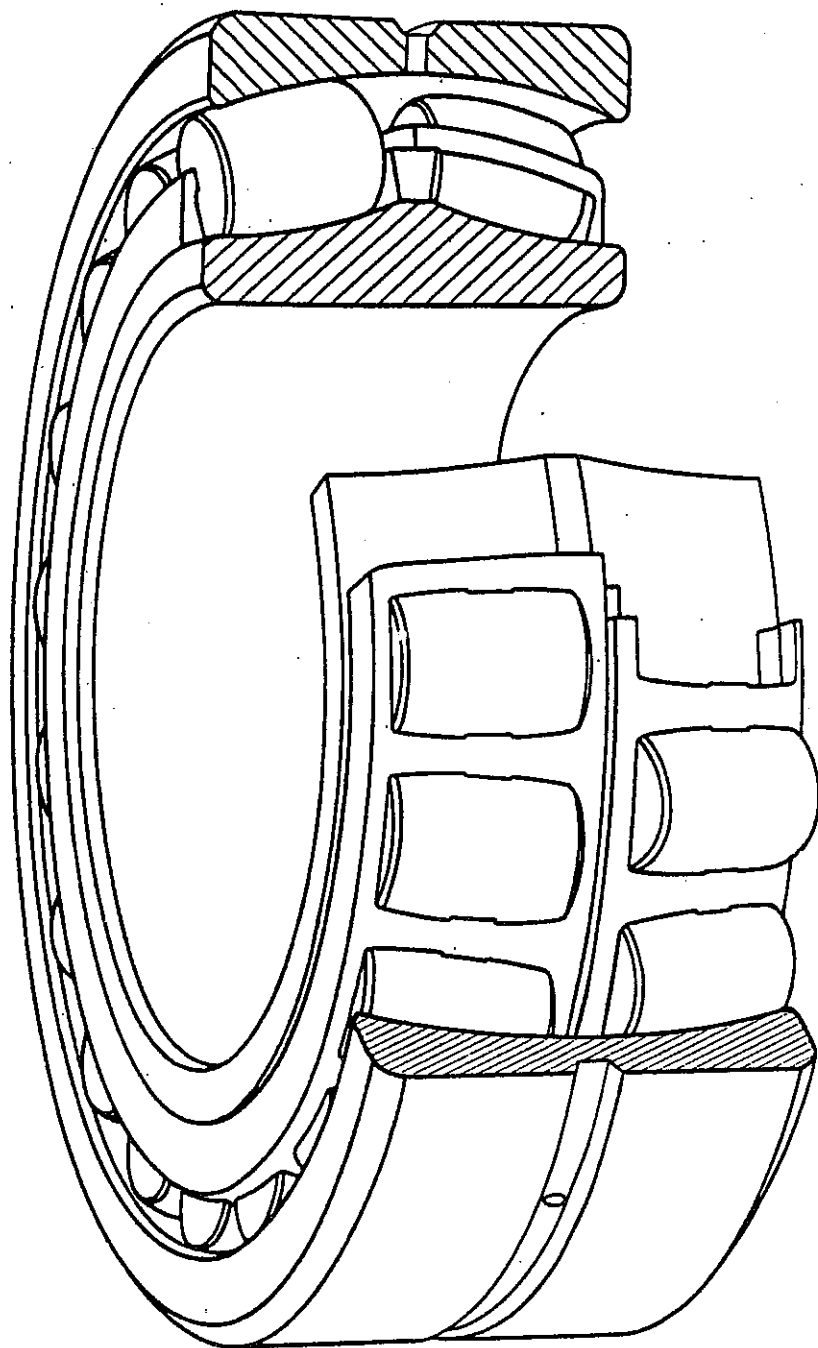
CASE 1	:	52 000 hours
CASE 2	:	66 000 hours
CASE 3	:	129 000 hours

**Design and selection of bearings and housings
used in material handling applications**

This example serves to illustrate that it is now possible to quantify the degree of contamination and its damage potential in a bearing arrangement. By using bearings of the correct internal design and housings designed and manufactured correctly and by using better sealing long bearing lives and trouble-free operation can be achieved.

REFERENCES:

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M Kellström, SKF Ball Bearing Journal 203
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M Kellström, ASME publication 79 - Lub - 23
3. Cleanliness and its importance on bearing performance.
E Ioannides, E Beghini, G Bergling, J Goodall-Wuttkowski, B Jacobson, SKF Ball Bearing Journal 242
4. SKF General Catalogue 4000/1 E



