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[54] **AXIAL PISTON TYPE MACHINE**

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[51] **Int. Cl.** **F01b 3/00**

[58] **Field of Search** 91/504, 505, 506; 92/12.2; 64/31

[56] **References Cited**

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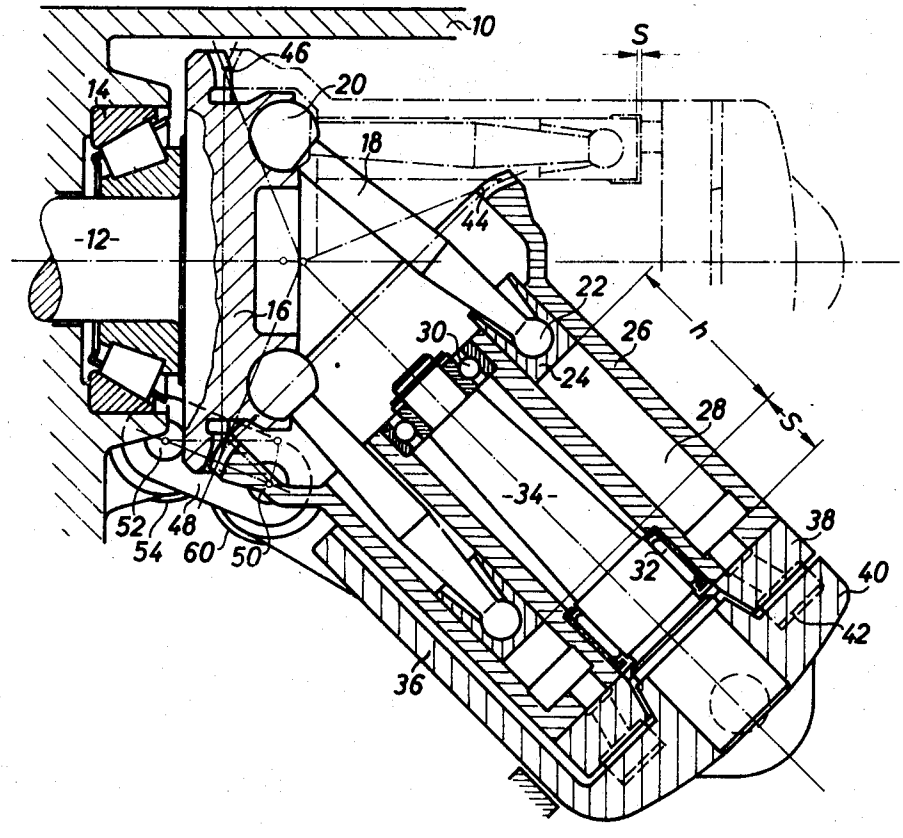
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[57] **ABSTRACT**

In an axial piston-type machine (pump, motor or transmission) with a pivotable cylinder block and axial pistons in articulated connection with the drive flange; the cylinder block is pivotable in every position about an instantaneous axis disposed outside the axes of the cylinder block and drive flange. The drive flange is in driving connection with the cylinder block through toothed members, particularly those having teeth positioned on toric surfaces, whose mesh is determined by the angle-bisecting plane between drive flange axis and cylinder block axis.

