Oct. 11, 1966 K. EICKMANN 3,277,834

ROTARY RADIAL PISTON MACHINE WITH ENLARGED PISTON STROKE

Filed July 9, 1963 4 Sheets-Sheet 1

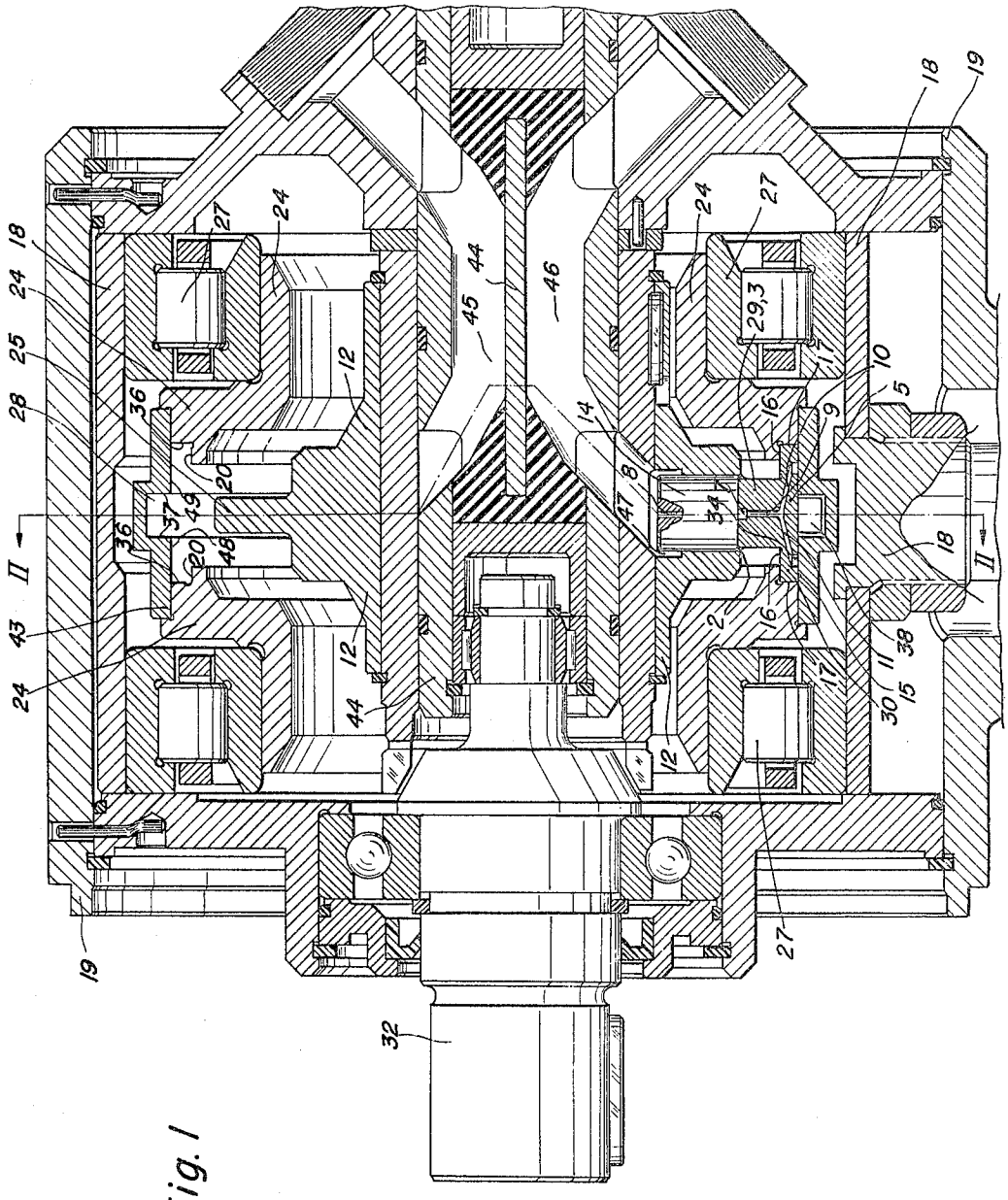


Fig. 1

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Fig. 2