CC

FIG.1 : SKF Spherical Roller Bearing

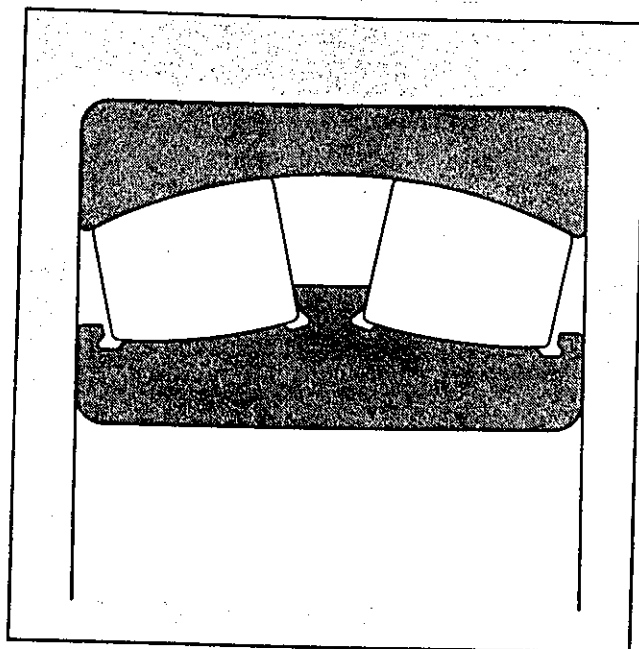


FIG. 2 : Design of the first spherical roller bearing

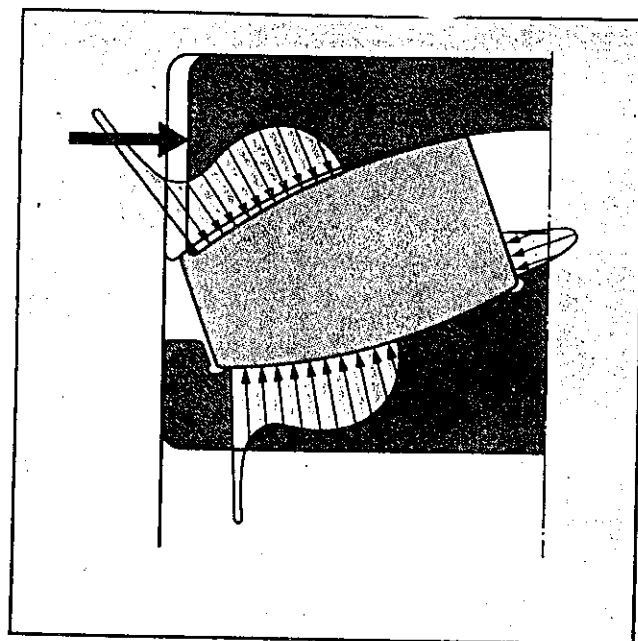


FIG. 3 : Axial load results in displacement of the roller load towards the outer end of the roller with an attendant risk of roller contact and stresses.

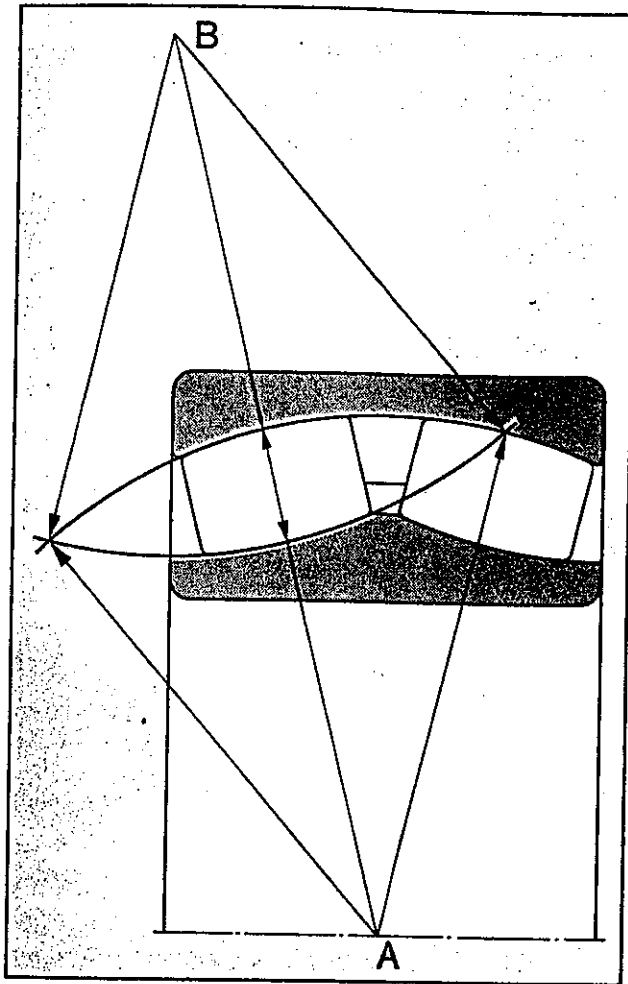


FIG. 4 : The largest diameter of the roller D coincides with a line joining the inner and outer ring raceway centres of curvature A and B.

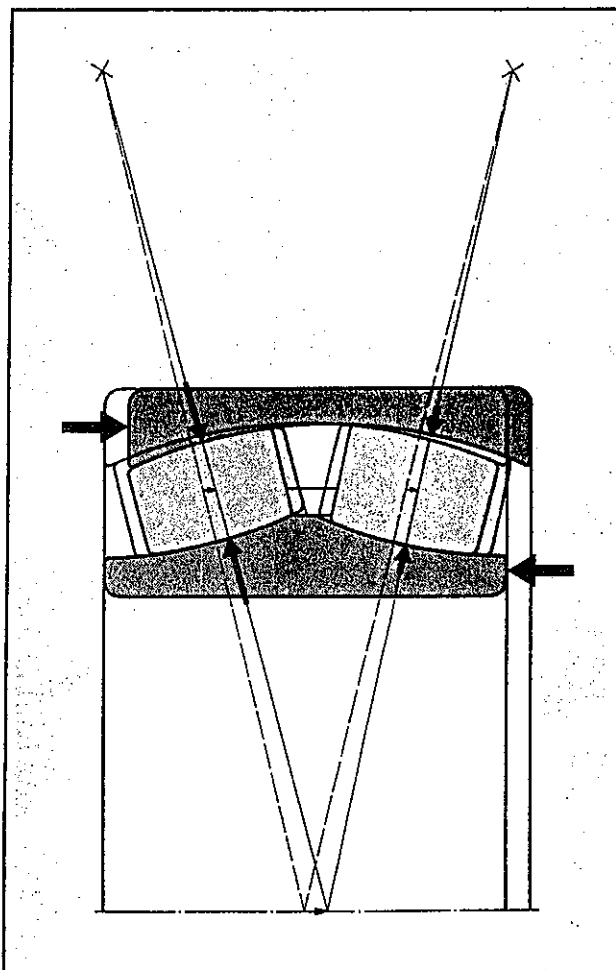


FIG. 5 : With axial load the rollers are displaced half the distance travelled by one ring relative to the other ring.