20 Claims, 11 Drawing Figures



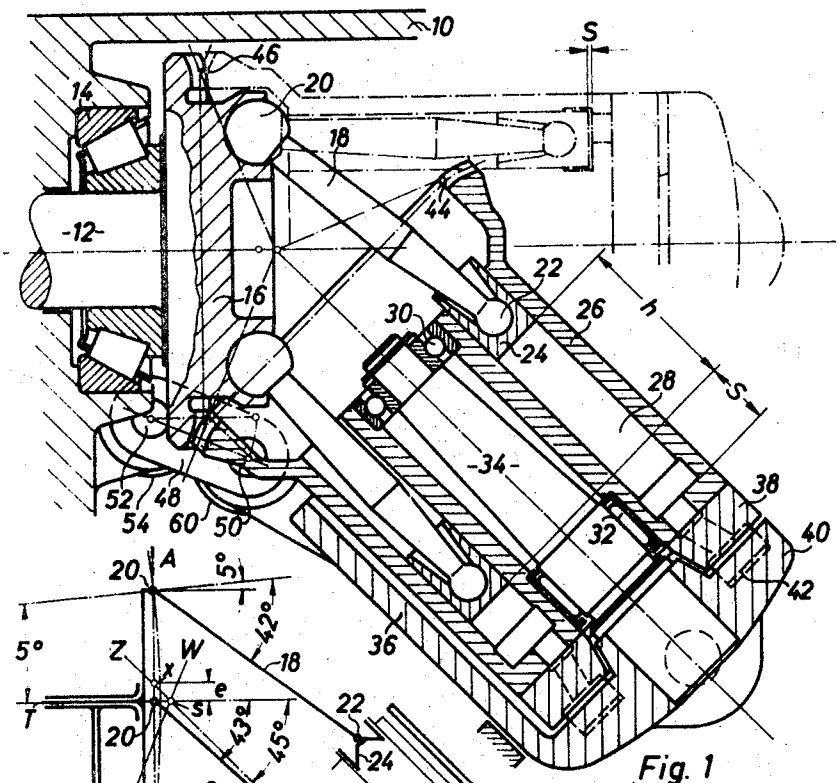


Fig. 1

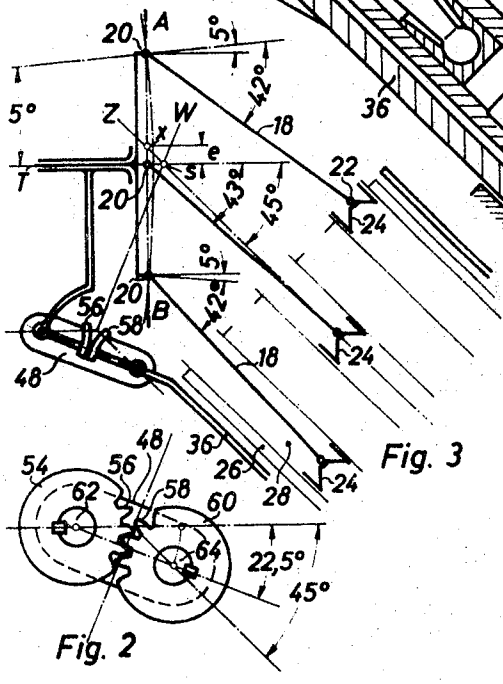


Fig. 3

Fig. 2

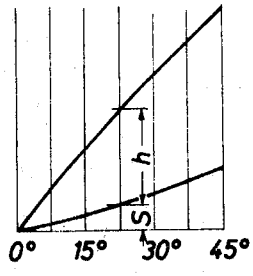


Fig. 4

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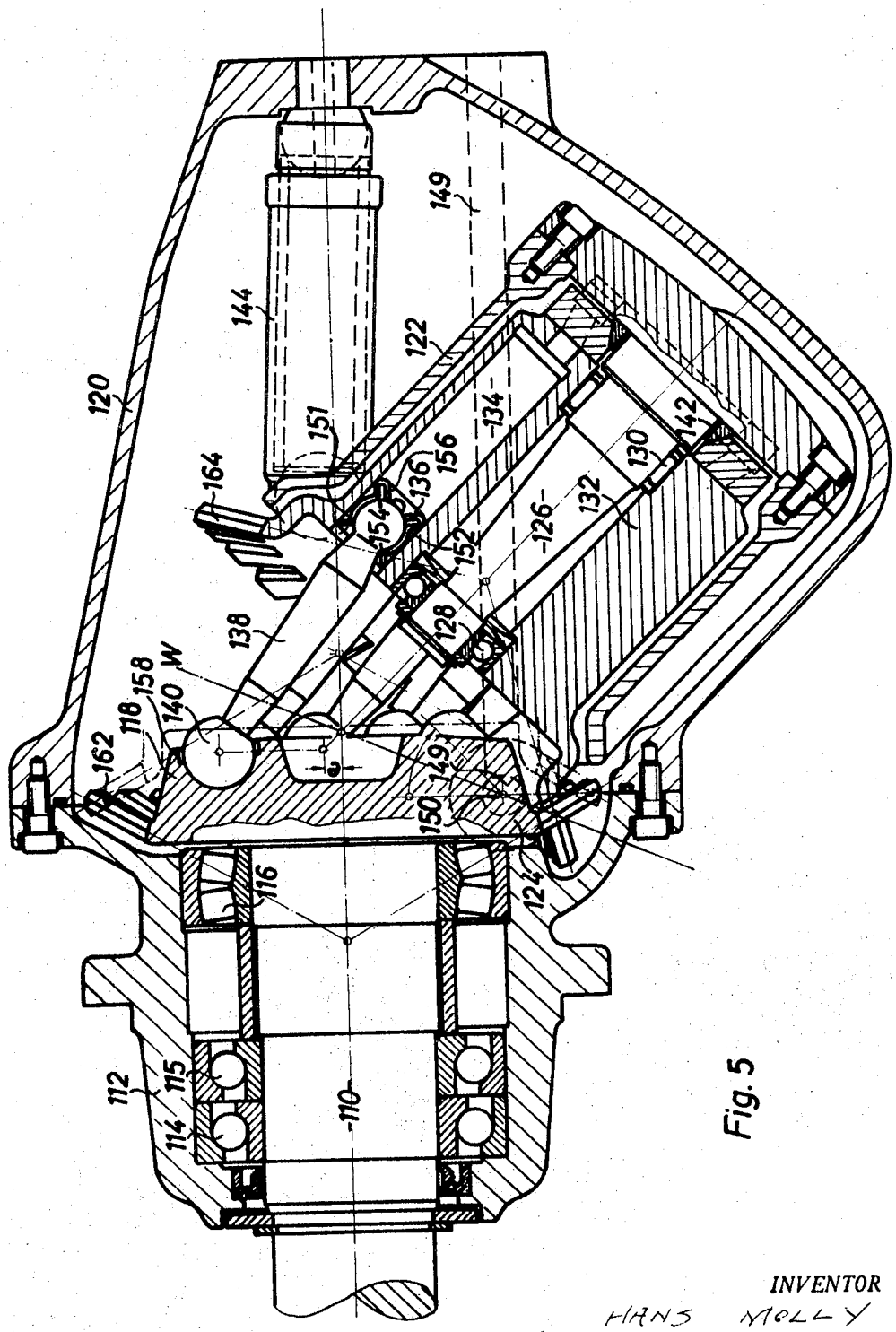


