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Wouters et al.

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[54] **CONTROL PLATE FOR A HYDROSTATIC PISTON MACHINE**

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[30] **Foreign Application Priority Data**

Oct. 28, 1970 Germany ..... P 20 52 878.3

[52] **U.S. Cl.** **91/485**, 91/487

[51] **Int. Cl.** **F04b 1/00**

[58] **Field of Search** 91/485, 486, 487, 91/499

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Assistant Examiner—Gregory LaPointe
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[57] **ABSTRACT**

The control valve plate for a hydrostatic axial piston pump has in its front control face kidney-shaped left and right control ports on opposite sides of an axial plane, and also hydrostatic bearings radially outwards of a circular groove which is located outward of the control ports and communicates with atmospheric pressure. Left and right pressure cylinders and pistons in the rear control face of the valve control plate are located radially outwards of the ends of the left and right control ports, but respectively connected by ducts with the right and members control ports, respectively.

9 Claims, 7 Drawing Figures

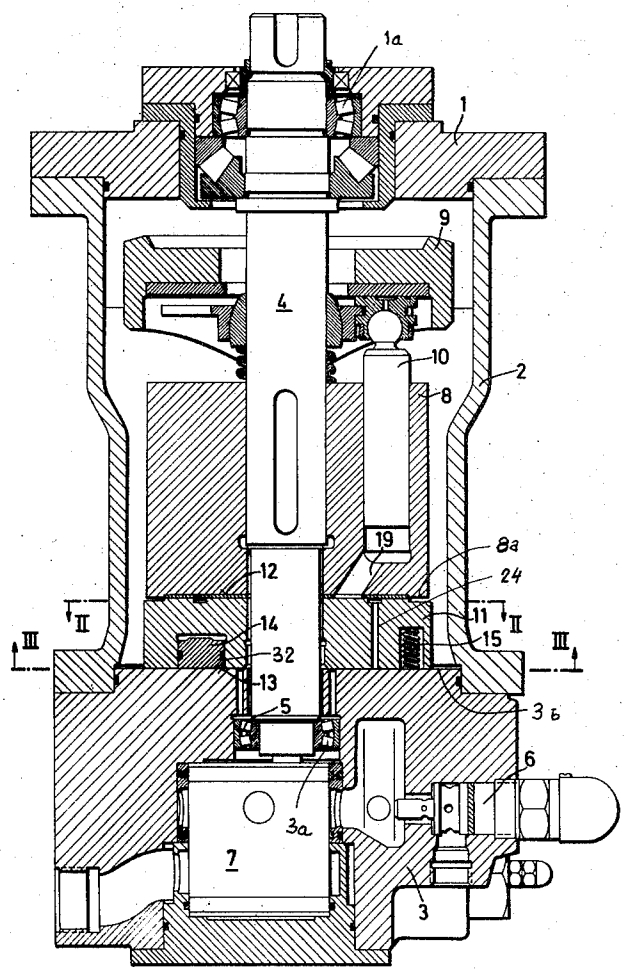

FIG. 1

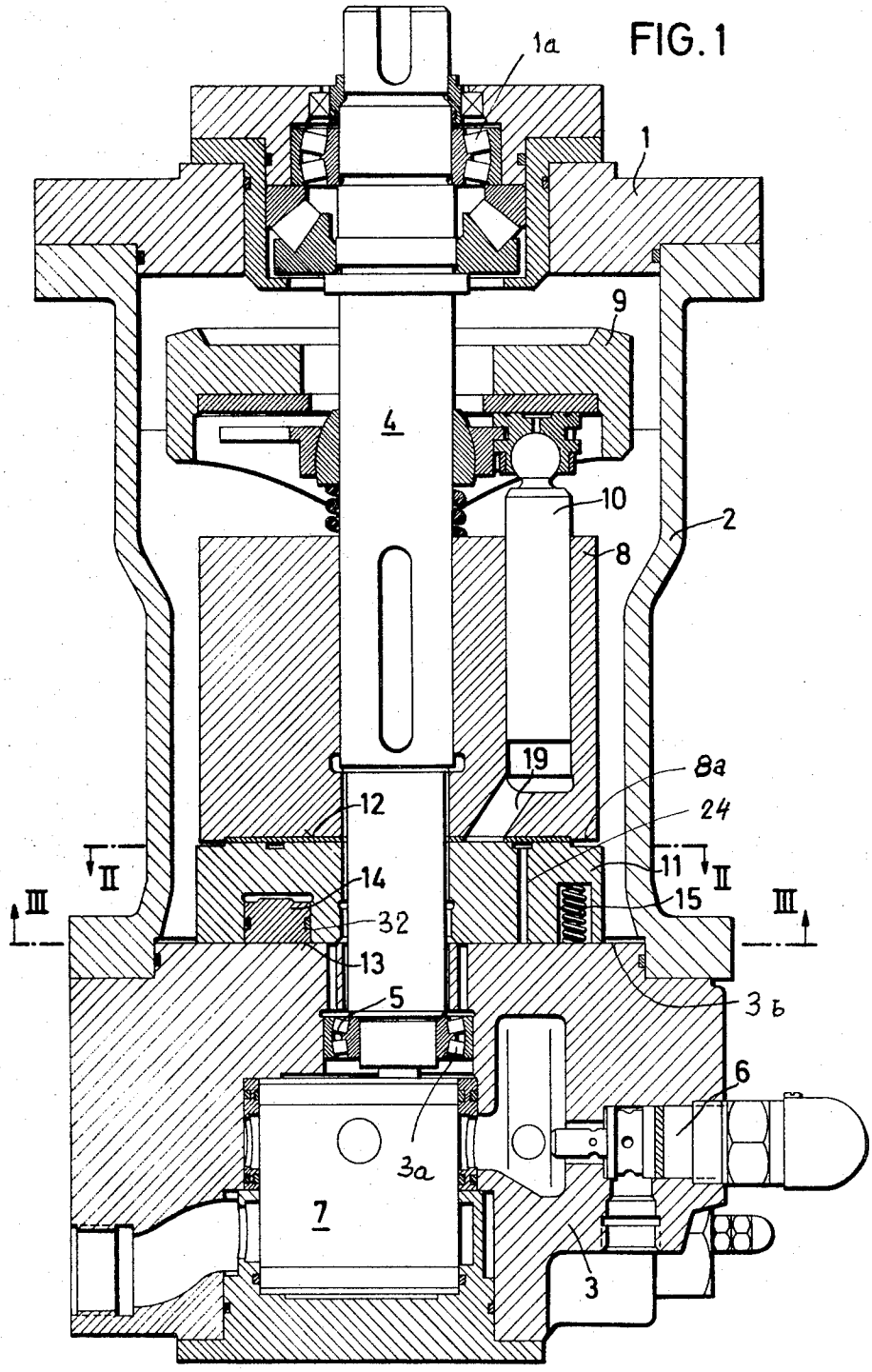

FIG. 2

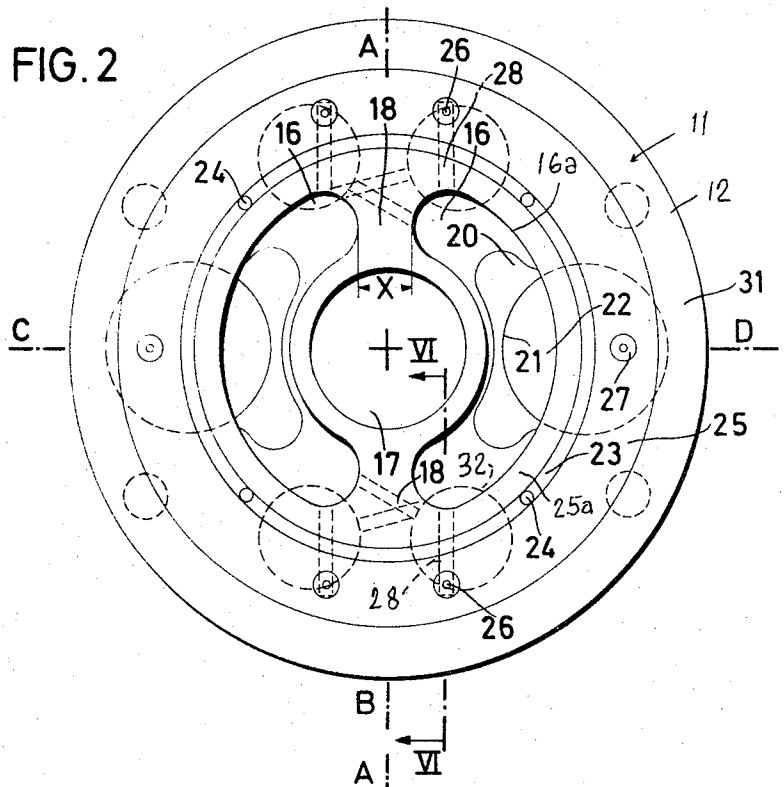
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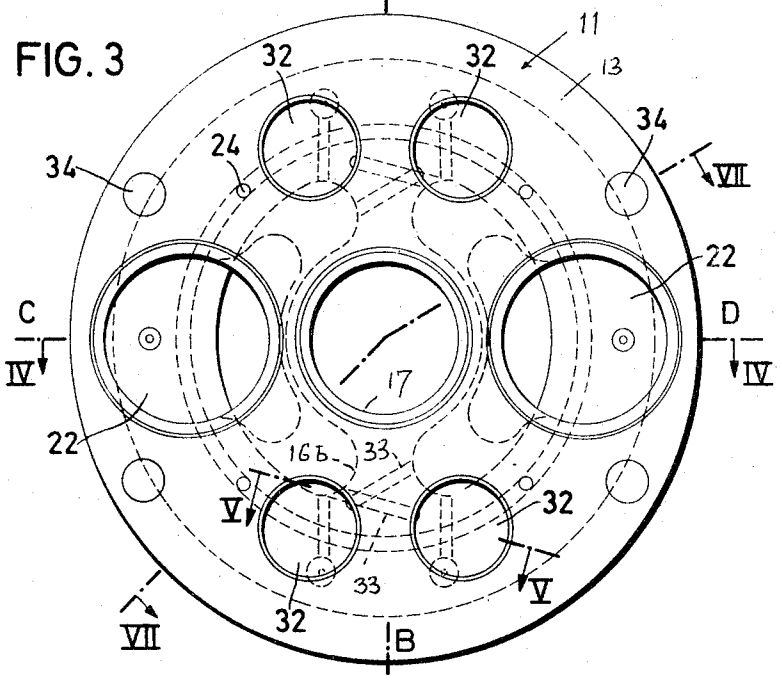
FIG. 3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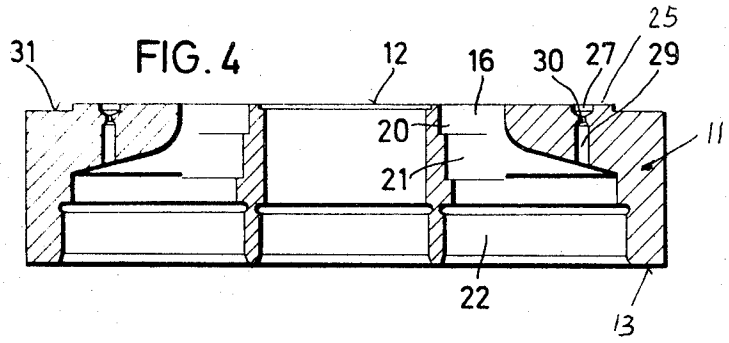