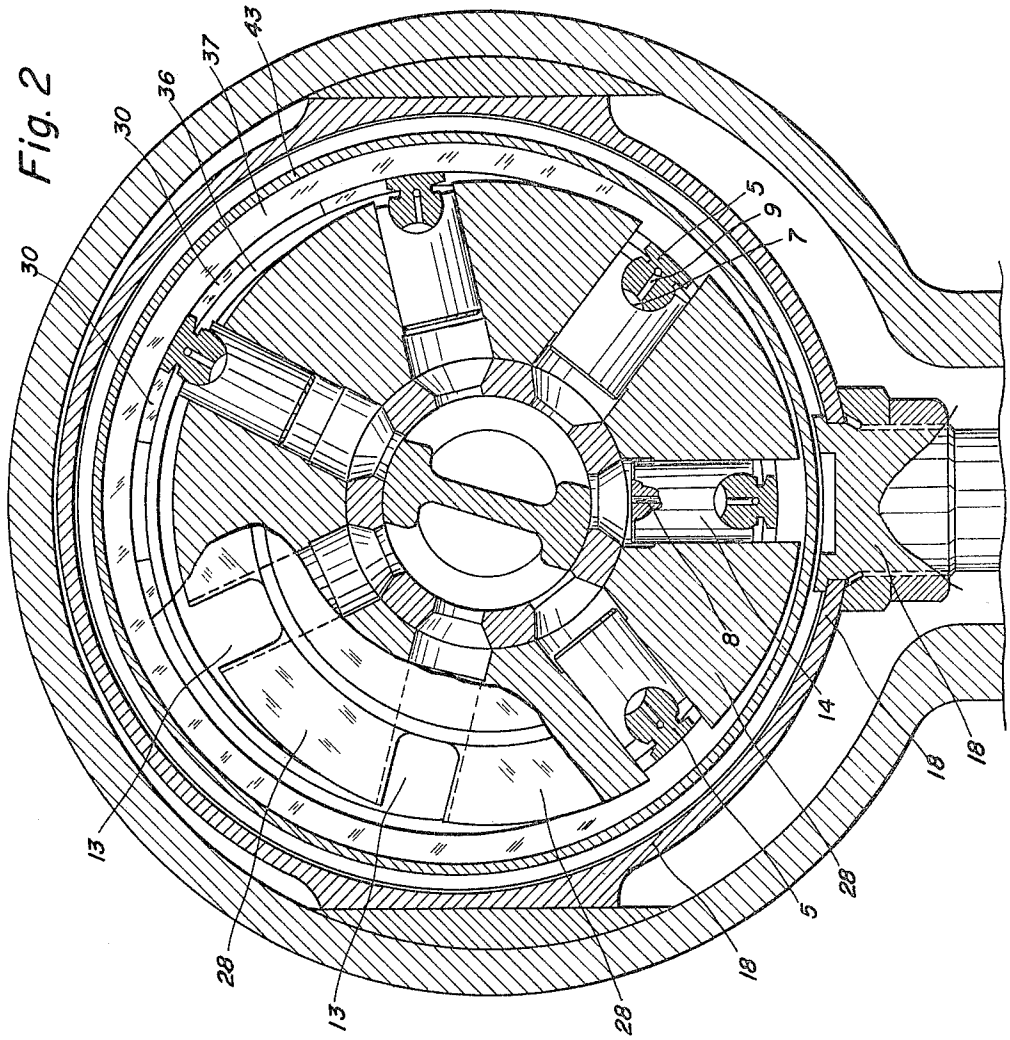
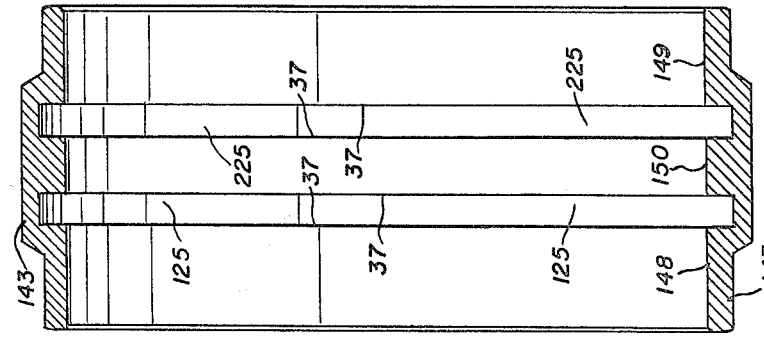


Fig. 12



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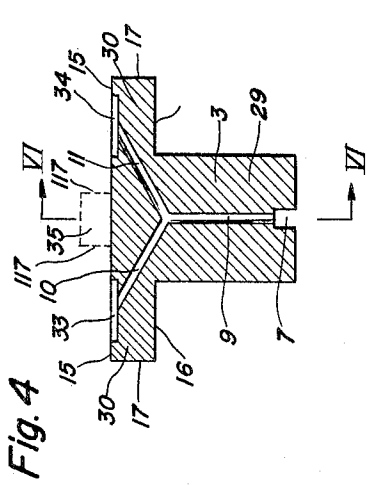