FIG. 6 : Definition of roller skew

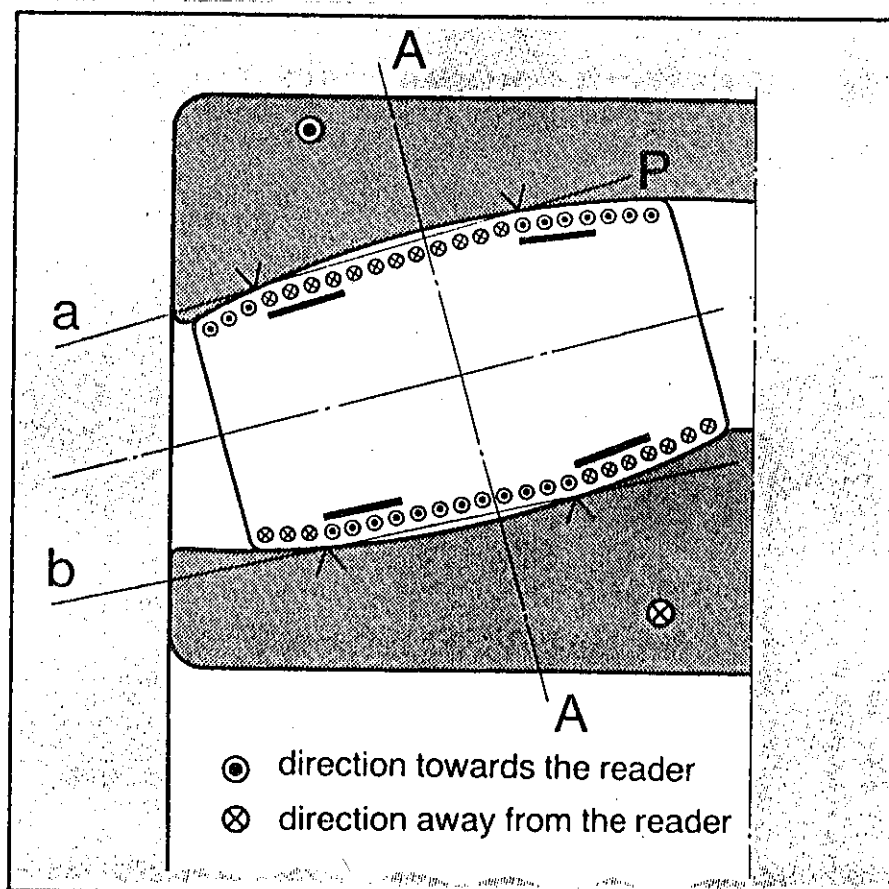
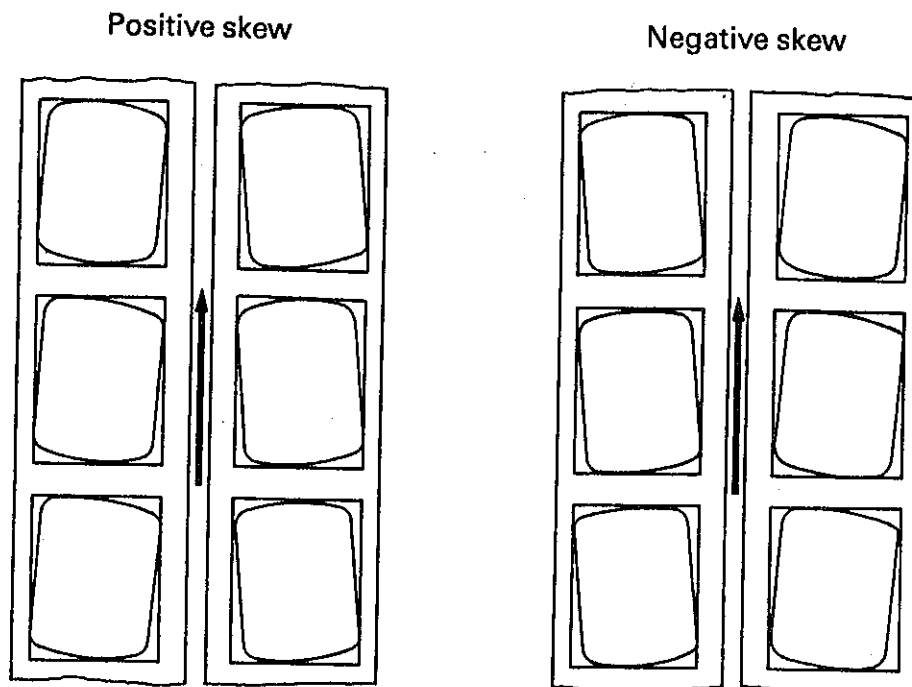


FIG. 7 : The frictional forces have different directions inboard and outboard the rolling point (marked V).

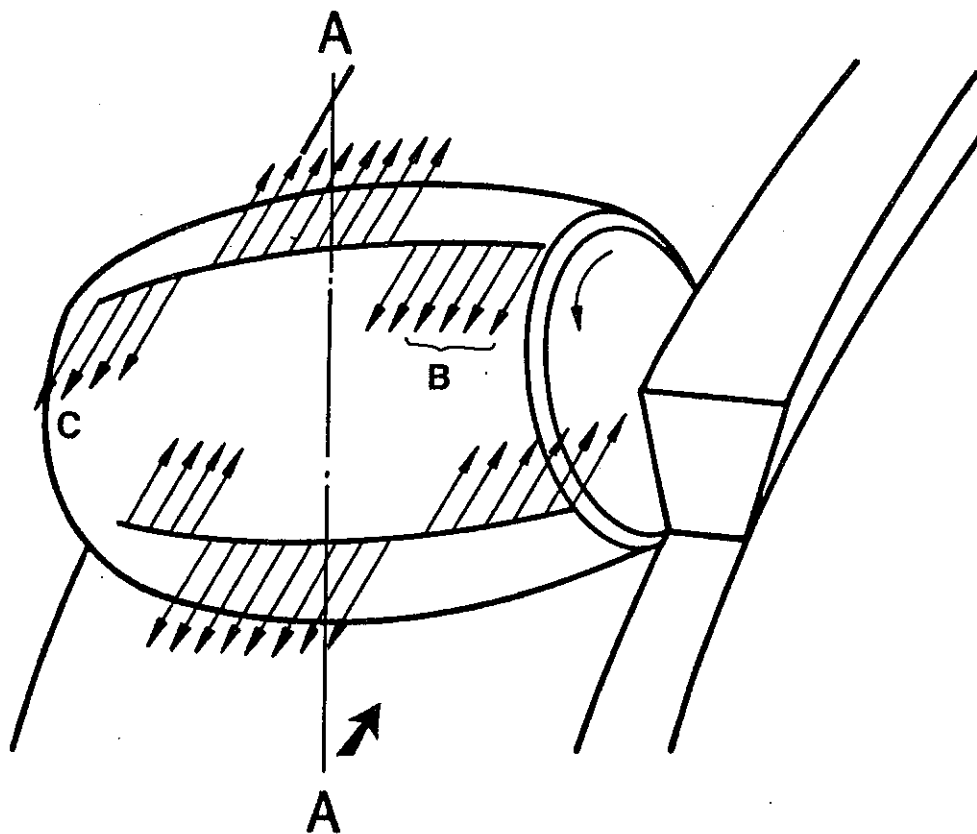


FIG. 8 : The direction of the friction forces on the roller. Note that for instance the forces B balance the forces C about the skewing axis A-A.

