

Sept. 16, 1941.

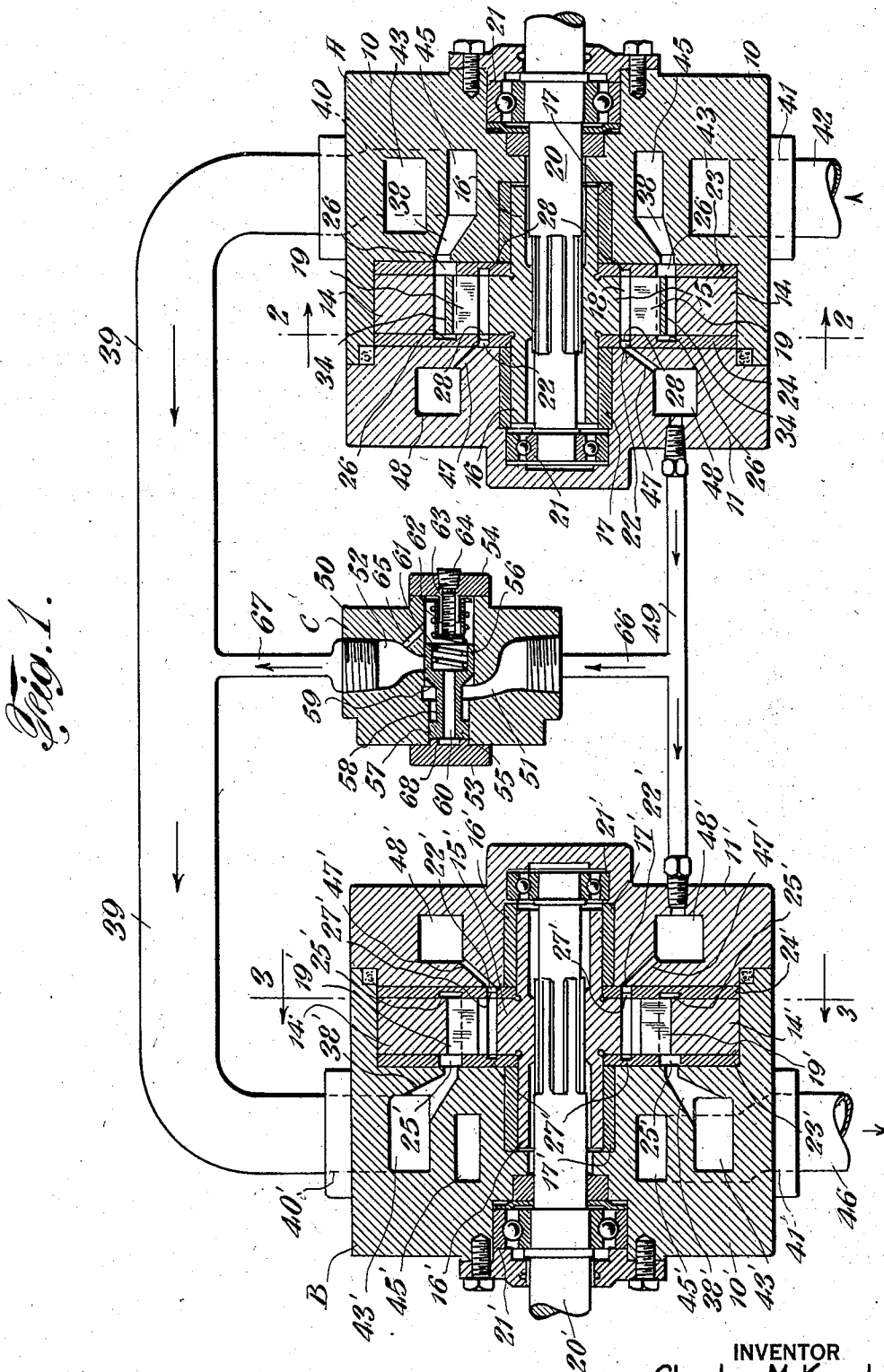
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2,256,459

FLUID PRESSURE DEVICE

Filed Feb. 12, 1941

4 Sheets-Sheet 1



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Fig. 2.

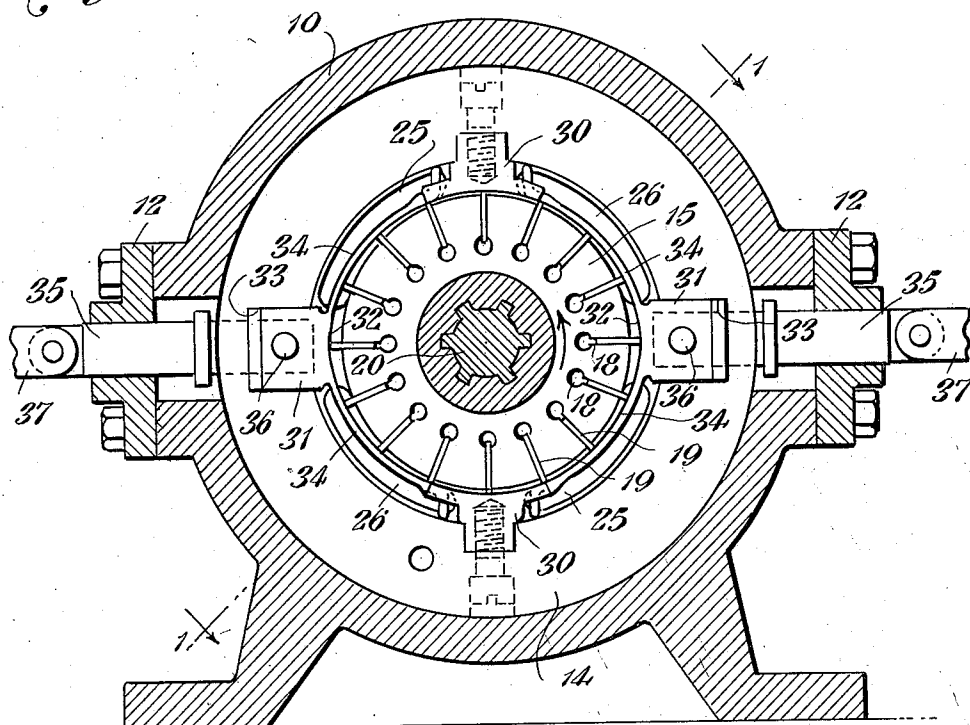


Fig. 2^b

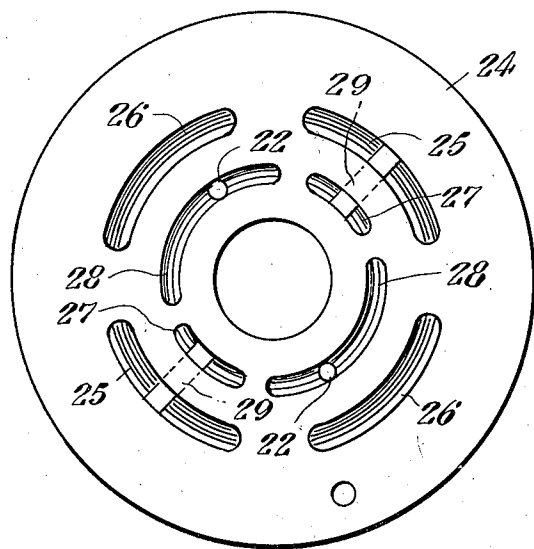
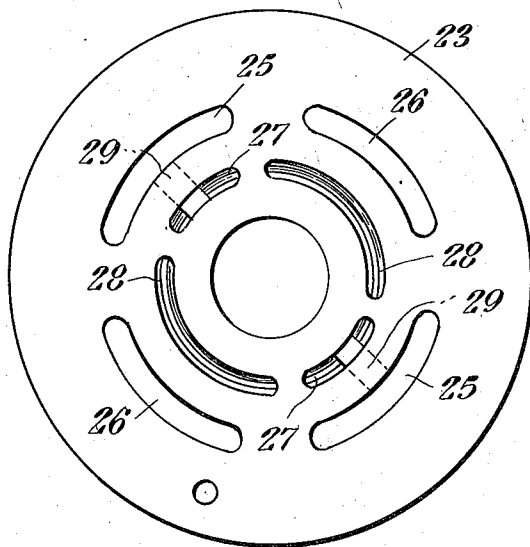


Fig. 2^a



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Fig. 3.