Fig. 4

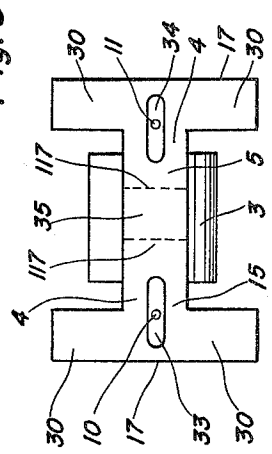


Fig. 5

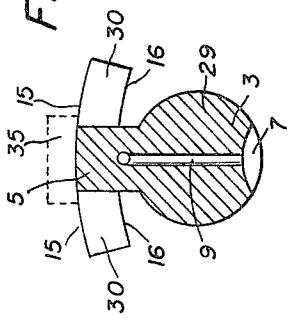


Fig. 6

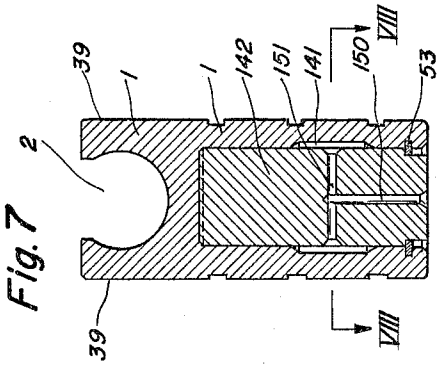


Fig. 7

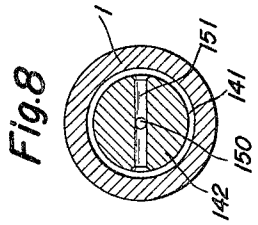


Fig. 8

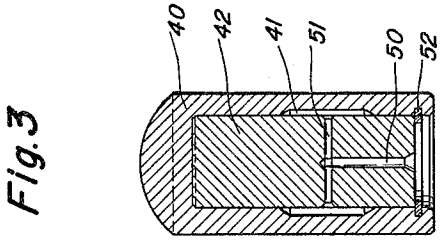


Fig. 3

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Fig. 11

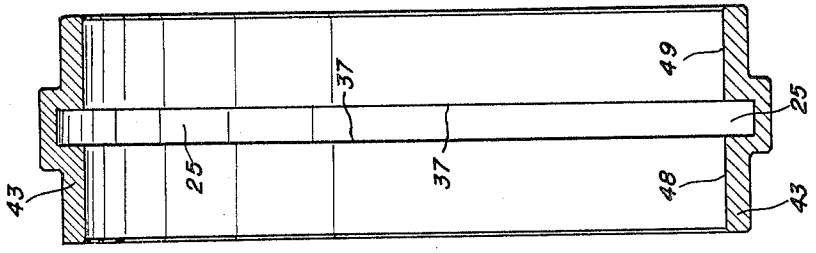


Fig. 10

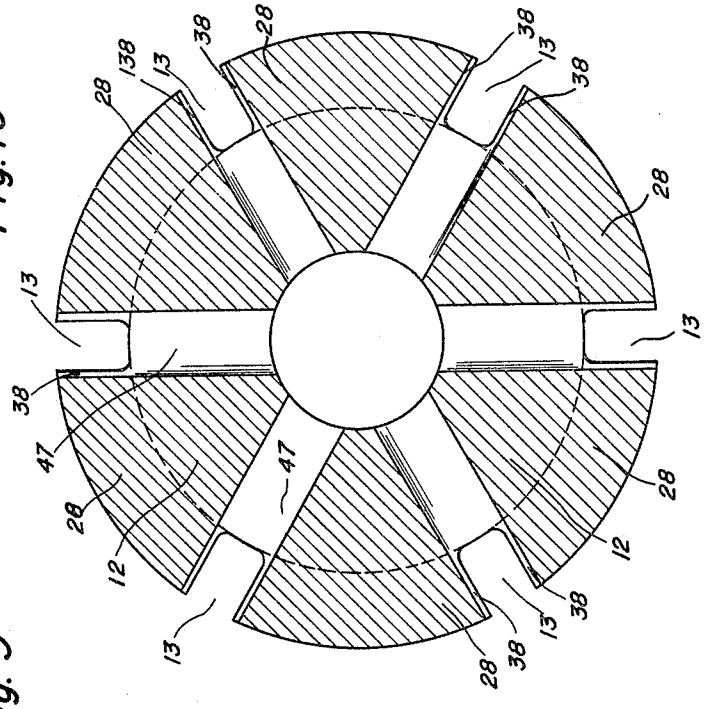
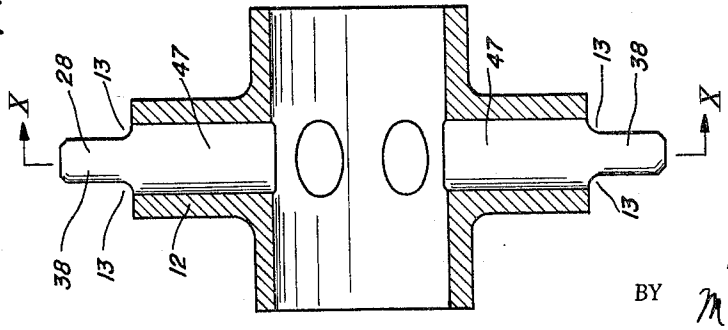