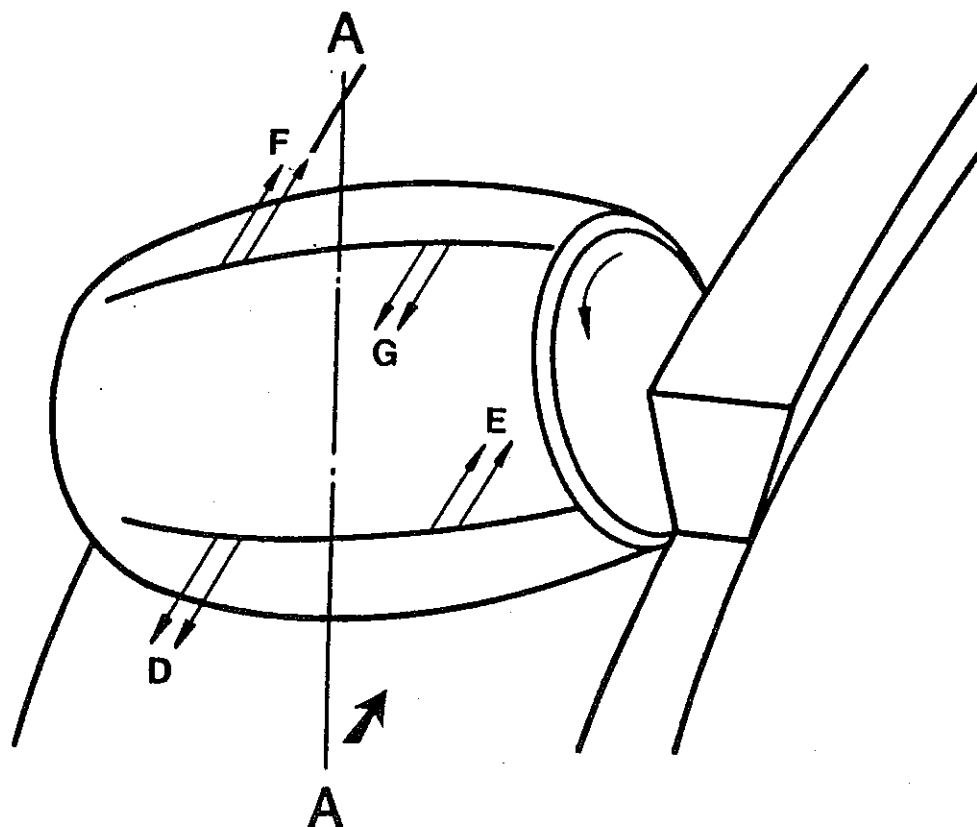


FIG. 9 : After rubbing out the forces not contributing to a skewing moment about A-A.

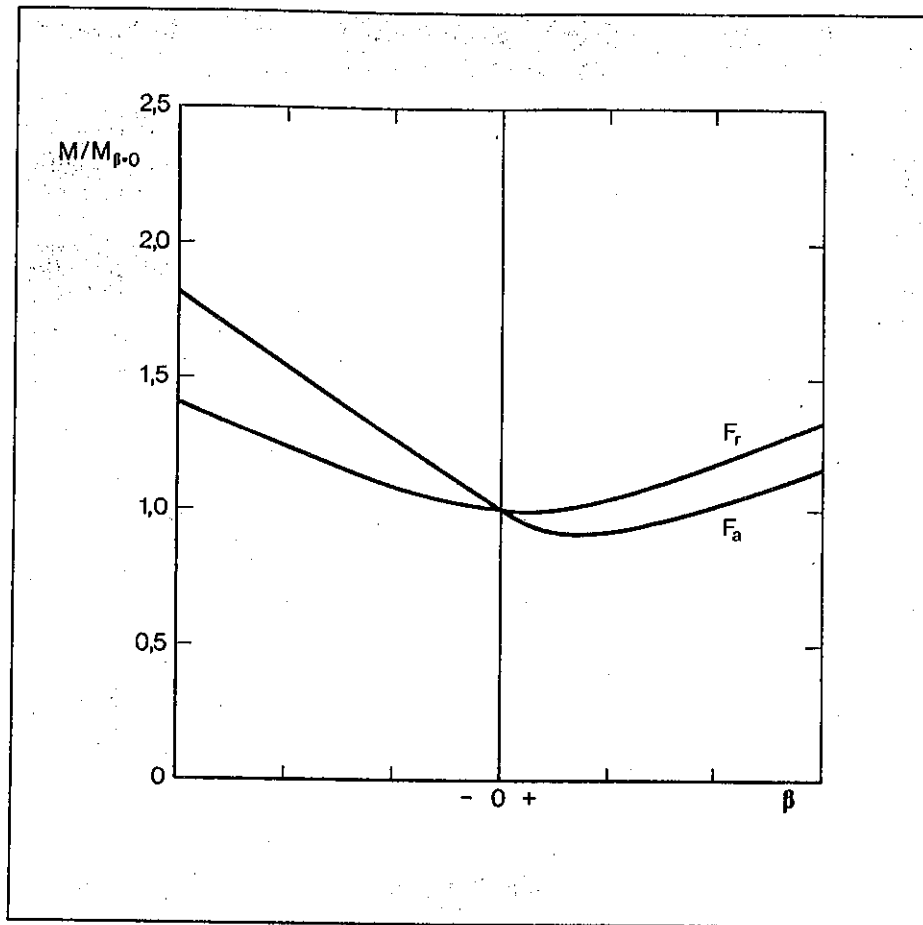


FIG. 10 : Under axial load, a particular positive roller skew angle gives the lowest friction.