Fig. 5

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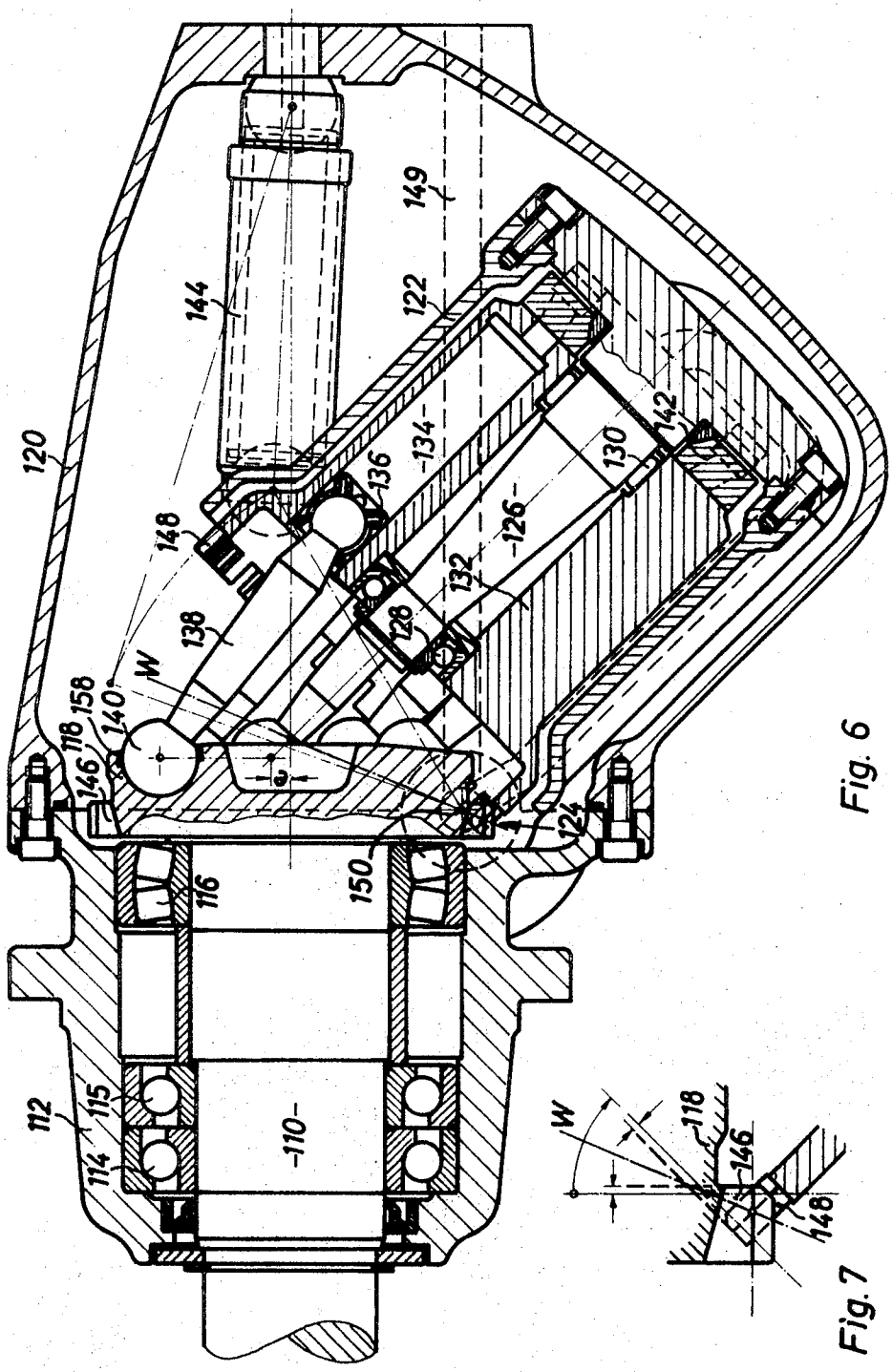
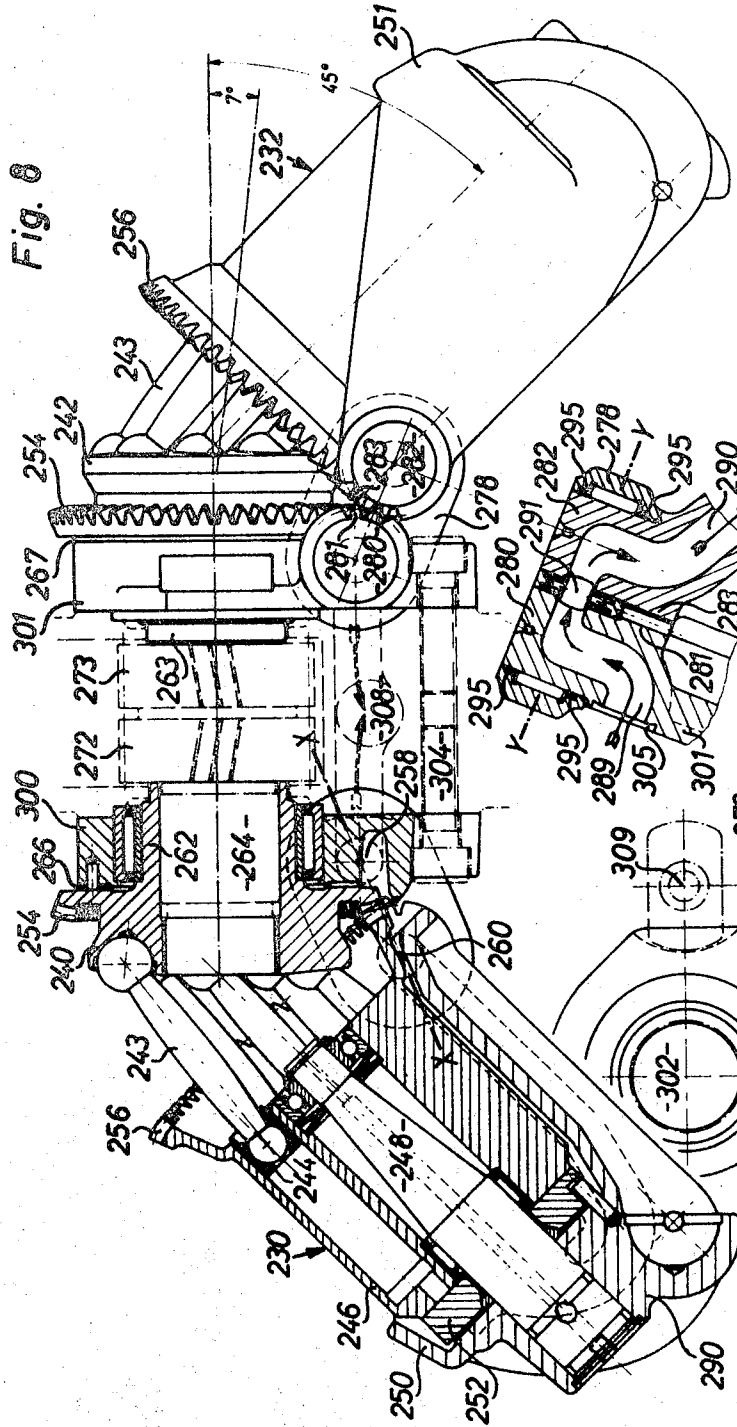


Fig. 6

Fig. 7

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AXIAL PISTON TYPE MACHINE

The present invention relates to an axial piston-type machine comprising a drive shaft with a drive flange, a cylinder block pivotable with respect to the drive shaft in a pivotable frame, axial pistons guided in the cylinder block and in articulated connection with the drive flange through piston rods, and a drive connection between the drive flange and the cylinder block.

The term "axial piston-type machine" is used herein to cover motors and pumps. Axial piston-type machines of the type indicated hereinbefore involve so-called "axial piston-type machines with torque development on the swash plate." The torque which is created in a motor by the oil pressure and is converted by a pump to oil pressure, is developed on the swash plate, i.e., the drive flange, while the cylinder block need only be carried along with a torque sufficient to overcome friction.