FIG. 4

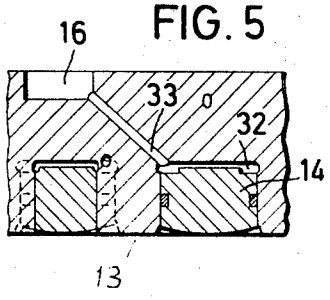

FIG. 5

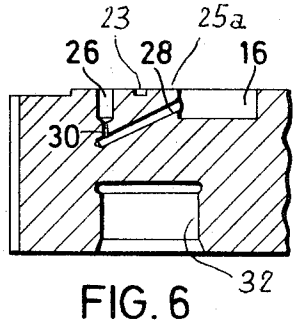

FIG. 6

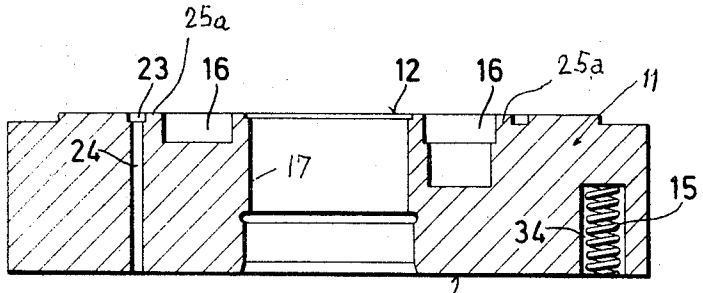

FIG. 7

CONTROL PLATE FOR A HYDROSTATIC PISTON MACHINE

BACKGROUND OF THE INVENTION

The present invention relates to a control valve body or plate for a hydrostatic axial piston or radial piston machine which may operate as a pump or motor. It is known to provide a control plate with two part-circular kidney-shaped control ports through which fluid flows into and out of inlet and outlet openings in the adjacent end face of a rotor. It is also known to provide pressure pistons between stator and the control plate which acts on the rear control face of the control plate to urge the same toward the rotor.