Fig. 9



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Patented Oct. 11, 1966

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ROTARY RADIAL PISTON MACHINE WITH ENLARGED PISTON STROKE

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Filed July 9, 1963, Ser. No. 293,657
Claims priority, application Germany, July 12, 1962, B 68,007
20 Claims. (Cl. 103—161)

This invention relates to fluid operated radial piston machines, such as hydraulic or pneumatic pumps, motors, transmissions or the like wherein the radial cylinders in which the pistons operate, during operation under power, periodically draw in and expel fluid. Machines of this type are known, and have been used particularly as oil-hydraulic pumps, motors, and gear transmissions, rotary pneumatic machines, motors and compressors, and rotary steam motors, combustion engines and the like.

In known rotary radial piston machines, a plurality of substantially radially directed cylinders are provided in a rotor and pistons are reciprocated longitudinally of the cylinders and radially of the rotor, during operation of the machine under power. This reciprocation of the pistons periodically varies the volume of the cylinders behind the pistons. A particularly efficient rotary radial piston machine is shown, described and claimed in my copending allowed patent application Serial No. 229,644 filed October 10, 1962. Machines of the type shown in this copending patent application have proven useful in operation and in practical application.

However, it is still possible to increase the power as well as the total efficiency of such rotary radial piston machines if the piston stroke can be amplified. In particular, in known machines, the piston stroke relative to the rotor diameter has been relatively small, and the only way in which the piston stroke could be increased was by enlarging the diameter of the rotor.

An object of the present invention is to provide, in rotary radial piston machines, increased piston strokes by utilizing novel formations such as piston guide extensions, radial extensions of the rotor, grooves and guiding rings or the like, guides for the piston shoes, and/or divided pressure balancing recesses.

Another object of the invention is to provide, in rotary radial piston machines, self-sealing pistons.

A further object of the invention is to provide a rotary radial piston machine in which the aforementioned expedients may be used either singly or in combination.

Previously, not enough attention has been paid to the importance of large piston strokes. Consequently, the relation of the piston stroke to the diameter of the rotor in which the pistons are reciprocated, has been relatively small. As a result, the power of the machine has been on the one hand limited, while, on the other hand, the power losses due to the friction of bearings and sliding parts have been unduly large. Accordingly, there has been an overall reduction in the efficiency of these machines.

While attempts have been made to obtain larger piston strokes, these attempts have resulted in larger diameters of the rotors and overall dimensions of the machine, consequently increasing the losses due to friction in bearings and sliding parts. In accordance with the present invention, this disadvantage is overcome by providing a large piston stroke in machines having small rotor diameters, with consequently small bearings, relatively short moving or sliding parts and resultant decrease in friction. Thus, not only is the power output of the machine per unit weight and unit dimension increased, but also the efficiency is increased.

In accordance with the invention, a radially outwardly extending annular groove is provided either in a stationary

casing or in a rotary ring mounted in the casing, this groove extending from the radially inner face of the casing or rotary ring in a radial direction into the casing or rotary ring. The rotor is provided with an axially narrow radial extension which can enter into this annular groove. Piston pivots or guide shoes are guided on the inner faces of the casing or rotary ring, and radially extended piston guides are formed on the axially narrow radial extension of the rotor and may extend beyond the respective pistons into the mentioned annular groove or grooves.

Another object of the invention is to provide, in the guiding surfaces of the piston guides or shoes, at least two fluid balancing recesses in axially spaced relation to the associated anuular groove or grooves in the casing or rotary ring.

A further object is to provide, in the arrangement just described, branch passages connecting each of the recesses to a central passage formed through the piston guide or shoe for the flow of fluid into the balancing recesses.

Still another object of the invention is to provide a multi-cylinder rotary radial piston machine having a plurality of such radial extending annular grooves in the piston guide means and with the rotor having a plurality of axially narrow radial extensions cooperable with the grooves.

In considering another object of the invention, it must be borne in mind that the seal between the piston walls and cylinder walls, in rotary piston machines is provided by a very small clearance between these walls. In cases of expansion, the sizes of these clearances change resulting in large leakage or, in the case of contraction, in sticking or welding occurring between the walls of the piston and the cylinder. The provision of plastic seals increases the friction resisting reciprocation of the pistons.

In accordance with the invention, these disadvantages are overcome by forming a bore through the piston and by so dimensioning the wall of the piston that it can expand or contract its diameter a limited amount in accordance with fluid pressure exerted thereon. The fluid under pressure in the cylinder flows into this bore and presses the piston wall to expand radially outwardly. The greater the pressure, the greater is the increase in the piston diameter, with corresponding increased narrowing of the clearance between the piston and cylinder walls. By providing these features with suitable dimensions and at suitable locations, the friction and the leakage in the clearance is substantially reduced. A further feature is the provision of fillers in the hollow pistons to prevent losses due to compression of fluid in dead spaces.