Machines of the type indicated have substantial advantages: An angular adjustment between swash plate and cylinder block is possible within a relatively large range. Moreover, it is possible to set the angle back down to relatively small values (approximately 50°) without the occurrence of an undesired loss in efficiency. The efficiency of such axial piston-type machines with torque development of the swash plate is very high as compared with other machine types. In hydraulic motors, particularly in the range of small pivotal movements of the cylinder block, the pressure oil commonly enclosed in the cylinder space exhibits undesired effects due to its compressibility. Therefore, it must be aimed at to keep this dead space in the upper dead center as small as possible. With the conventional pivotal movement of the cylinder block about an axis intersecting the axis of the drive shaft, the oil volume contained in the cylinder space remains constant and is relatively great. Therefore, in axial piston-type machines it has already been prior art to move the pivotal axis in a direction towards the pistons in the upper dead center. The result is that in all angular positions a constant or approximately constant dead space exists which can be kept small.

In the prior art axial piston-type machines of the type indicated hereinbefore, the movement of the cylinder block by the swash plate is effected through the piston rods. Moreover it is prior art to drive the cylinder block along through universal joint connections.

This type of drive results in constructional difficulties if one changes over to great angles of pivot which exceed, for instance 25°–30°. This applies particularly in the case when a pivotal movement of the cylinder block about an off-center point is effected.

It is an object of the present invention to provide an axial piston-type machine of the type indicated hereinbefore which permits a pivotal movement of the cylinder block up to angles of pivot as large as possible.

It is another object of the present invention to so devise an axial piston-type machine of the type indicated hereinbefore, that a pivotal movement of the cylinder block about a point disposed outside of the axis of the drive shaft is effected and the dead space in the upper dead center of the pistons can be kept small.

It is a specific object of the present invention to provide a drive connection between the drive flange and the cylinder block and a pivotal movement of the cylinder block which permits an off-center pivoting of the cylinder-block about great angles.

According to the invention this is attained by providing that the cylinder block is pivotable in every position relative to the drive flange about an instantaneous axis disposed outside the axes of cylinder block and drive flange, and that the drive connection with the drive flange is established through members having teeth whose mesh is determined by the angle-bisecting plane between drive flange and cylinder block axes.

Thus, according to the invention an off-center pivoting of the cylinder block is effected. The drive of the cylinder block can be achieved up to great angles of pivot through the drive connection of the invention in an unobjectionable manner.

The invention can be realized such that the drive connection is constituted by a bevel drive with teeth on toric surfaces and the pivotal movement of the pivotable frame of the cylinder block is effected in the form of a rolling movement of the toric surfaces on each other.

In this connection, a gearing may be provided forcing the rolling movement between housing and pivotable frame.

Such a gearing can be designed in different ways. Advantageously, the gearing is an angle-bisecting mechanism by which — in a section along the tangential plane — the center of the torus on the side of the cylinder block is pivotable about the center of the torus on the side of the drive flange through an angle which is at least approximately equal to half the angle of pivot of the pivotable frame. An angle-bisecting mechanism of the type indicated may be designed such that at least one side bar is articulated to housing and pivotable frame coaxially with the said torus centers, and moreover housing and pivotable frame are coupled with each other through a 1:1 pinion having two gear segments toothed rims coaxial with the torus centers.

An advantageous design of such an angle-bisecting mechanism is obtained in that the teeth are worked out only with a part of an arc of the circumference from the bearing flange body and the pivotable frame body respectively and provide space for the oil conduits on the bodies, which open into trunnions extending cylindrically to the teeth and held together by an oil-carrying side bar.

It is an object of the present invention to so devise an axial piston-type machine of the type indicated that a pivoting of the cylinder block up to angles of pivot as great as possible is rendered possible and moreover, a pivoting of the cylinder block about a point disposed outside the axis of the drive shaft is effected and thus, the dead space in the upper dead center of the piston can be kept small.

The pivoting of the pivotable frame about great angles such as, for instance, 45° and about a peripheral point disposed outside the axis of the drive shaft, in practice involves certain constructional problems, because provision must be made that the piston rods having a finite thickness, also in the upper dead center position in which the pistons are positioned deep in the cylinders, and where the maximum angle of pivot is involved, can still be moved into the cylinder at all without striking against the cylinder walls. Another problem resides in the fact of articulating the piston rods in such a manner to the drive flange on the one hand and to the piston on the other hand to ensure the pivotal

movability of the piston rods up to the maximum angle of pivot of the pivotable frame.

It is another object of the present invention to so devise an axial piston-type machine constructionally that the movability of the piston rods up to the maximum angles of pivot of the pivotable frame of, for instance, 45° is not impaired by the other component parts.

To solve this object, according to the invention provision is made that the point of intersection of the cylinder block axis with the drive flange axis for maximum angle of pivot of the pivotable frame is disposed in front of the plane on the side of the cylinder block, in which the piston rods are articulated to the drive flange.

It can be shown that with such a design of the axial piston-type machine in the critical range of maximum pivoting smaller inclinations of the piston rods with respect to the cylinder axes are obtained than with constructions in which the cylinder block axis intersects the drive flange axis in a point disposed in the plane of articulation. Thus, greater angles of pivot can be provided without the piston rods colliding with the cylinder walls in the upper dead center position.

In order to also keep the angles between piston rods and drive flange in a favorable range where the maximum angles of pivot are involved, the drive flange may furthermore have a spherically convex surface on the side of the cylinder block. The articulation of the piston rods to the drive flange can be effected in such a manner that spherical mounts are inset into the drive flange for articulation of the piston rods by means of ball joints in a direction of the surface normal of the convex drive flange surface — at an angle to the drive flange axis — , and provided with an enlargement from the equator of a ball of the ball joint of the piston rod received therein onward, into which enlargement a bearing metal ring is pressed which can be moved over the piston.

The movability of the piston rods relative to the pistons can be improved by providing that the piston is a sheet-metal body having cylindrical basic shape which is held for pivotal movement by a pair of rolled-up corrugations on a ball of a ball joint provided at the end of the piston rod on the side of the cylinder block, and which has a flanged rim supported against the front side of the ball. The pressure is substantially directly applied to the piston rods, while the thin-walled sheet-metal bodies permit a pivoting of the piston rods relative to the pistons up to comparatively great angles. In order to provide for a pressure balance and to counteract a pressure load on the flanged rim, the latter can be provided with apertures.