In a construction of the prior art, as exemplified by the German patent 829,553, a control plate is described in which pressure cylinders, in which pressure pistons are located, are connected by narrow ducts which open in the slide face of the control plate in a region which is passed by the inlet and outlet passages of the rotating rotor. The pressure of the pistons on which pressure fluid acts, is intended to assure sufficient pressure between the front control face of the control plate and the corresponding rotor end face, while leadkage losses are to be reduced. The machines according to the prior art obtain satisfactory results only when a predetermined pressure and rotary speed are maintained. Difficulties develop when a more universal use is attempted at higher or lower rotary speeds and pressures, due to the fact that the periodical load changes on the pressure pistons result in oscillations which may cause an undesirable separation of the control plate from the rotor end face so that a gap is formed which causes pressure and leakage losses. Furthermore, there is the danger of seizing and jamming in the plane of the control face.

SUMMARY OF THE INVENTION

It is one object of the invention to improve the construction of a control plate, and the cooperation between the front control face and the rotor end face of a hydrostatic piston machine, so that the machine can operate at full load at a very low speed without exceeding a minimum leakage. The same improved operational conditions are to be maintained at high rotary speed, and it is also an object of the invention that the machine operates under different operational conditions without requiring structural changes, and without the above-described disadvantages of the prior art.

With these objects in view, a pair of left and right control ports located on opposite sides of an axial plane, have ends connected by ducts with right and left pressure cylinders located also on opposite sides of the axial plane. The control ports are also connected with hydrostatic bearings on the front control face which are located radially outward of a circular groove in the front control face which is connected with atmospheric pressure, and separates annular surface portions of the front control face surrounding the control ports.

The present invention is preferably applied to a hydrostatic piston machine which includes a stator and a rotor having a rotor end face with inlet and outlet openings.

The control plate is non-rotatably, but movably mounted on the stator and has a center coinciding with the axis of the rotor, a rear control face cooperating with the stator, and a front control face in sliding contact with the rotor end face.

The control plate has left and right passages for the flow of fluid into and out of the inlet and outlet openings in the rotor, the left and right passages forming in the front control face a pair of left and right part-circular control ports, and forming in the rear control face left and right connecting ports, the left and right connecting ports and control port being disposed symmetrically on opposite sides of a first axial plane, and aligned in a second axial plane through the center extending perpendicular to the first axial plane.

The control plate has in the rear control face two, or three, pairs of left and right pressure cylinders and pistons disposed symmetrically on opposite sides of the first plane, the pairs being disposed symmetrically on opposite sides of the second plane.

The left and right pressure cylinders are located in the regions of the ends of the left and right control ports, respectively. The control plate has two pairs of crossing connecting ducts connecting the ends of the left and right control ports with the right and left pressure cylinders, respectively.

The front control face of the control plate incluides an outer annular surface portion, and an inner annular surface portion located radially outward of the control ports. An annular groove is provided between the outer and inner annular surface portions, and connected with atmospheric pressure.

The control front face has two pairs of left and right recesses located radially outward of the annular groove in the outer annular surface portion symmetrically on opposite sides of the first plane, and pairs of left and right recesses are located symmetrically on opposite sides of the second plane. The control plate is formed with channels connecting the left recesses with the left control port and the right recesses with the right control port, respectively, so that the recesses act as hydrostatic bearings. This arrangement of the invention effects the balancing of turning moments of pressure forces acting on opposite sides of the first and second planes.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is an axial sectional view of a rotary axial piston machine provided with the control plate of the present invention;

FIG. 2 is a front view of the control plate taken on line II—II in FIG. 1;

FIG. 3 is a rear view of the control plate taken on line III—III in FIG. 1;

FIG. 4 is an axial sectional view taken on line IV—IV in FIG. 3;

FIG. 5 is a fragmentary sectional view taken on line V—V in FIG. 3;

FIG. 6 is a fragmentary sectional view taken on line VI—VI in FIG. 2; and

FIG. 7 is an axial sectional view taken on line VII—VII in FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 illustrates an axial piston machine which may be operated as a pump or motor. It is also possible to reverse the direction of rotation of the rotor so that the direction of flow of the pressure medium is also reversed.