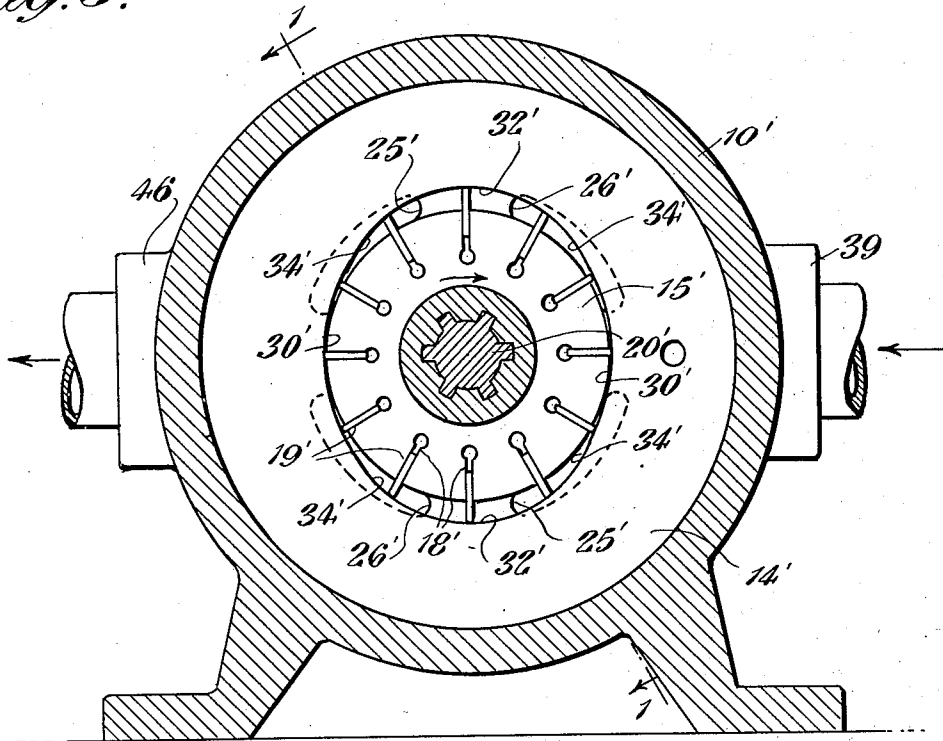


Fig. 4.

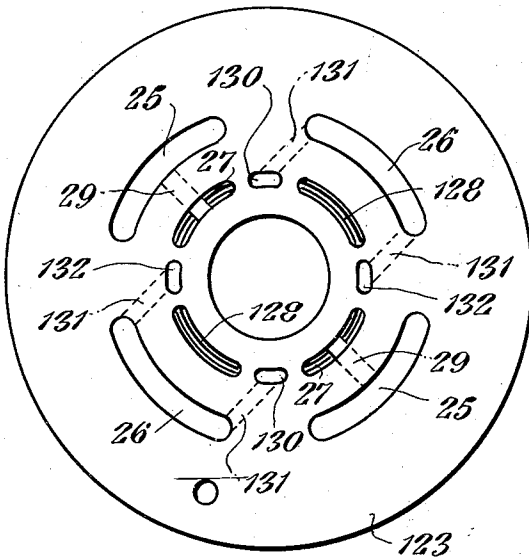
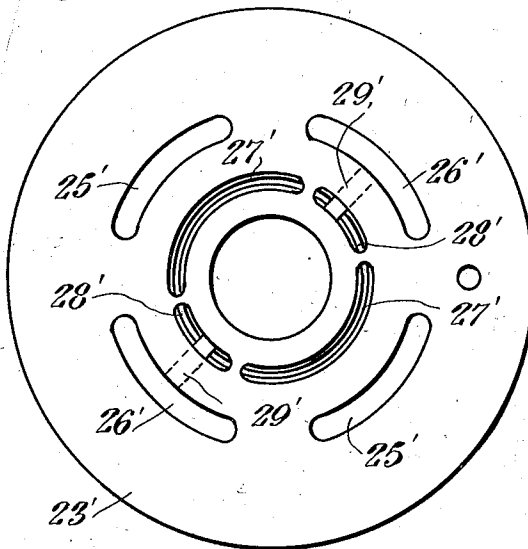


Fig. 3a.



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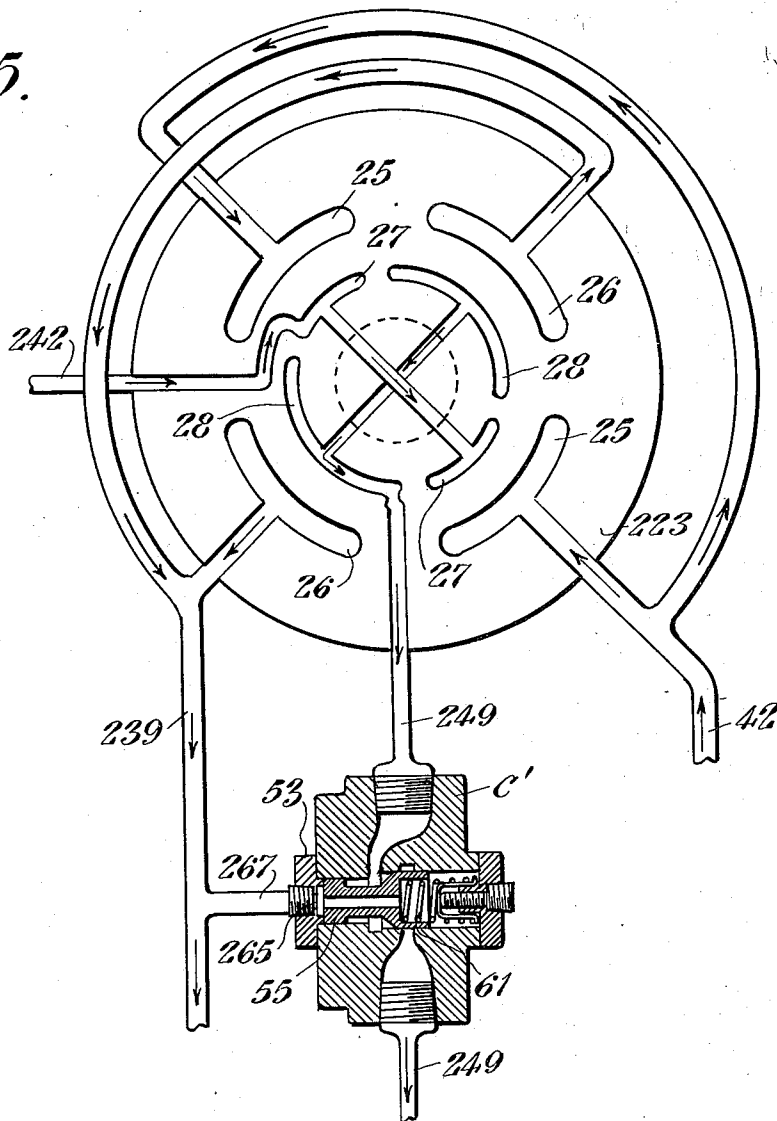
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Fig. 5.



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UNITED STATES PATENT OFFICE

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FLUID PRESSURE DEVICE

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Application February 12, 1941, Serial No. 378,524

15 Claims. (Cl. 103—136)

This invention relates to fluid pressure devices and more particularly to devices of this character employed as pumps capable of delivering two separate fluid volumes at the same or different pressures, although some features of the invention are likewise applicable to fluid pressure devices employed as fluid motors, as will be more particularly explained hereinafter. The present application is a continuation in part of co-pending application filed May 5, 1939, Serial No. 271,874.