Another advantageous drive connection between drive flange and cylinder block in which also in the case of great angles ensuring a mesh of several teeth of the toothed members established by a bevel beamed joint known per se whose two cones are arranged on the one hand above the drive flange and on the other hand above the cylinder block such that the bevel beams intersect in a plane containing the angle bisector of drive flange and cylinder block axes, and that the pivotable frame is pivotable about an axis disposed in this plane and vertical to the angle bisector.

Bevel beamed joints are known to comprise toothings whose teeth extend in a direction of the generatrix of a cone surface, the two toothings meshing such that the one toothing as related to a plane of symmetry, is disposed homologously with respect to the other. The use of such a bevel beamed joint for establishing a drive connection between drive flange and cylinder block in an axial piston-type machine permits a pivotal movement of the cylinder block through a relatively great angle. Commonly, in bevel beamed joints special contact means are used which are arranged on the bevel beams of the two bodies and thus permit a contact engagement in the point of intersection, which represents surface or line contact and avoids the cutting edge.

The great angles of pivot provided here and the spatial arrangement outside the hydraulic drive mechanism would render the design of such a bevel beamed joint with intermediate members such as balls, so disproprotionate that it is technically not applicable. Therefore, other possibilities must be found to satisfy the constructional requirement made here on the joint.

The simplest means is to design the generatrices, such as of a cylinder beamed joint in the manner of a cutting edge in order to carry out the carrying along through the cutting edges of drive flange and cylinder block parts. Unfortunately, during rotation some locations occur at which the cutting lines pass each other in such a manner that practically only a knife-sharp driving element could be operated with. These ranges would have to be avoided. According to the invention, the beamed joint is pivoted about an eccentric axis so that the pistons of the hydraulic drive mechanism can substantially remain in the upper dead center position. The cutting edges can be designed so short that they only have contact in the range of the axis of pivoting and accordingly may become very blunt edges. Thus, in the cylinder beamed joint in the range of the small ellipsoidal diameter the constructional problems occurring there have become irrelevant, primarily when avoiding the axially parallel position which should not be utilized, and the cutting edge joints are provided with blunt load-supporting cutting edges which furthermore are in multiple contact when a greater number of cylinder beams is applied.

A standard bevel beamed joint transmits on the total circumference and automatically centers the two waves associated with it. By the only partial transmission the centering of the joint must be provided with special means and — as shown by the design of the invention — setting means are provided for this purpose which ensure the intersection of the axes to be pivoted and which must be disposed in a common plane.

The concurrence of the cutting edges of the two rotary bodies is effected in a smooth manner, if the teeth have a weak amount of taper so that their tooth flanks are increasingly inclined with respect to each other towards the ends thereof. In a further modification of the invention the pivotable frame can be supported by means of opposing trunnions having channels for pressure fluid passage.

Besides the cylinder beamed joint also a strict bevel beamed joint can be applied, if in the latter the beams are similarly provided with short cutting edges only. However, in this connection the apex angle of the cones must be kept within a range of 90° – 135°, thus an obtuse bevel beamed system must be applied which for the provided restriction in the range of engagement makes it possible to operate with flatly designed bevel beam edges. Here too, an according tapering of the bevel beams towards the free end is advantageous so that a satisfactory running-in takes place, and a careful

support of the two rotary bodies should be provided so that the axes of the rotary bodies intersect.

The two aforesaid joints — the cylinder beamed joint and the bevel beamed joint — are edge joints, i.e., joints in which the two sets of teeth are directly in mesh with each other, thus without the interposition of bearing balls or like means, and which for realization of this possibility only have a partial transmission within which the edges of the joints are provided with obtuse angles ensuring the required life during operation.

A few illustrative embodiments of the present invention will now be described more fully with reference to the accompanying drawings, in which:

FIG. 1 illustrates an axial piston-type machine according to the invention in a longitudinal section.

FIG. 2 illustrates an angle-besecting mechanism used in the axial piston-type machine according to FIG. 1.

FIG. 3 is a schematic illustration showing the position of the point of intersection of drive flange axis and cylinder block axis to the plane of articulation of the piston rods in the embodiment according to FIG. 1.

FIG. 4 is a diagram showing the piston stroke and the dead space in an axial piston-type machine according to FIG. 1 in dependence on the angle of pivot.

FIG. 5 is a longitudinal section similar to FIG. 1 of another embodiment of the invention with a bevel beamed joint.

FIG. 6 illustrates an arrangement similar to FIG. 5, however with a cylinder beamed joint.

FIG. 7 illustrates a detail of FIG. 6.

FIG. 8 illustrates a machine unit designed with two hydraulic motors according to the invention.

FIG. 9 illustrates the oil supply through a side bar connecting the pivotable frame and the housing and constituting part of the angle-bisecting mechanism — similar to FIG. 2 — and cut along the line x—x of FIG. 8.

FIG. 10 is a section along the line y—y of FIG. 9.

FIG. 11 illustrates a top view on the front face of the bearing flange in the machine of FIG. 8.

In a housing 10 a drive shaft 12 is supported in a bearing 14. A drive flange 16 is mounted on the drive shaft 12. Piston rods 18 are articulated to the drive flange by means of ball joints 20 positioned on a circular arc around the axis of the shaft 12. The piston rods 18 are furthermore articulated to pistons 24 by means of ball joints 22. The pistons are received in axially positioned cylinder bores 28 in a cylinder block 26.

The cylinder block 26 is supported by means of bearings 30 and 32 on a trunnion 34 in a pivotable frame 36. A stationary valve portion 38 is pressed against the cylinder block 26 by pressure pistons 40 by means of pressure fields 42.

The cylinder block 26 has teeth 44 on a toric surface. Corresponding teeth 46 are provided on a toric surface on the swash plate 16. The teeth are in mesh with each other in the plane of the paper in FIG. 1 and in each angular position of the pivotable frame constitute a bevel drive through which the cylinder block 26 is driven by the drive flange 16. In order to ensure a safe mesh of the teeth 44 and 46 in every position, the pivoting of the pivotable frame is effected in the form of a rolling movement of the toric surfaces (bearing teeth 44 and 46) on each other.

This rolling movement is forced by a suitable gearing through which the pivotable frame 36 is connected with the housing 10.