The machine shown in FIG. 1 has three housing portions 1, 2 and 3 forming a stator. A shaft 4 is supported in housing part 1 on a main bearing 1*a*, and in housing part 3 on a smaller bearing 3*a*. Housing part 3 envelopes auxiliary devices such as a valve 6 and an auxiliary pump 7 which are of a well known construction and not an object of the invention. The intermediate housing portion 2 envelopes the drum-shaped cylindrical rotor 8, an adjustable wobble plate 9 and axial pistons 10 which are guided in working cylinders of rotor 8 communicating with inlet and outlet openings 19.

A control valve body, or control plate 11 in accordance with the invention, is non-rotatably, but axially and radially movably mounted in the intermediate housing 2 and has a rear control face 13 cooperating with an end face 3*b* of stator housing portion 3. The rear control face 13 of control plate 11 is provided with four pressure cylinders 32, best seen in FIG. 3, in which pressure pistons 14 are arranged which abut the end face 3*b* of housing portion 3, and urge control plate 11 toward the rotor end face 8*a*. Pressure pistons 14 preferably have at least partly gas-ionized circumferential surfaces. The rear control face 13 has additional recesses in which springs 15 are mounted and which also produce resilient forces for moving control valve plate 11 toward the rotor end face 8*a*.

The front control face 12, which cooperates with the rotor end face 8*a*, is best seen in FIG. 2. A pair of passages 20, 21, 22, 16 are aligned in an axial plane CD, and are respectively located on the left and on the right of the axial plane AB as viewed in the drawing, particularly in FIGS. 2, 3, 4 and 5. Elements on the left, or on the right side, respectively, of the axial plane AB, will be hereafter referred to and identified as "left" and "right."

The left and right passages have, respectively, left and right part-circular ports 16 in the front control face 12. The two control ports 16 are high-pressure and low-pressure ports, respectively, or discharge and inlet ports, respectively, and are symmetrically arranged in relation to the plane AB. The centers of curvature of the part-circular edges 16*a* are located at the center of the control plate 11 where the planes A, B and C, D intersect in the axis of rotor 8 and shaft 4.

Control ports 16 have ends with circular walls 16*b* which are spaced from each other a distance *x* so that a smooth separating surface portion 18 of control face 12 remains. The distance *x* is equal or greater than the corresponding dimension of the inlet and outlet openings 19 so that communication between adjacent openings 19 through control ports 16 is not possible. The variation of the shape of the passages 20, 21, 22, 16 in axial direction is best seen in FIGS. 2 and 4. Two steps 20 and 21 are produced by milling to provide a smooth flow between the kidney-shaped left and right ports 16 and the circular connecting ports 22 on rear control face 13. The connecting ports 22 are connected in a well known manner with the hydrualic circuit of the machine.

The control ports 16 produce pressure areas in the plane of the front control face 12 which extend outwardly from the control ports 16, with the pressure dropping in radially outward direction. The pressure area is bounded by the annular and circular groove 23 which is located between inner and outer annular surface portions of control face 12. Four bores 24, equally spaced in circumferential direction of the circular groove 23, extend in axial direction through the control plate 11, as best seen in FIG. 7. Bores 24 are connected with atmosphere, and consequently have atmospheric pressure for limiting the radial extension of the pressure area produced by control ports 16 on the front control face 12. The distance between the outer edges 16*a* of control ports 16, and the inner edge of the circular groove 23, is substantially the same as the distance between the inner edge of a control port 16 and the bore 17 at the center of the control plate 11.

Annular groove 23 is located radially inward of the annular surface portion 25 whose radial width corresponds to the radial width of the control ports 16.

Two pairs of left and right recesses 26 are provided in surface portion 25. The left recesses and the right recesses 26 are located symmetrically on opposite sides of the plane AB, and the two pairs of recesses 26 are located symmetrically on opposite sides of the plane CD. A third pair of recesses 27, also located in the annular surface portion 25 of front control face 12, is located aligned in the plane CD, the respective left and right recess 27 being arranged symmetrically on opposite sides of the plane AB.

Recesses 26 are spaced from palne AB substantially the same distances at the centers of the semicircular ends 16*b* of control ports 16. The four ends of control ports 16 are respectively associated with recesses 26 and connected with the same by channels 28, as best seen in FIGS. 2, 3 and 6. The recesses 27 are connected by axially extending channels 29 with the passage portions 21 which communicate with the control ports 16 and the connecting ports 22, as best seen in FIGS. 2 and 4.