Fluid pressure devices of the character under consideration find their widest present use as hydraulic pumps or motors, that is to say, as pumps for handling or motors whose motive fluid is a liquid, such, for example, as oil. The present invention will accordingly be described in connection with a pump for such use, although it will be understood that the invention is also applicable to pumps operating with elastic fluids and that some features of the invention are also applicable to fluid motors, as already stated.

One important use for a pump of the character under consideration is as the source of pressure fluid in a fluid power system in which it is necessary or desirable to employ operating pressure fluids having different but related pressures. This is the case, for example, when the fluid system includes a fluid motor of the vane type in which the vanes move inward and outward of the rotor in a substantially radial direction. In vane motors of this character it is often necessary to force the vanes radially outward during certain portions of their rotary travel, particularly at starting and when the motor is operating at low rotative speeds, so that the outer ends of the vanes will be held firmly in contact with the surrounding vane track and thus provide a movable resistance to the pressure fluid admitted to the pressure areas at the outer ends of the vanes of the fluid motor, whereby rotary motion is imparted to the rotor and the driven shaft of the vane motor. A highly practical and satisfactory method for forcing the vanes of the motor radially outward against the vane track is by introducing or admitting, behind the inner ends of the vanes, pressure fluid having a pressure greater than but related to the pressure of the fluid admitted to the pressure areas at the outer ends of said vanes, as fully explained in my co-pending application filed March 28, 1938, Serial Number 198,449. Thus fluid under two different but related operating pressures is used; the fluid having the higher of these two pressures, which for con-

venience is termed the "differential high pressure fluid," is admitted to the radially inner ends of the vanes, while fluid under the lesser of these two pressures is admitted to the pressure areas at the outer ends of the vanes of the vane motor.

An object of the present invention is to provide a simple and improved fluid pressure device of the character indicated.

Another object is to provide a pump capable of delivering two fluid volumes at different pressures for use, for example, in the above-mentioned fluid power system or for any other suitable purpose.

Another object is to provide a pump of this character in which both of the two fluid volumes may be simultaneously and conformably varied.

A further object is to provide a pump of this character capable of delivering two fluid volumes of the same or different circulated fluids at the same or different pressures.

A still further and more specific object is to provide a simple, rotary vane type pump of this character.

Other and more specific objects will appear from the description which follows.

The invention will be understood from consideration of the accompanying drawings which illustrate, by way of example, embodiments of the present invention.

In the drawings:

Fig. 1 is a view, partly diagrammatic and partly in section, showing a rotary piston element pump according to the present invention which serves as a source of pressure fluid in a fluid power system that includes a vane type fluid motor; Fig. 1 includes a longitudinal view of the pump taken along the line 1—1 of Fig. 2 and also includes a corresponding longitudinal sectional view of the vane type motor taken along the line 1—1 of Fig. 3;

Fig. 2 is a view of the pump unit, in vertical transverse section, taken along the line 2—2 of Fig. 1;

Fig. 2a is a view of one of the end plate elements of the pump unit showing the face thereof adjacent the rotor;

Fig. 2b is a view of the other of the end plate elements of the pump unit, showing the face thereof adjacent the rotor;

Fig. 3 is a view of the vane type motor unit, in vertical transverse section, taken along the line 3—3 of Fig. 1;

Fig. 3a is a view of one of the end plate ele-

ments of the motor unit showing the face thereof adjacent the rotor;

Fig. 4 is a view of a modified end plate element for the pump unit, also showing the face thereof adjacent the rotor;

Fig. 5 is a diagrammatic view, partly in section, showing a modification.

Figs. 1, 2, 2a, 2b, 3 and 3a are also shown in co-pending application filed May 5, 1939, Serial Number 271,874, in which certain parts of the subject matter thereof are claimed.

Referring now to these drawings, in Figs. 1 to 3a inclusive I have illustrated the present invention as embodied in a rotary piston element pump, here shown as a vane type pump A forming part of a fluid power system which includes a vane type fluid motor B. The pump A and the motor B may both be of fixed "stroke" or capacity per revolution or both of them may be of variable stroke, or one may be of variable stroke and the other of fixed stroke. In the embodiment illustrated in the drawings above mentioned I have shown the pump A as of variable stroke and the motor B as of fixed stroke, as will be hereinafter more fully explained.

In the particular embodiment of pump structure shown the pump casing is in two axially separate parts 10 and 11 (Fig. 1) which are suitably fastened together as by cap screws, not shown, and which cooperate to form a cavity for the rotor 15 and associated parts. The rotor 15 is rotatably supported by its hubs 16 which extend into bushings 17 carried by the casing parts 10 and 11 respectively and said rotor also has a slidable splined connection with the driving shaft 20 (Figs. 1 and 2) which passes through the bore of said rotor and is revolvably supported by a pair of bearings 21. A pair of mating end plates 23 and 24 are disposed on opposite sides of the rotor and between the spacer ring 14 and the casing parts, the arrangement being such that the rotor turns freely while its sides and the sides of the vanes 19 form substantially fluid-tight running fits with the adjacent faces of said end plates. The end plates 23 and 24 are provided with holes at their centers through which pass the rotor hubs 16, and are also provided with ports and fluid passages to be later described.

As best shown in Fig. 2 the pump A is a rotary piston multi-section or part pump consisting of two pumping sections or halves which are separated from each other by fixed abutments 30 and which discharge into a common discharge channel 45, to be presently described. The rotor 15 is provided with a multiplicity of vane slots 18 in each of which is a vane 19 adapted to move radially inward and outward therein as the rotor revolves. The radially outward ends of the vane 19 follow a trackway that controls their inward and outward movement and which comprises the two fixed abutments 30, two movable abutments 31 and connecting flexible track elements 34. The track surfaces on the inner ends of the fixed abutments 30 are preferably spaced a slight amount from the periphery of the rotor to provide a clearance therebetween which forms a "sealing chamber" that separates the high and low pressure areas on the opposite circumferential sides thereof, with separation being effected by the rotor and vanes in cooperation with the track surfaces on the fixed abutments 30. The movable abutments are slidably supported in slideways 33 formed in the spacer ring 14 on the interior of the casing and are

adapted to be radially adjusted with respect to the circumferential rotor surface. The work of pumping by the exposed outer ends of the vane 19 is done as the vanes move across an arc 32 on each movable abutment, termed the "working" or "pumping" arc, the fluid being received at one end of this arc and discharged at the other. Regulation of the "stroke" or volumetric capacity per revolution of the pump is effected by moving or radially adjusting the movable abutments 31 to vary the distance separating the pumping arcs 32 from the circumferential rotor surface; the flexible track elements 34 have extensible connections with the fixed abutments 30 thereby permitting adjustment of the movable abutments 31 without change of position of said fixed abutments 30.

The movable abutments 31 are adapted to be moved by means of a pair of adjusting rods 35 which are attached thereto as by the pivot pins 36. The adjusting rods extend through suitable holes in the spacer ring 14 and in the side covers 12 which close the horizontal adjusting rod bores formed in the casing part 10. Movement or adjustment of the adjusting rods 35 and movable abutments 31 may be effected by any suitable means, not shown, which may be conveniently connected with the links 37 on the outer ends of the adjusting rods. It will be understood that the volume of fluid pumped by the outer ends of the vanes of each pumping section is dependent upon the distance between the circumferential surface of the rotor 15 and the pumping arc 32 of the corresponding movable abutment 31 so that the output of each half of the pumping section may be infinitely varied at will. It will also be understood that the total volume of fluid pumped by the outer ends of the vanes comprises the combined volumes pumped thereby as the vanes pass across the pumping arcs of the two pumping sections. The particular structure of the rotor 15, vanes 19, fixed abutments 30, movable abutments 31, interconnecting track elements 34, etc., form no part of the present application but a part of my co-pending application, original filed December 24, 1938, Serial Number 247,586.