The foregoing features of the invention, and particularly the interfitting of the rotor and its extensions into the guide grooves of the casing or rotary ring, enable the attainment of larger piston strokes with respect to a given rotor diameter. Additionally, circumferential tilting during guiding of the pistons is positively prevented during the entire piston stroke. This increases the ability of the pistons and the associated guide means for a proper performance under high radial and circumferential loads, with resulting increase in the power output and useful life of the machine.

For an understanding of the principles of the invention, reference is made to the following description of typical embodiments thereof as illustrated in the accompanying drawings.

In the drawings:

FIG. 1 is a longitudinal or axial sectional view through one form of rotary fluid machine embodying the invention;

FIG. 2 is a diametrical sectional view taken on the line II—II of FIG. 1;

FIG. 3 is a longitudinal or axial sectional view through one form of self-sealing piston embodying the invention;

FIG. 4 is a longitudinal or axial sectional view through a piston pivoting or guiding shoe formed with balancing recesses in accordance with the invention;

FIG. 5 is a top plan view of the guide means shown in FIG. 4;

FIG. 6 is a sectional view taken on the line VI—VI of FIG. 4;

FIG. 7 is a view, similar to FIG. 3, illustrating another embodiment of a self-sealing piston;

FIG. 8 is a transverse sectional view taken along the line VIII—VIII of FIG. 7;

FIG. 9 is a longitudinal or axial sectional view through the rotor of a rotary radial piston machine embodying the invention;

FIG. 10 is a diametrical sectional view taken along the line X—X of FIG. 9;

FIG. 11 is an axial sectional view of the rotary guide ring shown in FIG. 1; and

FIG. 12 is a view, similar to FIG. 11, illustrating an alternative embodiment of the rotary guide ring.

Referring first to FIGS. 1 and 2, a rotary radial piston machine embodying the invention is illustrated as including a rotor **12** and a casing **19**, the casing **19** including an eccentricity adjusting device **18** which can be adjusted radially or diametrically of casing **19**. Rotor **12** is formed with substantially radially extending cylinders in which pistons **14** are reciprocable radially of rotor **12** and are provided with pivoted guide shoes **29**.

A rotatable guide ring **43** is disposed within casing **19** and is supported on rotatable support rings **24** which are rotatably mounted on bearings **27**. Ring **43** has radially inner surfaces **48** and **49** which have guiding engagement with the radially outer surfaces **15** or piston guide shoes **29** and with the extensions **30** of guide shoes **29**. Between guide surfaces **48** and **49**, ring **43** is formed with an annular groove **25** of substantially rectangular cross section, this groove extending radially outwardly into ring **43**. The rotor **12** may be suitably clutched or coupled to shaft **32** of the machine, and the control body **44** may be provided with fluid passages **45** and **46** for the supply and exhaust of fluid with respect to the cylinders **47** of rotor **12**, which latter is rotatably mounted in the machine.

Support rings **24** and rotatable rings **43** together form the guide means for the reciprocation of piston guide shoes **29** and pistons **14**. While these guide means are illustrated as being rotatable in the embodiment of the invention shown in FIGS. 1 and 2, they also can be stationary. As stated, the guide means have guiding surfaces for guiding the shoes **29**. For example, members **24** may have guide faces **20** for guiding the radially inner guide faces **16** of shoes **29**, and may have radially extending guide faces **36** to engage the radially extending end faces of shoes **29**. Furthermore, radially extending guide faces **37** are provided as part of the annular grooves such as **25**, **125** and **225** cooperable with the guide faces **117** of radial extensions **25** of shoes **29**.

Referring to FIGS. 4, 5 and 6, the radial outer guide surface **15** of a piston shoe **29** can be a single surface. Thus, this surface may be formed with fluid balancing recesses **33** and **34** which can communicate with each other to balance either partially or completely the radial forces on the shoe **29**. These fluid balancing recesses **33** and **34** are offset axially with respect to annular groove **25** of guide ring **43** so that they can be closed by the guide surfaces **48** and **49** of the guide means **43**.

Branch passages **10** and **11** connect recesses **33** and **34**, respectively, with central passages **9** in shoe **29**. The difference between known passages of this type and the passage **9** is that the passage **9** does not extend through the shoe **29** but only part way thereinto. A bore **8** in each associated position, as best seen in FIGS. 1 and 2, communicates with the recesses **7** of the associated shoe,

this bore **8** extending completely through the associated position and being in communication with the associated cylinder. The shoe guiding means comprises a central portion **5** on the trunnion **3** from which there extend relatively narrow bar portions **4** which connect extensions **30** with member **5**.