The recesses 26, 27, which form hydrostatic bearings, have only a limited axial depth, and adjacent the bottom portions of recesses 26, 27, channels 28 or 29 are constricted by a throttle portion 30, as shown in FIGS. 4 and 6. The throttles 30 prevent a strong flow of pressure fluid into the gap between the end face 8*a* of the rotor 8 and the front control face 12 in the event that a sudden pressure increase occurs. An annular stepped peripheral surface portion 31 surrounds the annular surface portion 25 of control face 12, as best seen in FIG. 4.

The rear control face 13 of the control plate 11 is best seen in FIG. 3 from which it is apparent that the pair of left and right connecting ports 22 is located in the axial plane C and D, while the left and right connecting ports 22 are symmetrically arranged on opposite sides of the plane AB. The centers of the connecting ports 22 and of the pressure cylinders 32 for pressure pistons 14 and the centers of the bores 24 are located at the circular center line of the circular groove 23. Connecting ports 22 have a diameter which is substantially equal to half of the inner diameter of the part-circular control ports 16. The centers of the left and right pressure cylinders 32 of the same pair are spaced substantially the same distance from the palne AB as the centers of the semi-circular ends 16*b* of the control

ports 16. Each end of a control port 16 communicates with a connecting duct 33, see FIGS. 3 and 5, which lead to the pressure cylinder 32 located on the respective other side of the plane AB. A left pressure cylinder 32 is connected by a connecting duct 33 with the end of a right control port 16 so that connecting ducts 33 cross each other in the region of the plane AB.

The pressure pistons in the cylinder chambers 32, see FIGS. 1 and 5, receive fluid under pressure from the control ports 16 through connecting ducts 33 and are pressed against the end face 3*b* of housing part 3, while the controlface 12 of control plate 11 is pressed against end face 8*a* of rotor 8.

The ratios of the forces and turning moments at the control plate 11 are selected so that the resultant moment of the pressure in each control port 16, multiplied with the respective lever arm plane the palne AB, plus the resultant moment from the hydrostatic bearings 26, 27 in one half of the control plate 11, multiplied with the respective lever arm to the plane AB, is compensated by the turning moment of the pressure in the respective connecting port 22 multiplied with the lever arm to the plane AB, plus the resultant moment from the pressure of left cylinder chambers 32 multiplied by the respective lever arm to the plane AB. Due to this arrangement, it is assured that each half of the control plate 11 in relation to the plane AB is balanced.

The pressure coil springs 15 in cylindrical recesses in the rear face 13 of control plate 11, see FIG. 7, bias control plate 11 toward rotor end face 8*a*, and are required during the starting of the machine to obtain contact between the front control face 12 and the rotor end face 8*a*. The centers of the cylindrical bore 34 and of the spring 15, are substantially spaced the same radial distance from the center of the control plate as the outermost point of a connecting port 22, see FIG. 3. With reference to the transverse plane CD, the centers of the cylindrical bores 34 are arranged in pairs of left and right bores 34 so that lines passing through the center of the control plate 11 and connecting the centers of diametrically disposed cylindrical bores 34, are tangents on opposite peripheral portions of the connecting ports 22.

The control plate according to the invention can not only be used for axial piston pumps and motors, but also for radial piston machines. The control faces 12 and 13 of the control plate 11 are shown to be planar, but it is possible to use spherically curved control faces.

It is of importance that the left pressure cylinders 32 receive pressure fluid from the right pressure ports 16, and the right pressure cylinders receive fluid from the left control ports 16, as viewed in FIG. 3, for example. This construction is based on the recognition that in this manner, the forces of the fluid pressure medium which tend to separate the front control plate 12 from the rotor end face 8*a*, can be compensated by hydraulic forces which are effective in a particular pattern on the rear control face 13 of the control plate 11. The pressure pistons 14 on the low pressure side have a favorable effect for the high pressure side since they are connected with the control port 16 of the pressure side so that a very favorable balancing of the forces and moments acting on the control plate is obtained. It is desired that for each pressure side, high-pressure side and low-pressure side, the sum of all forces acting on the front control face 12, and of all moments acting on the front control face 12, becomes zero. Such balancing of the front control face 12 permits the arrangement of the hydrostatic machines in a series connection.