FIG. 11 : The axial component of the friction forces which occur as a result of positive roller skew, assist in carrying the external axial load.

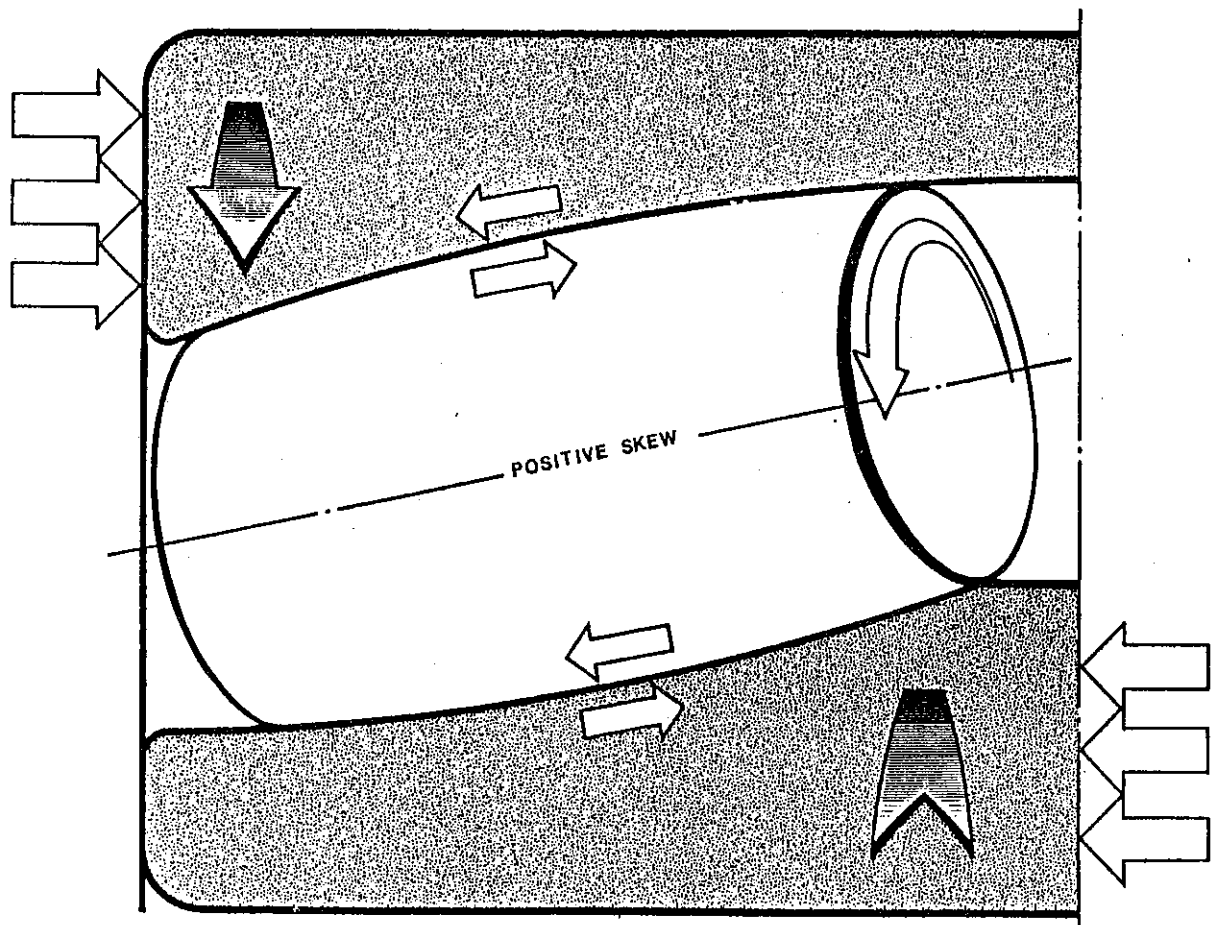
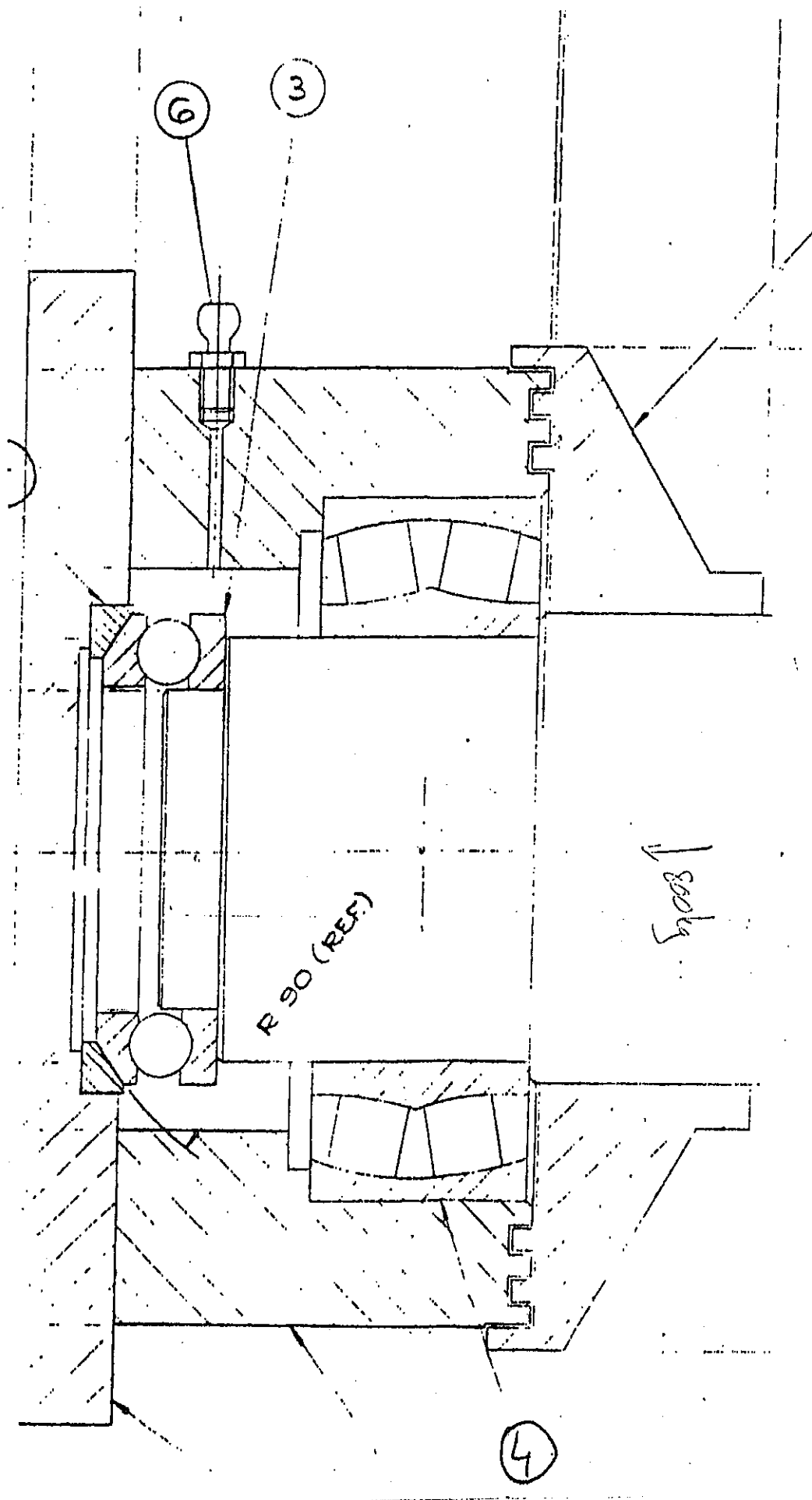