As already stated, fluid is admitted to the pumping chambers or pumping arcs at the sides of the vanes as they approach each pumping arc and fluid is discharged from the pumping chamber in like manner as the vanes recede therefrom. In the embodiment of Figs. 1 and 2, all admission and discharge to and from the outer ends of the vanes 19 is accomplished through ports in the end plate 23, these ports comprising a pair of diametrically opposite arcuate inlet ports 25 and a similar pair of outlet ports 26 as shown in Fig. 2a. The outlet ports 26 of the end plate 23 are also shown in the sectional view of Fig. 1. The end plate 24 (Fig. 2b) is likewise provided with similar ports 25 and 26 (here shown in Figs. 1 and 2b as recessed and not extending through the end plate 24) which serve principally as "balance ports" to contain fluid under the same pressure as that in the corresponding ports in the end plate 23 in order to substantially balance the hydraulic forces acting on the sides or axial ends of the vanes to prevent binding thereof.

Each outlet port 26 of the end plate 23 registers with a similar port formed in the side walls of the casing member 10 which is connected by a slanted passage 38 with the outlet conduit 45 as shown in Fig. 1. The outlet conduit 45 is

suitably connected, as indicated by the dotted lines at 40 in Fig. 1, with a passage 39 leading to the vane motor B. The inlet ports 25 of the end plate 23 are similarly connected with the inlet conduit 43 or they may be connected therewith in any other suitable manner, and the conduit 43 is connected with the fluid supply pipe 42, as indicated by the dotted lines at 41 in Fig. 1, which may be connected with a suitable reservoir, not shown.

When the rotor 15 revolves in a counter-clockwise direction, as viewed in Fig. 2, fluid enters through the inlet ports 25 of the end plate 23 and passes between the outer ends of those vanes 19 that are in the inlet area of each of the two pumping sections of the pump. Pumping is accomplished by the rotary motion of the outer ends of the vanes 19 as they sweep across the pumping arcs 32, said vanes 19 thus forcing fluid into the outlet area of each of the two pumping sections from which it passes out through the outlet ports 26 of the end plate 23 and into the discharge channel 45. As already stated, the size of the pumping chambers and the volume of fluid delivered by the pump are determined by the distance of the pumping arcs 32 from the rotor 15; as this distance may be varied in infinitely small increments from minimum to maximum, the size of the pumping chambers, and hence the volume of fluid pumped by the outer ends of the vanes, may likewise be varied from minimum to maximum.

The structure of the motor B (Fig. 1) is identical with that as already described in connection with the pump A except in certain parts to be presently explained. For convenience in distinguishing between pump and motor parts in the explanation which follows, the parts of the motor which are identical with those of the pump have been designated by the same reference numeral by adding "prime" ('), as for example the rotor of the pump A is designated by the reference numeral 15 and the rotor of the motor B by the reference numeral 15', etc.

The motor B, as here illustrated, is also a rotary piston multi-section or part device as best shown in Fig. 3, but as already stated is of fixed stroke or capacity per revolution. It is accordingly provided with a non-adjustable vane track comprising a vane track ring 14' having an interior vane-contacting track or surface. The vane track surface may be given any suitable contour but is preferably provided with concentric arcs 30' at its regions of least diameter and concentric working arcs or chambers 32' at its regions of greatest diameter, the arcs 30' and 32' being joined by intermediate connecting portions 34' of any suitable curvature producing satisfactory rates of inward and outward movement of the vanes 19' as the rotor 15' revolves.

Pressure fluid is admitted to the exposed outer ends of the vanes 19' as they approach the working arcs 32' and acts against the exposed outer ends of said vanes as they move across said working arcs, thus imparting rotary motion to the rotor 15' and the driven shaft 20'. Fluid is discharged from the outer ends of the vanes 19' as they recede from the working arcs 32'. All admission and exhaust to and from the outer ends of the vanes 19' is accomplished through inlet and outlet ports in the end plate 23' identical in arrangement with the already described ports of the pump's end plate 23 as will be evident from Fig. 3a, but it will be noted that the ports 25' of the motor B are the high pressure

ports and that the discharge ports 26' are its low pressure ports whereas the reverse relative pressure condition exists in the inlet ports 25 and outlet ports 26 of the pump A.

The inlet ports 25' in the end plate 23' of the motor B are connected with the motor's inlet channel 43' by means of registering ports in the side walls of the casing member 10' and slanted passages 38', as plainly shown in Fig. 1 wherein a sectional view through the ports 25' is illustrated. The inlet channel 43' of the motor B is connected with the passage 39 leading from the pump A as indicated by the dotted lines 40' of Fig. 1. The discharge ports 26' of the end plate 23' are connected in a similar manner, not shown, with the discharge channel 45' which in turn is connected with the return passage 46, as indicated by the dotted lines at 41', which leads to the reservoir, not shown. In this connection it may be pointed out that the fluid passages between the outlet channels of the motor B and the corresponding ports 26' in the end plate 23' are identical with the corresponding outlet passages of the pump A; the sectional view of the motor B is taken through its inlet areas whereas the sectional view of the pump A is taken through its outlet areas so that the exact arrangement of all ports and passages may be readily understood therefrom, although it will be understood that these exact arrangements are not necessary and may be varied if desired. The end plate 24' is also provided with recessed inlet ports 25' and outlet ports 26', similar to the ports in the pump end plate 24; these ports in the end plate 24' serve principally as "balance ports," as all fluid is admitted to and exhausted from the outer ends of the vanes 19' through the ports of the end plate 23' as already stated. The particular structure of the vane track ring 14', rotor 15' and plates 23' and 24', etc., forms no part of the present application but a part of application Serial Number 198,449, filed March 28, 1938, and it will be understood that any other suitable structure may be employed.

With the parts of the motor B in the position illustrated in Fig. 3 and with the pump A in operation and adjusted so that fluid is being pumped by the outer ends of its vanes 19, pressure fluid from the pump A will enter the inlet ports 25' of the motor B and rotate the rotor 15' and driven shaft 20' in a clockwise direction as viewed in Fig. 3. The speed of rotation of the rotor 15' of the motor B is determined by the volume of fluid admitted to the outer ends of its vanes 19' which in turn is determined by the volume of fluid delivered thereto by the pump A; the speed of rotation of the rotor 15' of the motor B may thus be infinitely varied from minimum to maximum by corresponding variation in the output of the pump A. In order for operation to take place however, it is necessary that the vanes 19' be firmly in contact with the vane track surface at the working arcs 32' and that there be similar contact between the ends of the vanes 19' and the vane track at the arcs 30' to thereby separate the two fluid sections of the motor B. This contact between the vanes 19' and the vane track is accomplished by introducing behind the radially inner ends of said vanes 19' fluid having a pressure greater than but correlated with the pressure of the fluid admitted to the inlet ports 25'. The means by which this higher pressure fluid (for convenience hereafter termed "differential high pressure

fluid") is produced and its pressure regulated and by which it is supplied to the inner ends of the vanes 19' of the motor B are important features of the present invention and will now be described.

Referring now to Fig. 2a, the pump end plates 23 and 24 are each formed with two pairs of arcuate recesses or grooves 27 and 28 in the faces thereof adjacent the rotor 15. These recesses 27 and 28 are positioned to register successively with the inner ends of the vane slots 18 as the rotor 15 revolves and they act as ports or passages for fluid to and from said vane slots 18 and hence are termed "vane slot ports."

The vane slot ports 27 are connected with the inlet ports 25 by radial passages or grooves 29 on the outer faces of the end plates 23 and 24 and the length of said vane slot ports 27 is such that the inner ends of each vane slot 18 connects therewith during the time that the outer end of its corresponding vane 19 is moving across the flexible interconnecting track element 34 that lies in each of the inlet areas of the pump A; the inner end of each vane slot 18 is thus connected with the fluid inlet supply during the time that its corresponding vane 19 is moving through the inlet areas of the pump A and is approaching the pumping arcs 32. The inner end of each vane slot 18 is thus filled with fluid as its corresponding vane 19 moves radially outward under the action of centrifugal force while said vane 19 is passing from each fixed abutment 30 toward the contiguous pumping arc 32.