The radially inner guide face **16** can be provided on extensions **30** to engage the guide surfaces **20**, and radially extending guide surfaces **17** also may be provided on extensions **30** or on the central part of shoe **29**. A radial extension means **35** can be provided on shoes **29** for extension into annular groove **25** to be guided in the latter. These extension members may be provided with radially extending axially separated guide faces **117**. The trunnions **3** form bearings for mounting the shoes in the associated pistons **14**.

The pistons, shoes and support rings shown in the drawings are by way of example only, as it is also possible for the piston pins or shoe assemblies to be contained within the respective cylinders, and for the radial extension **28** of the rotor **12** to extend at least partially into annular groove **25** in ring **43** or in the stationary casing. For example, it is possible to form the pistons with transverse bores receiving transverse bars extending axially throughout the length of the rotor. These bars may enter the axially extending transverse rotor slots **13** (FIG. 9) and from there into the piston shoes or slide elements, while being supported on guide rings or suitable guide means at either end of the rotor. Specific examples of this have not been shown in the drawings because they can be readily understood by those skilled in the art.

By reference to FIGS. 1, 2, 4 through 6 and 9 through 12, it will be shown how it is possible to provide rotary fluid machines with hitherto thought to be impossible large piston strokes without a resultant increase in rotor diameter, utilizing the principles of the invention. Such a large piston stroke is an important factor in improving the efficiency in power output of the machine. As previously stated, heretofore such a large piston stroke has been obtained only at the expense of increasing the rotor diameter whereas, in the present invention, the large piston stroke is attained without increasing the rotor diameter.

The feature of the invention which provides this longer piston stroke resides primarily in the annular groove **25** into which there extends the annular extension of rotor **12**, this extension entering at least partially into groove **25**. The groove **25** is preferably located in the center of ring **43** and extends outwardly into the ring. Thus, the inner guide face of ring **43** is divided into the two guide faces **48** and **49**, separated by groove **25**. This is particularly illustrated in FIG. 11. Instead of providing only one groove **25** in the guide ring or guide means, it is to provide a plurality of such guide grooves **25**, as illustrated particularly in FIG. 12.

Referring to FIGS. 9 and 10, the rotor **12** is provided with substantially radial cylinders **47** as is common in the art. Each cylinder **47** is provided with an axially extending transverse rotor slot **13**. The slots **13** receive the respective trunnions **3**, the narrowed shoe bar **4**, and the central member **5** of shoes **29**. The slots **13** open radially outwardly of rotor **12** and extend substantially parallel to the rotor axis and through the respective cylinders **47** and the extension **28** of rotor **12**. The radial extension **28** of rotor **12** is very narrow in an axial direction, to an extent such that the uncut parts thereof are axially narrower than the diameters of the cylinders **47**. Slots **13** have a transverse width less than the diameter of the associated cylinders **47**. Thus, a part of the wall of the associated cylinder **47** remains undisturbed by slot **13** and forms a radially extending guide wall **38**. Thus, if a piston **14** is inserted into a cylinder **47**, the outer surface of the piston is guided by the wall of cylinder **47** throughout the piston stroke. As is known in the art, pistons **14** can have diameters substantially equal to or

slightly less than the inner diameters of the associated cylinders. The pistons are guided not only by the walls of the associated cylinders 47, but also by the extended guide walls 38.

By virtue of the slots 13, the radial extension 28 of rotor 12 is divided into a plurality of circumferentially separated sections. In accordance with a relative eccentricity between the rotor axis and the axis of the guiding means, extension 28 extends more or less into annular groove 25. This provides for very large piston strokes with stable guiding of the associated pistons, and further makes it possible to handle the circumferential forces or components of forces with are either normal or substantially normal to the axes of the pistons 14.

As stated, an alternative embodiment of a guide ring is shown in FIG. 12 at 143, and is formed with a plurality of annular grooves such as 125 and 225 which divide the inner surface of ring 43 into a plurality of guide surfaces 148, 149, 150 or more. Thus, such a ring can be used for guiding a plurality of piston shoes of pistons arranged in axially spaced groups of a multi-piston group machine. In such an arrangement, the grooves 125, 225, etc., receive corresponding plural annular extensions of a rotor or of twin rotors. Each of the annular grooves is formed with radially extending guide faces 37. The arrangement of FIG. 12, when used, makes possible the provision of rotary piston machines having several groups of pistons, while providing for large piston strokes.

FIGS. 3, 7 and 8 show self-sealing pistons embodying the invention. As is usual in rotary piston fluid machines, the pistons have a close fit within the cylinders 47 providing a clearance between the walls of the pistons and the cylinder. However, the prevention of leakage through such small clearance cannot be perfectly attained, as a certain percentage of the fluid will flow through the clearance resulting in losses for the machine which decrease the volumetric and overall efficiency of the machine.