An embodiment of such a gearing is illustrated in the FIGS. 1 and 2. The pivotable frame 36 is connected with the housing 10 by a side bar 48. This side bar 48 is articulated to the housing 10 and the pivotable frame 36 in points which are disposed coaxial with the centers of the toric surfaces on which the teeth 44 and 46 are provided, as these centers are represented in the section of FIG. 1 which is disposed through the plane of engagement of the teeth. The "centers" 50 and 52 are actually the points of intersection of the circular central lines of the toric surfaces through the plane in which the toric surfaces contact each other. The side bar 48 is disposed behind the teeth 44, 46 in FIG. 1. A corresponding side bar is provided at the same distance in front of the paper plane in FIG. 1 (not visible in the sectional illustration). A disk 54 having a gear segment 56 is mounted on the housing 10. Disk 54 is keyed to the housing, see FIG. 2. The gear segment 56 is in mesh with a gear segment 58 of a disk 60. The latter disk is keyed to the pivotable frame 36. The side bar 48 keeps the pins 62, 64 to which the disks 54, 60 are keyed at a fixed distance and thus the teeth 44, 46 in mesh with each other. The gear segments 56 and 58 ensure a rolling movement upon pivoting of the pivotable frame 36. The side bar 48 pivots through a respective angle which is half as great as the angle of pivot of the pivotable frame 36, for example when the frame 36 has been pivoted to its maximum pivotable position of 45° in the present embodiment, then the side bar 48 has pivoted 22.5°; the gear segment 44 has then rolled about the gear segment 46 through the same angle.

By the off-center pivoting of the pivotable frame 36 and of the cylinder block 26 the dead space s can be kept small for all angular positions. This can be gathered from the diagram of FIG. 4 in which s is the dead space occurring in each pivotal position, while h represents the associated utilized stroke of the piston. Particularly for small piston strokes in the zero stroke position illustrated in dotted lines in FIG. 1, the dead space s is negligibly small.

As can be most clearly seen from the schematic illustration of FIG. 3, in the axial piston-type machine of FIG. 1 the arrangement is provided such that the point of intersection s of the cylinder block axis Z and of the drive flange axis T is disposed in front of the plane A-B of the piston rod-point of articulation on the side of the cylinder block (i.e., on the right in FIG. 3) in the outermost position of pivoting of the pivotable frame 36 and of the cylinder block 26 illustrated in FIG. 3. The cylinder block axis Z meets this plane in a point X which is displaced by a portion e with respect to the drive flange axis. By the way, the angle bisector W between the axial directions of drive flange and cylinder block in the tangential point of the torus teeth also passes through the point S.

By this arrangement of the cylinder block axis Z with respect to the drive flange axis T in the outermost pivotal position which results as a projection onto the cylinder block 26 of the circle on which the piston rods 18 are articulated to the drive flange 16, the ellipse is displaced with respect to the circle on which the axes of the cylinders 28 are disposed, and that is in a direction towards the outermost dead center position of the pistons 24 (towards the right upwardly in FIG. 1 and FIG. 3). Consequently, in the range of the inner dead center position of the pistons 24, i.e., where pistons 24 and piston rods 18 are inserted deep into the cylinder block

26, a smaller angle between piston rod and cylinder axis is obtained, while the angle in the outer dead center is slightly greater instead. There, this angle is however also not critical, as the piston rods 18 have been moved out of the cylinder 28. The angle between cylinder axis, respectively piston axis and piston rod can assume sufficiently great values owing to the short construction of the piston 24.

In the illustrated embodiment a maximum angle of pivot of 45° is attainable. In the lower dead center (below in FIG. 3) an angle between piston rod and drive flange axes of 47° is obtained, i.e., an angle between piston rod and cylinder axis of 2°. Despite the finite diameter of the piston rod 18 it can therefore project sufficiently far into the cylinder without contacting the cylinder walls. In the outer dead center (upwardly in FIG. 3) the angle between piston rod axis and drive flange axis is 37°, i.e., the angle between piston rod and cylinder axis is −8°. This relatively great angle, however, does not interfere with the outer dead center and is readily permitted by the ball joint 22.

By a spherically convex form of the drive flange surface, as it is indicated in FIG. 3 and also realized in the embodiments of the FIGS. 5 and 6 to be described hereinafter, further improved angular conditions can be obtained at the points of articulation on the side of the drive flange. In the outer dead center position the angle between the piston rod 18 and the surface normal is 42°, and the same angle results in the inner dead center position below, owing to the convex form of the surface, through the piston rods 18 themselves pivot from the upper to the lower dead center position through an angle of 2° − (−8°)=10° with respect to the drive flange axis. In an intermediate position maximum angles of inclination with respect to the surface normal of 43° are obtained which are readily permitted by the described ball joint construction. Though in the case of a plane drive flange surface only an angle of 37° between piston rod and surface normal would be obtained in the outer dead center, however, this angle would be 47° in the inner (lower) dead center, signifying a bad mount of the ball 20 of the piston rod 18.

In the embodiment of FIG. 5 the drive connection from the drive flange to the cylinder block is effected by means of a bevel beamed joint.

A shaft 110 is supported in a housing part 112 by means of bearings 114, 115, 116. A housing part 120 is connected with the housing part 112. A pivotable frame 122 is supported for pivotal movement in housing part 120 by means of a bearing support 124. A cylinder block 132 is rotatably supported in the pivotable frame 122 on a trunnion 126 by means of bearings 128, 130. Axial pistons 136 slide in cylinders 134 in the cylinder block, the cylinders being parallel to the axis of the cylinder block. The axial pistons 136 are connected through piston rods 138 with the drive flange 118 to which they are articulated by means of ball joints 140. The cylinder block 132 abuts a stationary valve portion 142 which is pressed against the cylinder block 132 by pressure fields. The pivotable frame 122 is pivotable about an axis 150 by means of an adjusting piston 144 relative to the drive flange 118 in the housing 120. A conduit 149 indicates the line connection of the pressure fluid to the pivotal axis 150 and thus to the pivotable frame 122.

To establish the drive connection between drive flange 118 and cylinder block 132 a bevel beamed joint with teeth 162, 164 designed as bevel beamed edge joint is provided whose points of mesh are always disposed on the angle bisector between drive flange axis and cylinder block axis, the cones defined by the teeth having a generating angle of 120°.

The embodiment of FIG. 6 is designed similarly to the embodiment of FIG. 5 and corresponding parts are referenced by the same reference numerals as there.