Fluid entering the inner ends of the vane slots 18 through the vane slot ports 27 as explained above is discharged into the vane slot ports 28 as the outer end of each vane 19 moves inward during the time it is passing from the pumping arc 32 of each pumping section through the corresponding outlet area of the pump and on to the contiguous fixed abutment 30. This will be understood by referring to Fig. 2 in which it will be observed that the vanes 19 occupy the extreme radially outward position when their outer ends are in contact with the pumping arcs 32; it will also be observed that said vanes 19 are moved progressively inward as said vanes traverse the interconnecting track element 34 intermediate said pumping arc 32 and the contiguous fixed abutment 30; and it will further be observed that the vanes 19 occupy the extreme radially inward position when their outer ends are in contact with the fixed abutments 30. It will thus be seen that each vane 19 functions as a piston reciprocating in its vane slot 18, the inner end of which serves as a cylinder therefor, and it will also be seen that each vane 19 is reciprocated twice for each revolution of the rotor 15. It will further be seen that admission of fluid to the inner ends of the vane slots 18 takes place simultaneously with admission of fluid to the outer end of the corresponding vanes 19 and that fluid is likewise discharged from both the inner and the outer ends of the vanes as said vanes recede from the pumping arcs 32 and approach the fixed abutments 30. The vane slot ports 28 in this embodiment are made of such length that they also connect with the inner ends of those vane slots 18 whose vanes 19 are in contact with the pumping arcs 32 and the fixed abutments 30 so that fluid pressure is applied to the inner ends of such vanes to assist in holding their outer ends firmly in contact with the vane track surfaces as said vanes move across the fixed and movable abutments.

The volume of fluid pumped by the inner ends of the vanes 19, per revolution of the rotor 15, for any particular rotor and vane assembly is dependent upon and varies conformably with the stroke of the vanes which, as already explained, is determined by the distance between the pumping arcs 32 and the circumferential rotor surface and may be infinitely varied at will. The volume of fluid pumped by the inner ends of the vanes may thus be infinitely varied from minimum to maximum and variation in the volume pumped by the inner ends of the vanes is effected simultaneously and conformably with variation in the fluid volume pumped by the outer ends of said vanes as they move across the pumping arcs.

Fluid pumped by the inner ends of the vanes 19 of the pump A is utilized to provide the differential high pressure fluid to force the vanes 19' of the motor B radially outward against the vane track. The vane slot ports 28 of the pump A are accordingly connected in any suitable manner with the vane slot ports 27' of the motor's end plate 24'. In the present instance the fluid passages providing this interconnection include a hole 22 in each of the vane slot ports 28 in the pump's end plate 24 and said hole 22 registers with a passage 47 leading to a channel 48 formed in the pump casing member 11. The channel 48 is connected as by a pipe 49 with a corresponding channel 48' in the motor casing member 11' and said channel 48' is connected through a passage 47' by a hole 22' with each vane slot port 27' in the motor's end plate 24'.

At this point it should be noted that the end plates 23' and 24' of the motor B are provided with vane slot ports 27' and 28' corresponding generally to the already described vane slot ports of the pump's end plates. The vane slot ports of the motor's end plates 23' and 24' differ from those of the pump's end plates, however, in that the vane slot ports 27' (which in this instance are its high pressure vane slot ports) are not only co-extensive with the inlet ports 25' but in this embodiment are of such length that each vane slot 18' connects therewith during the time that the vane 19' therein is traversing the arc 30' and the working arc 32' of each fluid section as well as while traversing the intermediate portion 34' of the track that lies in the inlet area of each fluid section of the motor B. Fluid entering the inner ends of the vane slots 18' of the rotor 15' is discharged into the vane slot ports 28' which are connected with the outlet ports 26' of the end plates 23' and 24' by radial passages 29' on the outer faces thereof.

In order to assure that the vanes 19' of the motor B are forced radially outward against the vane track it is necessary that the volume of fluid pumped by the inner ends of the vanes 19 of the pump A be equal to or greater than the actual fluid volume required to produce such radially outward movement of the vanes 19' of the motor B. That is to say, the volume of the fluid pumped per revolution of the rotor 15 of the pump A by the inner ends of its vanes 19, at any stroke or capacity of the pump A, must have a relation to the corresponding volume of the fluid pumped by the outer ends of said vanes 19 that is equal to or greater than the relation of the fluid volume required for the inner ends of the motor's vanes 19' per revolution of its rotor 15' with respect to the fluid volume that must be admitted to the outer ends of the motor's vanes 19' in order to produce one revolution of the ro-

tor 15'. This relation will vary with particular embodiments and is due in part, for instance, to the porting provided for the inner end of the vane slots 18' of the motor B.

With the arrangement illustrated in Figs. 1, 2, 2a, 2b, 3 and 3a, the flow of fluid with respect to the inner ends of the vanes of the pump and motor is as follows: Upon rotation of the pump rotor 15 in a counter-clockwise direction, fluid will flow from the supply pipe 42 into the inlet conduit 43, and to the inlet ports 25 of the pump's end plate 23, and will fill the spaces between the outer ends of the vanes 19 as they pass through the pump's inlet areas. Fluid also passes from the ports 25 of both end plates 23 and 24, through the radial passages 29 on the outer faces of said end plates, to the vane slot ports 27 of both end plates and into the inner ends of the vane slots 18. As the vanes 19 are moved inwardly while passing across the interconnecting track elements 34 in the outlet areas of the pump, fluid is pumped by the inner ends of said vanes 19 into the vane slot ports 28 of the end plate 24, through the holes or ports 22 in said end plate 24, into the passages 47, the channel 48, the pipe 49 and into the channel 48' of the motor B; thence through the passages 47', holes or ports 22' of the end plate 24', vane slot ports 27' of the end plate 24' and thence below the inner ends of the vanes 19' to force them outwardly and into contact with the vane track as the rotor 15' of the motor B turns in a clockwise direction. After passing the working arcs 32', the vanes 19' are forced inwardly as they pass across the cam surface of the vane track's intermediate connecting portions 34' that are positioned in the motor's outlet areas and fluid is discharged by the inner ends of the vanes 19', this fluid passing out through the vane slot ports 28' of both of the end plates 23' and 24', through the radial passages 29' on the outer faces of said end plates and into the outlet ports 26' of both of the end plates 23' and 24'; fluid passing out through the ports 26' of the end plate 24' passes across the rotor through the spaces between the outer ends of the vanes 19', into the ports 26' of the end plate 23', thence, together with the fluid discharged by the outer ends of the vanes and the fluid that is discharged by the inner ends of the vanes 19' through the ports 26' of the end plate 24', into the discharge channel 45' and finally into the return passage or pipe 46.

Theoretically it is merely necessary that the inner ends of the pump's vanes 19 supply precisely the volume of fluid required by the inner ends of the motor's vanes 19' but in commercial practice this is difficult if not impossible of attainment because of variation in leakage, fits of the parts, etc., which will occur as between individual pumps and motors even though made to the same dimensions and close tolerances. In practice therefore it is necessary that the inner ends of the pump's vanes supply fluid in excess of the volume actually required by the inner ends of the motor's vanes 19'. This may be accomplished in numerous ways, such, for example, as by making the vanes 19 of the pump A thicker than the vanes 19' of the motor B so that the inner end of each pump vane has an area greater than that of each motor vane 19'. In the present embodiment however this is accomplished by the simple method of providing the pump's rotor 15 with a greater number of vanes than are provided in the motor's rotor 15'; this is clearly

shown in Figs. 2 and 3 in which it will be observed that the pump's rotor 15 is provided with sixteen vanes whereas the motor's rotor 15' is provided with twelve vanes.

It is also necessary to provide a path of escape for the excess fluid pumped by the inner ends of the pump's vanes 19 and not required by the inner ends of the motor's vanes 19'. Moreover, it is necessary that the pressure of the fluid admitted to the inner ends of the vanes 19', to force them radially outward against the vane track, be greater than but correlated with the pressure of the fluid admitted to the ports 25'. The means by which both these requirements are met will now be described.