In order to prevent or to reduce such leakage losses, the piston 40 of FIG. 3 has a shallow annular recess 41 in its inner surface which decreases the thickness of the piston wall through a limited extent of the latter and at a specified location. Passage means are provided for supply of fluid to annular space 41, and the fluid pressure acting in this space deforms the wall of piston 40 radially outwardly so that the piston diameter increases adjacent the space 41. This increase in pressure results in an increase in the outer diameter of the piston, whereby the clearance between the piston and cylinder walls is decreased.

In accordance with Newton's law of sharing of fluids, if the clearance decreases the leakage decreases with the third power of the radial extent of the clearance. Thus, the effect of the annular space 41 is to provide a very effective decrease of leakage through the clearance, thereby providing an efficiently sealed rotary fluid machine. In the actual design or formation of annular space 41, it must be taken into account that too large an annular space would result in too large a radial dimension of the piston, thereby narrowing the clearance too much and increasing the friction. This adverse effect can be avoided by suitable design and machining as well as location and dimensioning of annular space 41. In the embodiment of FIG. 3, a large diameter bore is formed in the piston and a plug or filler 42 is positioned in the bore to prevent dead space within the piston and prevent internal compression losses in the fluid. The passage means are illustrated as including an axial bore 50 and a diametric bore 51. In the embodiment of FIG. 7, a similar filler 142 is provided in association with an annular recess 141. In this embodiment, there is an axial bore 150 and a transverse bore 151 communicating therewith.

In the arrangement of FIG. 3, a snap ring 52 is snapped into an annular groove in the inner wall of the piston to secure the plug or filler 42 in position. In FIG. 7, the ring 43 is preferably formed of a soft and deformable metal like copper or the like, and is deformed by pressing into the annular groove in the piston wall and the corresponding seat on the filler 142. An arrangement of this type is not possible with the embodiment of FIG. 3, as space is required for the assembly of snap ring 52. Thus, the embodiment of FIG. 7 is better able to prevent dead space than is the embodiment of FIG. 3. In both embodiments the axial bores 50 or 150 extend into the transverse bores 51 or 151, respectively, and bores 51 and 151 communicate with the annular recesses 41 and 141, respectively. The axial bores 51 or 151 are in communication with the associated cylinders 47.

Furthermore, recesses 54 can be provided in the exterior surface of the piston 1 of FIGS. 7 and 8 for the purpose of decreasing the wall thickness and limiting the extent of radial deformation of the piston wall. These external recesses 54 may also act as lubrication grooves or recesses. The piston 1 is provided with a circular recess 2 to receive the trunnion 3 of the associated piston shoe.

The exemplary piston shoe guide means are illustrated by way of example only, and other suitable guide means or guide shoes can be used with the other feature of this invention.

The fluid handling machine of the invention may have a fixed displacement or may have a variable displacement. The pistons may expel fluid from the respective cylinders either during the inward stroke of the piston or during the outward stroke thereof in dependence on whether the guide means surround the fluid handling body or if the fluid handling body is hollow and the guide means are located within the hollow body.

While specific embodiments of the invention have been shown and described in detail to illustrate the application of the principles of the invention, it will be understood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

1. A fluid handling machine comprising, in combination, a casing, a fluid handling body supported in said casing and formed with angularly spaced substantially radial bores constituting cylinders; pistons reciprocable in said cylinders during rotation of said rotor to cyclically vary the effective volumes of said cylinders to displace fluid relative to said cylinders; guide means radially of said fluid handling body; and guide shoes, each operatively connected to a respective piston, operatively engaged with said guide means to reciprocate the associated pistons; said guide means including means having a cylindrical guide surface formed with at least one axially narrow annular guide groove therein opening radially thereof; said fluid handling body having at least one radially extending axially narrow annular rib thereon, each rib extending at least partially into the associated guide groove in said guide means.

2. A fluid handling machine, as claimed in claim 1 in which said machine is a rotary fluid machine and said fluid handling body comprises a rotor rotatably supported in said casing; said guide means being eccentric relative to said rotor.

3. A rotary fluid machine, as claimed in claim 2, each rib being substantially centered, axially of the rotor, with a respective group of cylinders having their axes lying in a common diametric plane through the rotor.

4. A rotary fluid machine, as claimed in claim 3, in which the axial width of each rib is less than the diameter of the cylinders on whose axes it is centered.

5. A rotary fluid machine, as claimed in claim 4, in which said rotor bores are formed through each of said ribs, whereby each rib is subdivided by a plurality of angularly spaced slots each centered on the axis of a respective cylinder; the facing surfaces of each slot forming congruent extensions of the internal surface of the

associated cylinder for extended guiding of the associated piston.

6. A fluid handling machine, as claimed in claimed 1, in which each guide groove divides said cylindrical guide surface into a pair of axially spaced guide surface portions; each guide shoe having radially facing axially spaced guiding surfaces each engaged with a respective one of the associated pair of guide surfaces.