It is also important for the functioning of the control plate 11 of the invention, that the pressure fluid is continuously and directly supplied to the pressure cylinders of the pressure pistons 14. In all operational conditions, independently of the rotary speed and the pressure, the pressures which tend to separate the control plate 11 from the rotor 8, are opposed by a continuous force derived from the control port 16 on the high-pressure side and acting on the widely spaced pressure cylinders 32. The high-pressure control port 16 is connected with pressure cylinders 32 located on the same side as the lower pressure control port 16. The gap between the rotor end face 8a and the front control face 12 can be exactly determined and maintained in all operational conditions of the machine.

The hydrostatic bearings 26, 27, which continuously receive pressure fluid from the control port 16 of the high-pressure side, participate in an advantageous manner in the stabilization of the operational position of the control plate 11 so that lubrication takes place between rotor end face 8a and front control face 12 in a reliable and uniform manner.

The balancing of the control plate 11 in the above-described manner has the result that the annular groove 23, conencted with atmospheric pressure, can be provided between the control port 16 and the hydrostatic bearings 26, 27. In this manner exactly determined annular inner and outer surface portions of the front control face 12 are formed on opposite sides of the annular groove 23, and a thin film formed by the pressure fluid is uniformly distributed on the annular outer and inner surface portions 25, 25*a* so that no forces which could cause tilting of the control plate are created. The hdyrostatic bearings 26 and 27 are advantageously located in the outer surface portion 25, as shown in FIG. 2. The channels 28 and 29 are constricted at 30, but widened at the recesses 26 and 27. The recesses 26 and 27 assist in stabilizing the position of the control plate 11, but also cause a uniform formation of the oil film on the front control face 12, while the constricted throttle portion 30 reduces the effect of high pressure peaks, and prevents the flowing out of a great amount of pressure fluid in the event of an increase of the width of the gap between the front control face 12 and the rotor end face 8a. Consequently, the control plate 11 tends to remain in the correct position.

The function of the control plate 11 is improved when the hydrostatic bearing recesses 26, 27 are located on both sides of the plane AB, symmetrically arranged and disposed on a circular line having its center on the center of the control plate which coincides with the rotor axis and forms the line of intersection of planes AB and CD.

The circumferential surface of the pressure piston is preferably partly or completely gas-ionized which improves the sliding of the pressure pistons 14 in the pressure cylinders 32.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of control valve bodies for hydrostatic piston machines.

While the invention has been illustrated and described as embodied in a control plate balanced in relation to two perpendicularly intersecting axial planes, it is not intended to be limited to the details shown, since

various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims.

I claim:

1. In a hydrostatic piston machine including a stator, and a rotor having a rotor end face with inlet and outlet openings, in combination, a control plate non-rotatably but freely movably mounted on said stator for axial and radial movement, and having a center coinciding with the axis of said rotor, a rear control face cooperating with said stator, and a front control face in sliding contact with said rotor end face; said control plate having left and right passages for the flow of fluid into and out of said inlet and outlet openings, said left and right passages forming in said front control face a pair of left and right part-circular control ports, and forming said rear control face left and right connecting ports, said left and right control ports and connecting ports being disposed symmetrically on opposite sides of a first axial plane, and aligned in a second axial plane through said center extending perpendicularly to said first axial plane; said control plate having in said rear control face left and right pressure cylinders disposed symmetrically on opposite sides of said first and second planes; said control plate having two pairs of crossing over connecting ducts connecting said left and right control ports with said right and left pressure cylinders, respectively; said front control face of said control plate including at least one surface portion, and a groove between said surface portion and said control ports connected with atmospheric pressure; said control front face having two pairs of left and right recesses located radially outward of said annular groove in said surface portion symmetrically on opposite sides of said first plane, said pairs of recesses being located symmetrically on opposite sides of said second plane, said front control face having a third pair of left and right recesses located in said surface portion on opposite sides of said first plane and aligned in said second plane; and said control plate being formed with channels connecting said left recesses with said left control port and said right recesses with said right control port, respectively, and with left and right channels connecting said left and right recesses, respectively, of said third pair of recesses with the centers of said left and right control ports, respectively, so that said recesses act as hydrostatic bearings, and turning moments of pressure forces on opposite sides of said first and second planes, respectively, are balanced.