Referring to Fig. 1, the passage 49 is connected with a passage 66 leading to the fluid inlet port of a "differential relief" or "pressure reducing" valve C. The outlet port of the valve C is connected to a passage 67 leading to the passage 39. The function of the valve C is to regulate the flow of fluid (i. e., the excess fluid not required by the motor's vanes 19') from the passage 49 to the passage 39 in such manner that the pressure of the fluid in the passage 49 exceeds by a substantially constant, predetermined amount the pressure of the fluid in the passage 39 in order to provide "differential high pressure" relation to the fluid supplied to the inner ends of the motor's vanes 15' with respect to the pressure of the fluid supplied to the outer ends thereof. The valve C may accordingly assume any suitable form of "differential pressure", resistance, "relief" or "pressure reducing" valve capable of accomplishing this function. The particular structure of the valve C illustrated in Fig. 1 has been found to function reliably and satisfactorily in practice and will now be described.

The valve C includes a housing 50 provided with a valve bore in which a valve piston 55 is slidably fitted. The valve piston 55 is formed with two heads of unequal diameter, the diameter of the head 56 exceeding the diameter of the head 57, and the valve bore is similarly formed with two unequal diameters in order to provide sliding fits with said heads. The heads 56 and 57 are separated by a "neck" or reduced portion 58 having a tapered end 59 adjacent the head 56, and the neck 58 and its tapered end 59 are of such length that one or the other of them is in communication with the valve's inlet port 51 in all positions of adjustment of the valve piston 55.

The valve piston 55 is urged toward its fully closed position, in which it is shown in Fig. 1, by a spring 61, one end of which is received within a recess in the adjacent end of the valve piston 55 and the other end of which bears against a somewhat "hat-shaped" abutment piece 62. The abutment piece 62 also bears against a screw 63 carried by the cover 54 and said screw 63 provides means by which the compression of the spring 61 may be adjusted; in the present instance the screw 63 is of the headless type and a pipe plug 64 closes the outer end of the enlarged opening provided for use in adjusting said screw's position.

Both ends of the valve piston 55 are adapted to be acted upon by fluid having the same pressure as that in the valve's outlet port 52. The outlet port 52 is accordingly connected with the passage 65 which connects with the end of the valve bore containing the spring 61 at a point which will not be covered by the head 56 when the valve piston 55 is in its maximum open posi-

tion. A hole or passage 60 extends axially through the valve piston 55 so that both ends of the valve bore will contain fluid under the same pressure as that in the valve's outlet port 52.

With this arrangement it will be seen that the valve piston 55 is urged toward its fully open position (or toward the right as viewed in Fig. 1) by a fluid-exerted force determined by the pressure of the fluid in the inlet port 51 and equal in amount to the force produced by the action of this pressure fluid upon a surface area equal to the difference in the areas of the two heads 56 and 57. Similarly the valve piston 55 is urged toward its fully closed position (or toward the left as viewed in Fig. 1) by fluid-exerted force determined by the pressure of the fluid in the inlet port 52 and equal in amount to the action of this pressure fluid upon an area equal to the difference in areas of the heads 56 and 57, and this fluid-exerted force is supplemented by the force of the spring 61 acting in the same direction.

The valve piston 55 is accordingly moved by one or the other of these opposing forces whenever they are unbalanced and will be so moved until these opposing forces are made equal to each other by change in the relative pressures in the inlet port 51 and outlet port 52 produced by movement of the valve piston 55. In this manner the valve piston 55 moves to regulate the flow of fluid from the passage 49 to the passage 39 to provide pressure in the passage 49 that exceeds the pressure in the passage 39 by an amount determined by the force exerted by the spring 61. This relative difference in pressures is maintained irrespective of absolute pressures; that is to say, irrespective of the actual amounts of the pressures existing in the inlet port 51 and outlet port 52 respectively and, within the limits of the "rate" of the spring 61, is likewise maintained substantially constant irrespective of the volume of fluid passing through the valve C. The valve piston 55 is immediately moved to its fully closed position, as shown in Fig. 1, by the spring 61 whenever the difference in pressures is less than the amount determined by said spring and in the fully closed position the head 57 completely closes the outlet port 52 thus cutting off all fluid communication between the valve's inlet port 51 and outlet port 52.

The cover 53 is provided with a narrow flange 68 which projects into the valve bore and acts as a stop for the valve piston 55 so that substantially all of the adjacent end of the valve piston is continuously exposed to pressure fluid even when the valve is in its closed position.

The valve C thus functions to regulate the flow of excess fluid pumped by the inner ends of the pump's vanes 19 so that differential high pressure relationship is at all times maintained between the pressure of the fluid supplied to the inner and outer ends of the motor vanes 19'; that is to say, the pressure of the fluid supplied to the inner ends of the vanes 19' at all times exceeds by a substantially constant, predetermined amount the pressure of the fluid supplied to the outer ends thereof. The amount of this pressure difference may be adjusted as required by means of the screw 61 and is preferably kept at the lowest value producing satisfactory operation of the vanes 19' of the motor B. In practice it has been found that pressure differential of from ten to thirty five or forty pounds per sq. in. is usually sufficient although differential pressures up to and including seventy-five pounds

per sq. in. have been successfully employed in systems of this general character.

The present invention has numerous advantages. For example, the vane type pump supplies fluid at two different pressures, thus making it unnecessary to pass the entire output of the pump through a pressure reducing or differential pressure valve, thus increasing the efficiency of the transmission. Moreover, when a variable capacity vane pump is employed, as in the present instance, the volume of fluid delivered at each of the two relative pressures is varied in corresponding or substantially proportional amounts so that any change in one will produce a corresponding change in the other, thereby assuring an ample supply of fluid at each of these two different pressures and at the same time avoiding any material excess in the volume needed at any time. In this connection it should be noted that the volume of fluid required by the inner ends of the motor vanes 19' will always bear a proportional relationship to the volume of fluid required by the outer ends of said vanes 19', and these two volumes will change proportionately with change in rotative speed of the rotor 15'. For example, to use purely arbitrary figures in which leakage is neglected, let us assume that a fluid volume of 10 gals. per min. admitted to the outer ends of the vanes 19' causes the rotor 15' to revolve at 600 R. P. M. and that a fluid volume of 1 gal. per min. is then required by the inner ends of the vanes 19'; a fluid volume of 20 gals. per min. would have to be admitted to the outer ends of the motor vanes 19' to cause the rotor 15' to revolve at 1200 R. P. M. and a fluid volume of 2 gals. per min. would then be required by the inner ends of said vanes 19' at this speed. It will thus be seen that variation in the volume of fluid pumped by the outer ends of the pump vanes 19, in order to alter the speed of motor B, will simultaneously vary the fluid volume supplied to the inner ends of the motor vanes 19' in accordance with the requirements thereof at the changed speed of the motor.

The small differences in the pressures of the fluid pumped by the inner and the outer ends of the pump vanes 19, according to the present embodiment, does not adversely affect the operation of the pump A and is so small that it does not cause undue deflection or increase in wear of the flexible interconnecting track elements 34.

It is frequently convenient to utilize the differential high pressure at the inner ends of the vanes during the portion of their rotary movement in which the outer ends thereof are moving across the working arcs 32 and across the portions of the vane track on the fixed abutments 30 that separate the two fluid sections of the pump, as in the embodiment already described. While this arrangement gives satisfactory operation, it is not essential and pressure other than that of the differential high pressure fluid may be employed at the inner ends of the vanes during this part of their rotary movement. This will be understood, for example, from consideration of Fig. 4 which illustrates a modified form of end plate for the pump A.