FIG. 12 : Proposed bearing arrangement for a vertical turnover pulley.



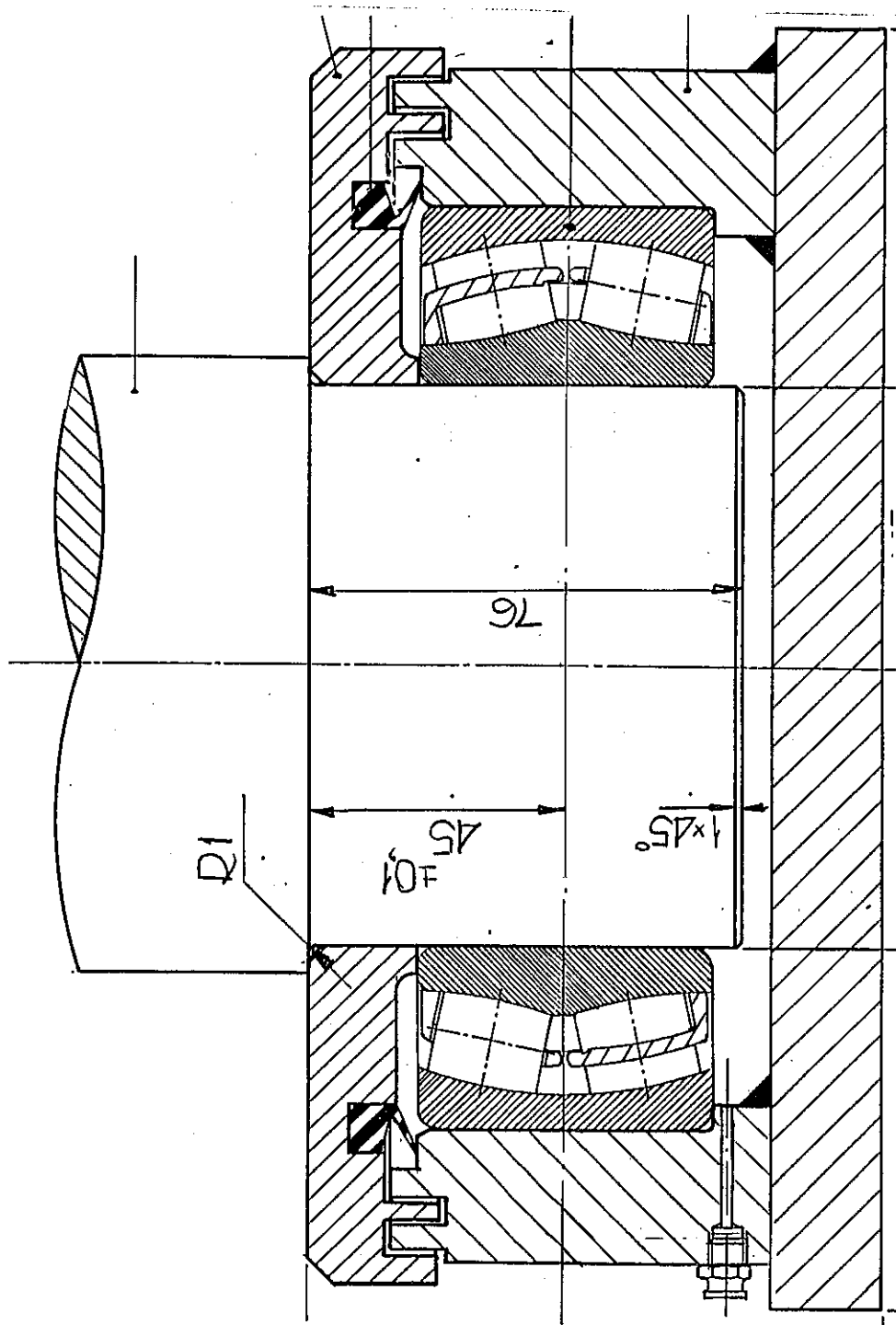


FIG. 13 : SKF solution.