The drive connection between the drive flange 118 and the cylinder block 132 is established by a cylinder beamed joint. This cylinder beamed joint comprises teeth 146 on the drive flange 118 and teeth 148 on the cylinder block 132. The teeth 146 are disposed on a cylinder jacket and are mounted to the drive flange 118 in a radial direction.

The teeth 148 extend in an axial direction. The cylinders defined by the teeth 146 and 148 intersect each other in a plane containing the bisector of the angle drive flange axis and cylinder block axis (FIG. 7). The pivotable frame 122 is pivotable in the housing 120 about an axis disposed in this plane and normal to the angle bisector W.

The pivotal axis 150 of the pivotable frame is substantially tangential to the cylinder beamed teeth 146 on the drive flange 118 which is provided at a small distance around the rim of the piston rod articulating points on the drive flange. The cylinder beamed teeth are weakly tapering teeth whose tooth flanks are increasingly inclined with respect to each other towards the ends.

In order to also permit an unobjectionable operation of the pistons 136 and of the piston rods 138 in the cylinder block 132 in the case of great angles of pivot, also in these two embodiments in the fully pivoted position the point of intersection of the cylinder block axis with the drive flange axis is placed in front of the plane of the points of articulation of the piston rods 138 on the side of the cylinder block (see FIG. 6) so that the ellipse projected by the cylinders 134 onto the plane is eccentric with respect to the drive flange axis by a distance. In order to also permit the pivotal movement of the piston rods 138 with respect to the drive flange 118 in the case of great angles of pivot, the outer face of the drive flange 118 is slightly spherically. The pistons 136 are sheet-metal parts which ae pressed around the crowned ball of the piston rod 138 so that a large pivotal movement of the piston rod 138 with respect to the pistons 136 is possible. All these measures serve to also ensure unobjectionable kinematics of the pistons and piston rods in the case of great angles of pivot.

To this end, the piston 136 is a sheet-metal body of cylindrical basic shape which is held for pivotal movement by a pair of rolled up corrugations 151, 152 on a ball 154 of a ball joint provided at the end of the piston rod 138 on the side of the cylinder block. The piston bears against the front face of the ball with a flanged rim 156 provided with apertures. The bearing support of the piston rods 138 on the drive flange 118 is formed by ball joints 140 seated in spherical mounts in the drive flange — in a direction normal — 118 to the convex drive flange surface — at an angle to the drive flange axis — each socket being provided with an enlargement 158 from the equator of the ball received therein. Into this enlargement a bearing metal ring is pressed which can be moved over the pistons 136.

Pivoting of the pivotable frame 122 with respect to the housing 120 is effected by means of an adjusting

piston 144, respectively a piston cylinder unit designed as telescopic tube. The pivotable frame 122 is supported by means of oppositely arranged trunnions 150 containing channels 149 for the passage of pressure fluid.

FIGS. 8 to 11 illustrate as another embodiment of the present invention a motor unit designed as a self-contained assembly, including two hydraulic motors 230, 232. The motor unit 230 is shown in section in FIG. 8. Each of the motors 230 and 232 comprises a drive flange 240, 242 to which piston rods 243 are articulated. Pistons 244 are mounted on the piston rods 243. The pistons are guided in cylinders in a cylinder block 246. The cylinder block 246 is rotatably supported on a trunnion 248 in a pivotable frame 250 and abuts against a stationary valve portion 252.

The rotation of the cylinder block by the drive flange is effected by a bevel drive having teeth 254, 256 on toric surfaces. The toric surfaces have the centers 258, 260 in the plane of engagement and intersection. Pivoting of the pivotable frame and of the cylinder block 246 is effected about an off-center axis in the form of a rolling movement of the toric surfaces on each other, so that the dead space in the upper dead center of the pistons 244 is kept as small as possible.

The drive flanges 240, 242 of the two motors 230, 232 are supported in an axial direction with their hubs 262, 263 through the coupling shaft 264. Slide disks 266, 267 guide the drive flanges 240, 242 against the bearing flanges 300, 301 and absorb occurring residual forces. Teeth 272, 273 are provided on the coupling shaft 264 and are in mesh with wheels not illustrated having the function to transmit the mechanical output of the hydraulic machine.

In FIG. 9 illustrating a section along the line X—X of FIG. 8, it is shown how the pivotable frames 250, 251 are supported against the bearing flanges 300, 301 and how this bearing support is utilized for the oil supply. In a connecting side bar 278 provided with two side-by-side bores a trunnion 280 on the side of the bearing flange as well as a trunnion 282 on the side of the pivotable frame are mounted.

The trunnions 280, 282 are provided with teeth 281, 283 on part of their circumference, which teeth are in mesh with each other. The remaining portion of the trunnions as part of the bearing flange immediately transmitting to the same the axial forces transferred by the side bar 278 and providing space for the incorporation of the oil channels 289, 290.

The channel 289 in the bearing flange opens into an annular groove 305, 307 provided for a sealing O-ring. From channel 289 the oil can be passed on in a conduit 308, as indicated in FIG. 8.

As can be seen from FIGS. 9 and 8, the oil is conducted in the pivotable frame through the channel 290 to the stationary valve portion 252 of the hydraulic motor.

FIG. 11 is a top view on the front face of the bearing flange 300 and provides information on the attachment of the bearing flange and further passage of the oil. The sealing function of the O-ring in the groove 305, 307 is ensured by the main tightening screws 304, 306 and the fixing straps 309 shown in dotted lines, which, depending on the type and design of the housing, permit an additional attachment of the bearing flange in the vicinity of the bearing bore 302.

FIG. 10 shows the bearing support of the side bar 278 on the two trunnions 280, 282. The great side bar forces are absorbed by the needle bearings 285, 287. Since a recess 291 is necessary for further conduction of the oil, apertured cages 293, 294 must be provided for the two arrays of needles, which are coupled through teeth whose form only permits a small pivoting in the necessary range. Thus, the recess in the apertured cage can be restricted to a minimum. As is shown in FIG. 9, four O-rings 295 seal the side bar 278 against discharge of the oil on the trunnions 280, 282.

By articulating the pivotable frame to the bearing flange by means of side bars which at the same time are used for the oil conduction, a unit is obtained which is held together independently of a housing. This unit can be assembled as a whole. The connection to stationary fluid conduits is effected by having the fluid ports opening in a plane surface of the bearing flange. With this plane surface the bearing flange can be affixed, such as by bolts, to another plane surface having corresponding fluid ports.