The end plate 123 of Fig. 4 corresponds generally to the end-plate 23 of Fig. 2b but is modified to provide a pair of vane slot ports 128 which are arranged to connect with the inner ends of the vanes during only the time that the outer ends thereof are moving from the working arcs 32 toward the fixed abutments 30, that is to say, during only the portion of their rotary move-

ment in which they are moving radially inward. The rotor face of the end plate 123 is also formed with two pairs of recessed vane slot ports 130 and 132 respectively which are disposed intermediate the vane slot ports 27 and 128 and are adapted to connect with the inner ends of the vanes 19 during only the portion of their rotary movement in which the outer ends thereof are traversing respectively the arcs on the fixed abutments 30 which separate the two fluid sections of the pump and the working arcs 32. Each of the vane slot ports 130 and 132 is connected with one of the high pressure or discharge ports 26, as by passages 131 formed on the outer face of the end plate 123 as indicated by the dotted lines in Fig. 4. The end plate 123 of Fig. 4 is otherwise the same as the end plate 23 of Fig. 2a. The mating end plate for use with the modified end plate 123 is, of course, correspondingly modified, and fluid pumped by the inner ends of the vanes passes out through suitable openings in the vane slot ports 128 of said mating end plate, these openings corresponding to the openings 22 of the end plate 24 as shown in Fig. 2b.

With this arrangement, fluid from the discharge or high pressure ports 26 for the outer ends of the vanes is supplied to the inner ends of the vanes during the time that the outer ends thereof are moving across the working arcs 32 and the portions of the track surface on the fixed abutments 30 which separate the two fluid sections of the pump. The vanes 19 are thus held firmly in contact with the vane track during this portion of their rotary movement and the arrangement has the advantage of somewhat reducing the radially outward force active to urge the vanes into contact with the vane track at these points to separation between the high and low pressure areas of the pump with a consequent reduction in friction and wear.

The pump A may be modified in other ways. For example, it may be modified in accordance with the arrangement diagrammatically illustrated in Fig. 5 in which the circulated fluid pumped by the inner ends of the vanes 19 may be the same as or different from the circulated fluid pumped by the outer ends thereof and in which the pressure of the fluid pumped by the inner ends of said vanes 19 may be the same as or different from the pressure of the fluid pumped by their outer ends.

Referring now to Fig. 5, as schematically shown the fluid supply pipe 42 is connected with the two inlet ports 25 of the modified end plate 223. The pair of inlet vane slot ports 27 are suitably connected with a separate fluid supply pipe 242 which may take its supply from the same source as that of the supply pipe 42 or the two supply pipes 42 and 242 may each take its supply from a separate source, as when the circulated fluid to be pumped by the inner ends of the vanes 19 is to be different from the circulated fluid pumped by their outer ends. It will be observed that the recessed grooves 29 (which connect the vane slot ports 27 with the inlet ports 25 in Figs. 2a and 2b) are omitted in the modified end plate 223 of Fig. 5.

The two outlet ports 26 of the modified end plate 223 are appropriately connected with the discharge or high pressure passage 239 and the outlet or discharge vane slot ports 28 are likewise suitably connected with a separate outlet conduit 249. The pressure of the fluid pumped by the inner ends of the vanes 19 is regulated by a modified valve C' whose inlet and outlet

ports are both connected with the conduit 249. The valve C' is substantially the same as the already described valve C of Fig. 1, differing therefrom only in certain particulars which will now be explained. Referring to Figs. 1 and 5 for convenience in comparison, the passage 65 of the valve C of Fig. 1 is omitted in the valve C' of Fig. 5; the cover member 53 of the valve C' is provided with a passage 265 which is suitably connected with the discharge passage 239, as by a branch passage 267. With this modified arrangement both ends of the valve piston 55 of the valve C' are acted upon by fluid having the same pressure as that in the discharge passage 239. The valve C' of Fig. 5 functions in the same manner as the valve C of Fig. 1, so that with the arrangement illustrated in Fig. 5 the pressure of the fluid in the vane slot ports 28 and in the portion of the passage 249 intermediate said vane slot ports and the valve C' is kept at a value exceeding by a substantially constant amount (determined by the spring 61) the pressure of the fluid in the passage 239 and in the outlet ports 26.

The spring 61 is omitted in the modified valve C' when it is desired that the fluid in the vane slot ports 28 and in the portion of the passage 249 intermediate said vane slot ports and said valve C' be kept at the same pressure as that in the passage 239 and in the outlet ports 26. The valve piston 55 is then acted upon solely by the opposing hydraulic forces and is moved responsive to any difference in these forces in a direction to produce balance thereof, thus equalizing the pressure of the fluid passing to the valve C' from the vane slot ports 28 with the pressure of the fluid in the passage 239.

While described and explained in connection with a vane type pump, some features of the present invention are likewise applicable to fluid pressure devices employed as vane type fluid motors. For example, modified end plates of the character illustrated in Fig. 4 may be employed in vane type fluid motors, such, for example, as the motor B illustrated in Figs. 1 and 3. The term "fluid pressure device" as used in the appended claims is accordingly intended to include both pumps and fluid motors.

It is to be understood that the foregoing are merely exemplifying disclosures and that changes, some of which have been indicated, may be made in the apparatus without departing from the invention which is defined in the appended claims.

I claim:

1. A rotary vane pump having a rotor provided with a plurality of vane slots, vanes movable inward and outward in said slots in a substantially radial direction with respect to said rotor, the inner ends of said slots forming working chambers for the inner ends of said vanes as said vanes reciprocate therein, a casing including a pumping chamber for the outer ends of said vanes as said vanes rotate with said rotor, passages for the admission of fluid to the inner ends of said slots and to the outer ends of said vanes, and separate outlet passages for the discharge of fluid from the outer ends of said vanes and the inner ends of said slots respectively for utilizing separately the rotary and radial movements of the vanes to deliver two fluid volumes at least in part separately usable, including means responsive to difference in the fluid pressures of said two volumes for regulating the pressure of the fluid of one of said

volumes conformably with the pressure of the fluid of the other of said volumes.

2. A rotary vane pump having a rotor provided with a plurality of vane slots and vanes reciprocable therein, the inner ends of said slots forming working chambers for the inner ends of said vanes as said vanes reciprocate therein, a casing including a pumping chamber for the outer ends of said vanes as they rotate with said rotor, passages for the admission of fluid to the inner and outer ends of said vanes, separate outlet passages for the discharge of fluid from the outer ends of said vanes and the inner ends of said slots respectively whereby the inner and outer ends respectively of the vanes pump separate fluid volumes at least in part separately usable, and a fluid connection between said separate outlet passages including valve mechanism active to regulate the flow of fluid between said outlet passages to maintain the fluid in the outlet passage for the inner ends of said pump vanes at a pressure exceeding by a substantially constant amount the pressure of the fluid in the outlet passage for the outer ends of said pump vanes.

3. A rotary vane pump having a rotor provided with a plurality of vane slots and vanes reciprocable therein, the inner ends of said slots forming working chambers for the inner ends of said vanes as said vanes reciprocate therein, a casing including a pumping chamber for the outer ends of said vanes as they rotate with said rotor, passages for the admission of fluid to the inner and outer ends of said vanes, separate outlet passages for the discharge of fluid from the outer ends of said vanes and the inner ends of said slots respectively whereby the inner and outer ends respectively of the vanes deliver two, at least in part uncombined, fluid volumes, and a fluid connection between said separate outlet passages including valve mechanism active to regulate the flow of fluid between said outlet passages to maintain a substantially constant pressure differential between the pressure existing in one of said outlet passages with respect to the pressure existing in the other of said passages.

4. A variable capacity rotary vane pump having a rotor provided with a plurality of vane slots and vanes movable inward and outward in said slots in a substantially radial direction with respect to said rotor, the inner ends of said slots forming working chambers for the inner ends of said vanes as said vanes reciprocate therein, a casing including a pumping chamber for the outer ends of said vanes as said vanes rotate with said rotor, passages for admission of fluid to the inner ends of said slots to the outer ends of said vanes, separate outlet passages without free and constantly open fluid connection therebetween for the discharge of fluid from the outer ends of said vanes and the inner ends of said slots respectively, whereby the rotary and radial movements of the vanes are utilized separately to pump separate fluid volumes to pump two fluid volumes which are at least in part separately usable, means for simultaneously varying the volumes of fluid pumped by the inner ends and the outer ends of said vanes and means for maintaining the fluid pressure of one of said volumes equal to or greater than the fluid pressure of the other of said volumes.