2. In a hydrostatic piston machine including a stator, and a rotor having a rotor end face with inlet and outlet openings, in combination, a control plate non-rotatably but movably mounted on said stator and having a center coinciding with the axis of said rotor, a rear control face cooperating with said stator, and a front control face in sliding contact with said rotor end face; said control plate having left and right passages for the flow of fluid into and out of said inlet and outlet openings, said left and right passages forming in said front control face a pair of left and right part-circular control ports, and forming in said rear control face left and right connecting ports, said left and right control ports and connecting ports being disposed symmetrically on opposite sides of a first axial plane, and aligned in a second axial plane through said center extending perpendicularly to said first axial plane; said control plate having in said rear control face two pairs of left and right pressure cylinders disposed symmetrically on opposite sides of said first plane, and said pairs being disposed symmetrically on opposite sides of said second plane, said left and right pressure cylinders being located in the regions of the ends of said left and right control ports, respectively; said front control face of said control plate including an outer annular surface portion, and an inner annular surface portion located radially outward of said control ports, and an annular groove between said outer and inner annular surface portions connected with atmospheric pressure; said control front face having two pairs of left and right recesses located radially outward of said annular groove in said outer annular surface portion symmetrically on opposite sides of said first plane, said pairs of recesses being located symmetrically on opposite sides of said second plane; and said control plate being formed with channels connecting said left recesses with said left control port and said right recesses with said right control port, respectively, said left and right recesses being equally spaced in radial direction from said center of said control plate, and said recesses in said front control face being wider than the respective channels, each of said channels having a constricted portion forming a throttle adjacent the inner end of the respective recess so that said recesses act as hydrostatic bearings, and turning moments of pressure forces on opposite sides of said first and second planes, respectively, are balanced.

3. In a hydrostatic piston machine including a stator, and a rotor having a rotor end face with inlet and outlet openings, in combination, a control plate non-rotatably but movably mounted on said stator and having a center coinciding with the axis of said rotor, a rear control face cooperating with said stator, and a front control face in sliding contact with said rotor end face; said control plate having left and right passages for the flow of fluid into and out of said inlet and outlet openings, said left and right passages froming in said front control face a pair of left and right part-circular control ports, and forming in said rear control face left and right connecting ports, said left and right control ports and connecting ports being disposed symmetrically on opposite sides of a first axial plane, and aligned in a second axial plane through said center extending perpendicularly to said first axial plane; said control plate having in said rear control face two pairs of left and right pressure cylinders disposed symmetrically on opposite sides of said first plane, and said pairs being disposed symmetrically on opposite sides of said second plane, said left and right pressure cylinders being located in the regions of the ends of said left and right control ports, respectively; said control plate having two pairs of crossing over connecting ducts connecting the ends of said left and right control ports with said right and left pressure cylinders, respectively; said front control face of said control plate including an outer annular surface por-

tion, and an inner annular surface portion located radially outward of said control ports, and an annular groove between said outer and inner annular surface portions connected with atmospheric pressure; said control front face having two pairs of left and right recesses located radially outward of said annular groove in said outer annular surface portion symmetrically on opposite sides of said first plane, said pairs of recesses being located symmetrically on opposite sides of said second plane, said front control face having a third pair of left and right recesses located in said outer annular surface portion on opposite sides of said first plane and aligned with said second plane; and said control plate being formed with channels connecting said left recesses with said left control port and said right recesses with said right control port, respectively, and with left and right channels connecting said left and right recesses, respectively, of said thrid pair of recesses with the centers of said left and right control ports, respectively, so that said recesses act as hydrostatic bearings, and turning moments of pressure forces on opposite sides of said first and second planes, respectively, are balanced.

4. Control plate as claimed in claim 3 wherein said left pressure cylinders are located radially outward of the ends of said left control ports, and said right pressure cylinders are located radially outward of the ends of said right control ports.

5. Control plate as claimed in claim 3 wherein said left pressure cylinders are located radially outward of the ends of said left control ports, and said right pressure cylinders are located radially outward of the ends of said right control ports; and comprising pistons in said pressure cylinders.

6. Control plate as claimed in claim 5, wherein said recesses in said front control face are wider than the respective channels; and wherein each of said channels has a constricted portion forming a throttle adjacent the inner end of the respective recess.

7. Control plate as claimed in claim 3, wherein said left and right recesses are equally spaced in radial direction from said center of said control plate.

8. Control plate as claimed in claim 3, comprising pressure pistons in said cylinders having at least partly gas-ionized circumferential surfaces.

9. Control plate as claimed in claim 3, wherein said recesses in said front control face are wider than the respective channels; and wherein each of said channels has a constricted portion forming a throttle adjacent the inner end of the respective recess.

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