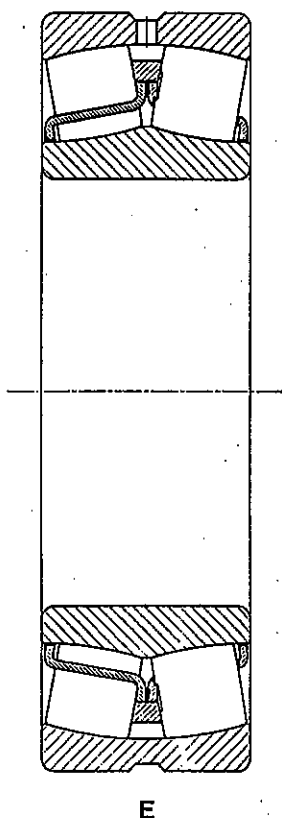
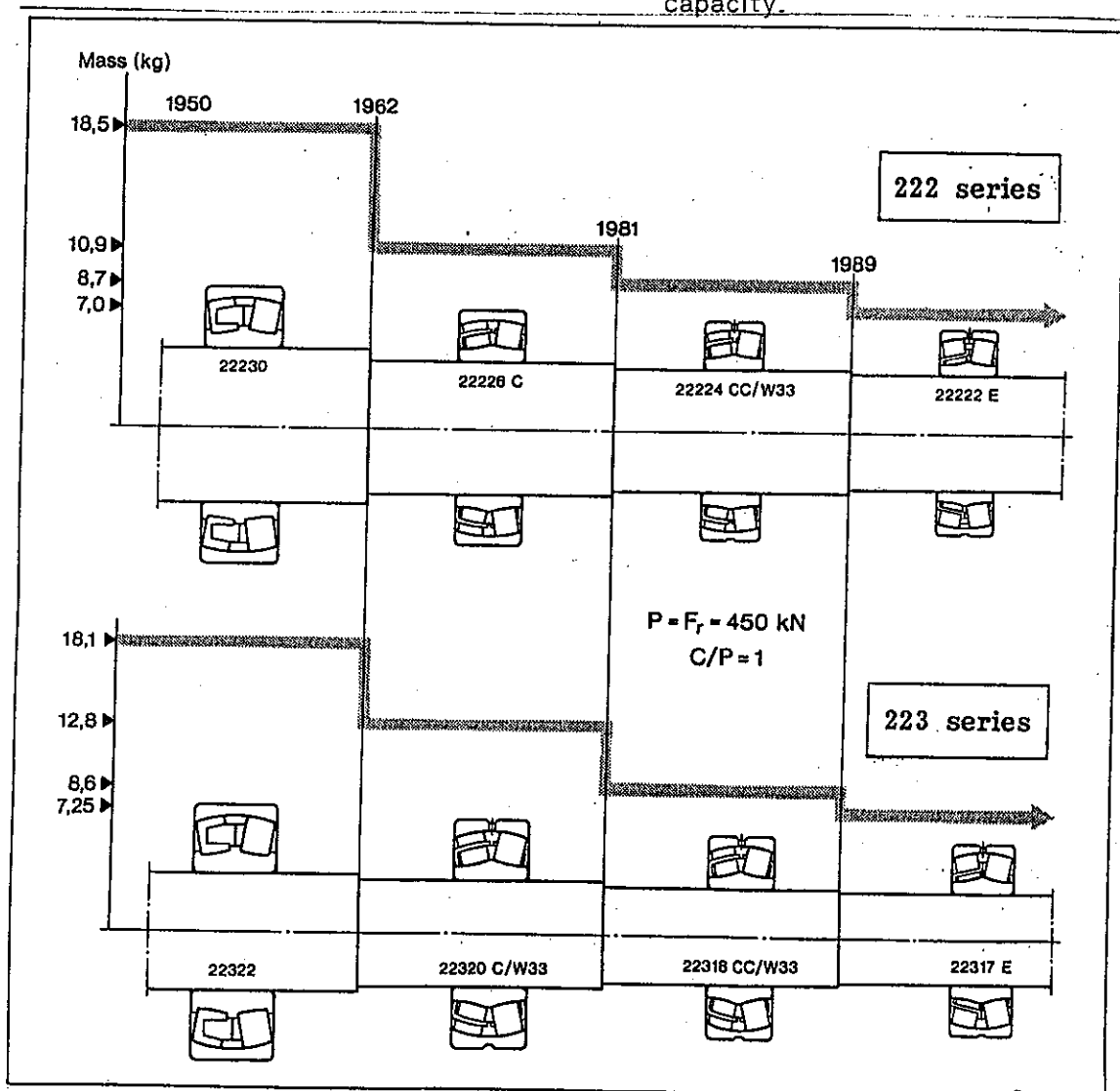


FIG. 14 : New E-design spherical roller bearing.

FIG. 15 : Evolution of the spherical roller bearing. All eight bearings have roughly the same capacity.



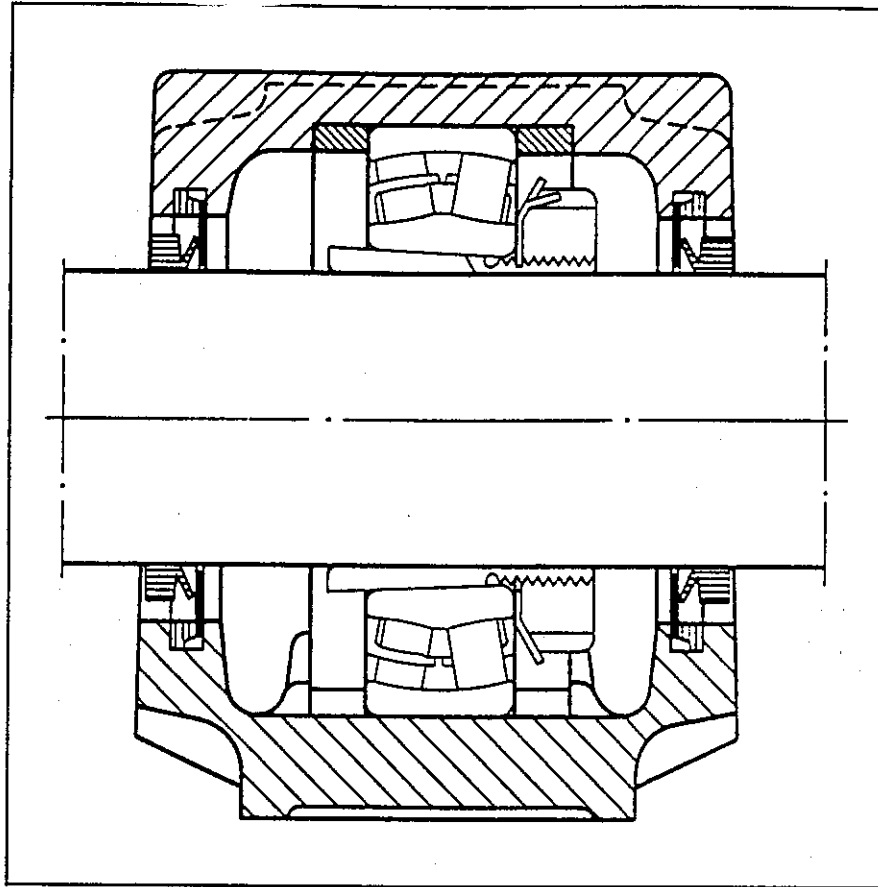
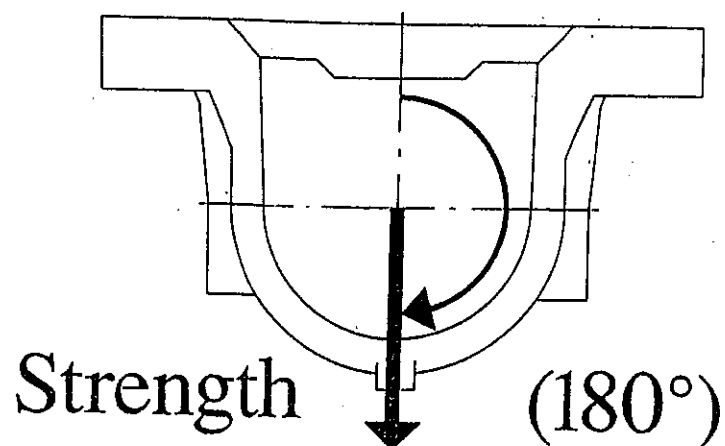