5. A rotary vane pump having a rotor provided with a plurality of vane slots and vanes movable inward and outward in said slots in a substantially radial direction with respect to said rotor, the inner ends of said slots forming working

chambers for the inner ends of said vanes as said vanes reciprocate therein, a casing including a pumping chamber for the outer ends of said vanes as said vanes rotate with said rotor, means for admitting fluid to the inner ends of said slots and to the outer ends of said vanes, separate outlet passages without free and constantly open fluid connection therebetween for the discharge of fluid from the outer ends of said vanes and the inner ends of said slots respectively, and means for maintaining the pressure existing in one of said outlet passages at a value at least equal to the pressure existing in the other.

6. A rotary vane pump having a rotor provided with a plurality of vane slots and vanes movable inward and outward in said slots in a substantially radial direction with respect to said rotor, the inner ends of said slots forming working chambers for the inner ends of said vanes as said vanes reciprocate therein, a casing including a pumping chamber for the outer ends of said vanes as said vanes rotate with said rotor, a first port for admitting a fluid supply to the outer ends of said vanes, a second port for admitting a fluid supply to the inner ends of said slots and arranged to connect therewith while the outer ends of the vanes therein are moving in connection with said first named port, a third port for the discharge of fluid by the outer ends of said vanes, a fourth port for the discharge of fluid from the inner ends of said slots and arranged to connect with the inner ends of said slots while the outer ends of the vanes therein are moving in connection with said third named port, separate discharge passages for said third and fourth named ports arranged to provide two fluid volumes at least in part separately usable and means responsive to the fluid pressures existing in both of said discharge passages for regulating the pressure of the fluid in one of said discharge passages conformably with the fluid pressure existing in the other of said discharge passages.

7. In a rotary vane type fluid pressure device, a rotor having a plurality of vanes movable inwardly and outwardly thereof in slots formed therein, the inner ends of said slots comprising working chambers for the inner ends of said vanes as said vanes move inwardly and outwardly, a vane track for guiding the vanes in their in and out movement and provided adjacent the rotor with a chamber disposed between high and low pressure areas on the opposite circumferential sides thereof, the outer ends of said vanes being subject to the respective pressures in said chamber and in said areas while passing there-through, a low pressure port arranged to connect with the inner ends of said slots while the outer ends of the vanes therein are passing through the low pressure area, a high pressure port arranged to connect with the inner ends of said slots while the outer ends of the vanes therein are passing through said high pressure area, a third port disposed intermediate said high and low pressure ports and arranged to connect with the inner ends of the slots during only the time that the outer ends of the vanes therein are moving through said chamber, means for maintaining in said high pressure port a pressure greater than but correlated with the pressure in said high pressure area and means for maintaining in said third port a pressure substantially equal to the pressure in said high pressure area.

8. In a rotary vane type fluid pressure device, a rotor having a plurality of vanes movable inwardly and outwardly thereof in slots formed

therein, the inner ends of said slots comprising working chambers for the inner ends of said vanes as said vanes move inwardly and outwardly, a high pressure port and a low pressure port arranged to connect successively with the outer ends of the vanes as they rotate in unison with the rotor, a working chamber for the outer ends of said vanes disposed circumferentially intermediate said high and low pressure ports, and means for supplying fluid from said high pressure port to the inner ends of the slots during only the portion of their rotary movement in which the outer ends of the vanes therein are moving intermediate said high and low pressure ports, means for substantially equalizing the pressure in the inner ends of said slots with the pressure in said low pressure port during the time that the leading and trailing faces of the corresponding vanes are connected with said low pressure port and means for maintaining in the inner ends of said slots fluid pressure related to but greater than the pressure in said high pressure port during the time that the leading and trailing faces of the corresponding vanes are connected with said high pressure port.

9. In a rotary vane type pump, a rotor having a plurality of slots, vanes in said slots movable inwardly and outwardly in a substantially radial direction, the inner ends of said slots comprising working chambers for the inner ends of said vanes as said vanes move inwardly and outwardly, a pumping chamber for the outer ends of said vanes, separate passages for the admission of fluid to the outer ends of said vanes and the inner ends of the slots respectively, separate passages without free and constantly open fluid connection therebetween for the discharge of fluid from the outer ends of said vanes and the inner ends of said slots respectively, whereby the rotary and radial movements of the vanes are utilized separately to supply separate volumes of pressure fluid that are at least in part separately usable and means for maintaining the fluid pressure of one of said volumes equal to or greater than the fluid pressure of the other of said volumes.

10. The combination of a rotary piston-carrying element having radially movable pistons, separate pumping chambers for the outer and inner ends respectively of said pistons, means for causing the inner and outer ends of said pistons to pump separate fluid volumes without free and constantly open fluid connection therebetween and means responsive to the fluid pressures of both of said volumes for regulating the pressure of the fluid of one of said volumes conformably with the pressure of the fluid of the other of said volumes.

11. The combination of a rotary piston-carrying element having pistons rotatable therewith and reciprocable with respect thereto, means utilizing separately the rotary and reciprocating movements respectively of the pistons to pump two fluid volumes without free and constantly open fluid connection therebetween and valve means responsive to the fluid pressures of both of said volumes for regulating the pressure of the fluid of one of said volumes conformably with the pressure of the fluid of the other of said volumes.

12. In a rotary vane type fluid pressure device, a rotor having a plurality of slots, vanes in said

slots movable inward and outward with respect to said rotor, said slots comprising working chambers for said vanes as said vanes move inwardly and outwardly, a working chamber for said vanes as said vanes rotate with said rotor, means utilizing separately the rotary and the inward-and-outward movements respectively of the vanes for the circulation of two separate uncombined fluid volumes without fluid connection therebetween and means responsive to the fluid pressures of both of said volumes for maintaining the fluid pressure of one of said volumes equal to or greater than the fluid pressure of the other of said volumes.

13. In a rotary vane type pump, a rotor having a plurality of slots, vanes in said slots movable inward and outward with respect to said rotor, said slots comprising working chambers for said vanes as said vanes move inwardly and outwardly, a working chamber for said vanes as said vanes rotate with said rotor, means utilizing separately the rotary and the inward-and-outward movements respectively of the vanes to pump two fluid volumes that are at least in part separately usable and means responsive to difference in fluid pressures of said volumes and active to maintain the fluid pressure of one of said volumes equal to or greater than the fluid pressure of the other of said volumes.

14. In a rotary vane type pump, a rotor having a plurality of slots, vanes in said slots movable inwardly and outwardly with respect to the rotor, the inner ends of said slots forming working chambers for the inner ends of said vanes as said vanes move inwardly and outwardly, a casing including a working chamber for the outer ends of said vanes, means for admitting fluid to the inner ends of said slots and to the outer ends of said vanes, separate outlet circuits without fluid connection therebetween for said chamber and for the inner ends of said slots respectively, whereby the outer and inner ends respectively of said vanes pump two wholly separate uncombined fluid volumes, and means responsive to the pressures of both of said volumes for maintaining the fluid pressure of one of said volumes equal to or greater than the fluid pressure of the other of said volumes.

15. In a variable capacity rotary vane type pump, a rotor having a plurality of slots, vanes in said slots movable inwardly and outwardly with respect to the rotor, the inner ends of said slots forming working chambers for the inner ends of said vanes as said vanes move inwardly and outwardly, a casing including a working chamber for the outer ends of said vanes, means for admitting fluid to the inner ends of said slots and to the outer ends of said vanes, separate outlet circuits without fluid connection therebetween for said chamber and for the inner ends of said slots respectively, whereby the outer and inner ends respectively of said vanes pump two wholly separate uncombined fluid volumes, means for simultaneously varying the two fluid volumes pumped by the outer and the inner ends respectively of said vanes, and means responsive to the pressures of both of said volumes for maintaining the fluid pressure of one of said volumes equal to or greater than the fluid pressure of the other of said volumes.

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