7. A fluid handling machine, as claimed in claim 6, in which the guiding surfaces on said guide shoes are spaced axially a distance at least equal to the thickness of said rib, whereby said guiding surfaces may move radially of the periphery of the surface of said rib.

8. A fluid handling machine, as claimed in claim 1, in which each cylinder has piston guide surface means projecting radially of the periphery of said body, the external dimensions of said piston guide surface means, axially of said body, being such that said piston guide surface means may enter said groove.

9. A fluid handling machine, as claimed in claim 6, in which each of the two guiding surfaces of a guide shoe has a recess therein opening radially thereof, said recesses being disposed on opposite sides of said rib; and means for supplying fluid under pressure in balanced relation to the recesses of each pair.

10. A fluid handling machine, as claimed in claim 9, in which said last-named means comprises an axial passage extending partly through each guide shoe from the inner end thereof, and a pair of branch passages each communicating with said axial passage at one end and with the respective recess at the opposite end; and further including an axial passage through the associated piston establishing communication between the axial passage in the respective guide shoe and the interior of the cylinder inwardly of the associated piston.

11. A rotary fluid machine, as claimed in claim 5, in which each guide shoe includes a substantially radially extending portion pivotally connected to the radially outer end of the associated piston, an axially extending central portion at the outer end of the pivot portion and having dimensions, circumferentially of the rotor, such that it can extend through the slots in said rib, and a pair of circumferentially arcuate portions each at a respective axial end of said central portion and spaced axially on either side of said rib, said arcuate portions having radially outer guiding surfaces in engagement with said cylindrical guide surface on either side of said annular groove.

12. A rotary fluid machine, as claimed in claim 11, in which each guide shoe is pivotal, relative to its associated piston, about an axis extending parallel the rotor axis.

13. A rotary fluid machine, as claimed in claim 11, in which each guide shoe has radially inner guide surfaces engageable with radially outwardly facing guide surfaces on said guide means and with radially extending axially spaced guide surfaces at each axial end thereof engageable with mating guide surfaces on said guide means.

14. A rotary fluid machine, as claimed in claim 2, in which said rib is formed with angularly spaced slots therethrough extending axially of said rotor and dividing said rib into arcuate sections; at least one arcuate section being engaged in said annular groove at all times, and the number of arcuate sections engaged in said annular groove at any time being dependent upon the relative eccentricity of said guide means.

15. A rotary fluid machine comprising, in combination, a casing; a rotor rotatably supported in said casing and formed with angularly spaced substantially radial bores constituting cylinders; pistons reciprocable in said cylinders during rotation of said rotor to cyclically vary the effective volume of said cylinders inwardly of said pistons to displace fluid relative to said cylinders; guide means in said casing surrounding said rotor and having a controllable eccentricity relative to the axis of said rotor; guide shoes, each operatively connected to a respective piston, operatively engaged with said guide means to reciprocate the associated pistons; each piston being a substantially hollow cylinder, and the cylindrical wall of each piston being thinned along an angular zone of limited axial extent intermediate the piston ends to provide a flexible piston wall; and means for applying fluid under pressure to said thinned wall portions to vary the outside diameter of said thinned walled portions in accordance with the fluid pressure to correspondingly vary the clearance between the external surface of each piston and the internal surface of the associated cylinder.

16. A rotary fluid machine, as claimed in claim 15, in which each thinned wall portion is formed by an annular recess in the inner cylindrical surface of each piston.

17. A rotary fluid machine, as claimed in claim 16, including a cylindrical plug filling the hollow interior of each piston; said plug being formed with passage means for supplying fluid under pressure to said annular recess.

18. A rotary fluid machine comprising, in combination, a casing; a rotor rotatably supported in said casing and formed with angularly spaced substantially radial bores constituting cylinders; pistons reciprocable in said cylinders during rotation of said rotor to cyclically vary the effective volume of said cylinders inwardly of said pistons to displace fluid relative to said cylinders; guide means in said casing surrounding said rotor and having a controllable eccentricity relative to the axis of said rotors; guide shoes, each operatively connected to a respective piston, operatively engaged with said guide means to reciprocate the associated pistons; each piston having a radially flexible wall surface extending annularly thereof through a limited axial distance intermediate the ends of the piston; and means for supplying fluid under pressure to the interior of each piston to deflect said flexible wall portion to vary the exterior diameter of each piston in accordance with the fluid pressure to correspondingly vary the clearance between the external surface of each piston and the internal surface of the associated cylinder.

19. A rotary fluid machine, as claimed in claim 18, in which said means for supplying fluid under pressure comprises an axial passage extending inwardly from an exposed end of each piston and in communication with the cylinder space inwardly of each piston, and a diametric passage intersecting said axial passage and communicating at its opposite ends with the interior surface of said flexible wall portion.

20. A rotary fluid machine, as claimed in claim 2, in which said means having a radially inner cylindrical guide surface comprises a ring rotatably mounted within said casing.

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