FIG. 16 : Spherical roller bearing mounted on adapter sleeve in an SNH plunger block.

Note how the locating bearing is positioned by means of two locating rings.



kN		
140	SKF	SNH 511-609
115		SNV 100
97		SN 511
91		SN 511
88		SN 511
87		SNU 511-609
85		SN 511
84		SSN 511
79		SN 511
78		SN 511
73		SN 511
69		SNE 511
68		SN 511
65		SN 511
55		S 511

FIG. 17 : Strength of plummer block housings

SKF vs competitors

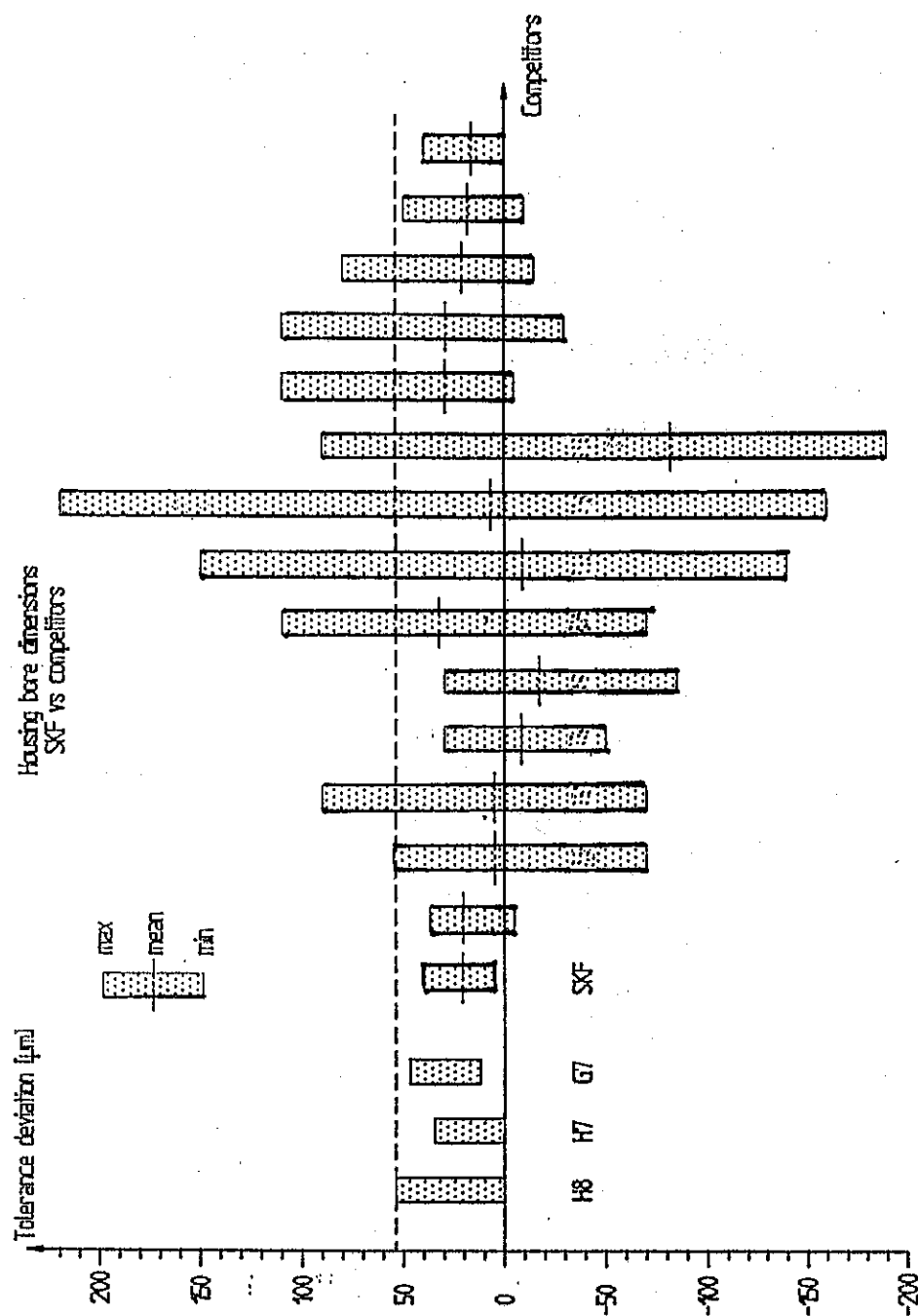


FIG. 18 Housing bore dimensions
SKF vs competitors