The invention is claimed as follows:

1. In an axial piston-type machine comprising a main frame, a drive shaft mounted in said frame for rotation about an axis, a drive flange attached to said shaft and rotatable therewith, a frame pivotable with respect to the drive shaft about an axis, a cylinder block mounted in said pivotable frame for rotation about an axis intersecting the axis of the drive shaft, axial pistons mounted in cylinders in the cylinder block, first connecting means between the drive flange and the pistons, and second connecting means rotatably connecting said flange and said cylinder block, the improvement comprising:

in all positions of pivotal movement said pivotal axis being outside the axes of rotation of the shaft and the cylinder block; and

said second connecting means comprising two toothed members, a first connected to the cylinder block for rotation therewith and a second connected to the drive flange for rotation therewith, the teeth of said members engaging each other at a point of mesh, said point being located on the plane bisecting the angle between the two axes of rotation.

2. In a machine as set forth in claim 1, wherein each of said members has a toroidal surface, said teeth extending from the respective surfaces, and including means connecting said frames for providing said pivotal movement of the pivotal frame and a rolling movement of the toroidal surfaces on each other during said pivotal movement.

3. In a machine as set forth in claim 1, including gearing means interconnecting the frames and controlling the pivotal position of the pivotal frame with respect to the main frame.

4. In a machine as set forth in claim 3, wherein said surface of the first member is formed about a first center and said surface of the second member is formed about a second center, and said gearing means is an angle bisecting mechanism by which — in a section along a tangential plane — the first center is pivotable about the second center through an angle which is at least approximately equal to one-half the total angle of pivot of the pivotal frame.

5. In a machine as set forth in claim 4, wherein said means for providing said pivotal movement includes a

side bar articulated to the main frame and to the pivotal frame, and said gearing means includes two pinions of equal size and each having teeth positioned coaxial with the respective centers.

6. In a machine as set forth in claim **5**, wherein said gearing means includes two trunnions with each pinion being mounted on a respective trunnion, said pinions having teeth only on a portion of their peripheries with the remainder of the peripheries being cylindrical, said side bar fitting over the two pinions, said trunnions, pinions and side bar defining part of an oil passageway communicating between said cylinder block and said main frame.

7. In a machine as set forth in claim **1**, wherein said first connecting means includes piston rods articulated to said flange in a plane, and said cylinder block axis intersects the drive shaft axis at a point which, at time of maximum pivot of the pivotable frame is positioned at the cylinder block side of the last mentioned plane.

8. In a machine as set forth in claim **7**, wherein the side of said flange adjacent the cylinder block has a surface which is spherically convex.

9. In a machine as set forth in claim **8**, wherein said first connecting means includes spherical mounts on each of the piston rods and the flange has spherical sockets therein, said sockets each having an axis that is normal to said convex surface and an enlargement extending from the equator of the sphere of the mount, and including a bearing metal ring for each socket and receivable in the enlargement of the respective socket, each ring having an opening larger in diameter than the respective piston.

10. In a machine as set forth in claim **9**, wherein each piston is a sheet metal body of cylindrical basic shape and having a pair of rolled-up corrugations defining a semicylindrical socket at the interior of the body and a flanged rim at the base of said socket, each piston rod having a ball received in the respective socket.

11. In a machine as set forth in claim **1**, wherein said second connecting means comprises a bevel beamed joint (known per se) having two cones, one cone being on the flange and the other cone being on the cylinder block, said pivotable axis being located in said plane.

12. An axial piston-type machine as claimed in claim **11**, characterized in that the bevel beamed joint is a cylinder beamed joint, i.e., the cone apex is in the infinite.

13. An axial piston-type machine as claimed in claim **12**, characterized in that the pivotal axis is displaced laterally with respect to the flange axis so that the inner dead center position of the pistons remains approximately unchanged in all pivotal positions of the pivotable frame for minimum dead volume in the cylinders.

14. In a machine as set forth in claim **13**, wherein the teeth on the flange define a circle positioned relatively close to said first connecting means at the flange, said pivotal axis being substantially tangential to said circle.

15. In a machine as set forth in claim **14**, including a pair of spaced trunnions mounted on said pivotable axis and forming the pivotal mount, said machine defining passageways for oil communication to said cylinder block, part of said passageways being in said trunnions.

16. In a machine as set forth in claim **11**, wherein the teeth are weakly tapering with the tooth flanks being increasingly inclined with respect to each other towards the distal ends.

17. An axial piston-type machine as claimed in claim **11**, characterized in that the generating angle of the cones of the bevel beamed joint is an obtuse angle, such as for example of 120°.

18. An axial piston-type machine as claimed in claim **1**, characterized in that the bevel beamed joint is a bevel beamed edge joint.

19. In an axial piston-type machine comprising a bearing member, a drive shaft having a drive flange and mounted in said bearing member, a pivotable frame pivotable with respect to said drive shaft, a cylinder block mounted in said pivotable frame, axial pistons slideable in said cylinder block, and piston rods pivotably connecting said drive flange and said pistons, and drive connection means between said drive flange and said cylinder block, the improvement comprising:

said bearing member having a fluid connection; said pivotable frame having a fluid passage; side bars connecting said pivotable frame with said bearing member, at least one of said side bars having a fluid passage between the fluid connection provided on the bearing member and said passage in the pivotable frame.

20. In an axial piston-type machine as claimed in claim **19**, wherein said bearing member having fluid connection ports for high and low pressure fluid in a plane surface thereon, said bearing member with said plane surface being affixed to another plane surface provided with corresponding connection ports.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,760,692 Dated September 25, 1973

Inventor(s) Hans Molly

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Inventor's name	"Hans Molly, Dr." should be "Hans Molly"
Inventor's address	"Eugen-Essig-Strasse, 48, Malsch, Germany" should be "Dr. Eugen-Essig-Strasse, 48, Malsch, Germany"
Col. 1, line 24	"50°" should be "5°"
Col. 2, line 38	delete "toothed rims"
Col. 3, line 54	insert "of pivot" before "ensuring a mesh"
Col. 3, line 55	after "toothed members" insert "is obtained in that the drive connection is"
Col. 7, line 31	"through" should be "though"
Col. 8, line 45	"ae" should be "are"

Signed and sealed this 2nd day of April 1974.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

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