Jan. 2, 1951 F. BERRY 2,536,486

FLUID POWER DEVICE

Filed April 27, 1945 4 Sheets-Sheet 1

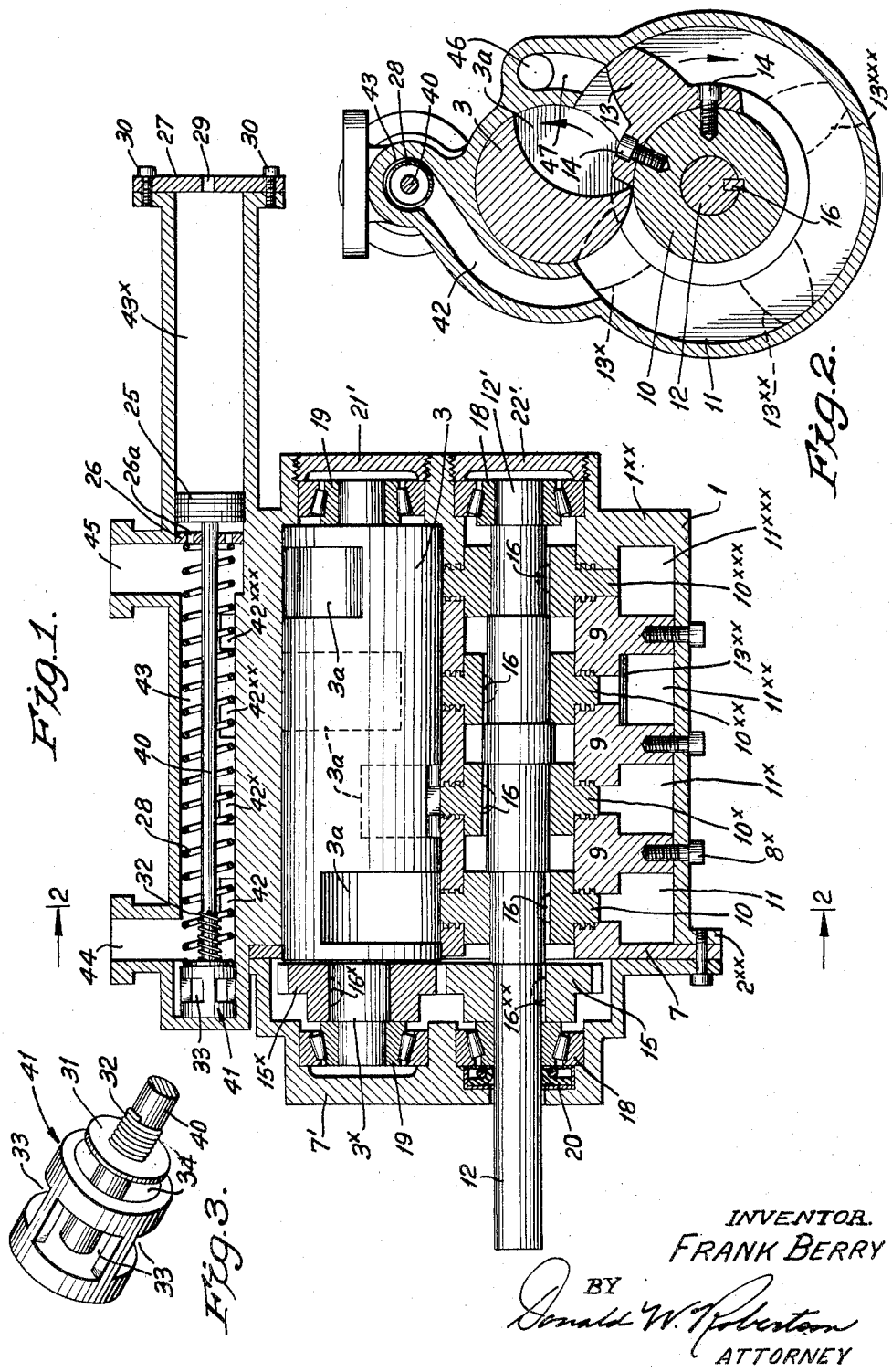


Fig. 1.

Fig. 2.

Fig. 3.

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Jan. 2, 1951 F. BERRY 2,536,486

FLUID POWER DEVICE

Filed April 27, 1945 4 Sheets-Sheet 2

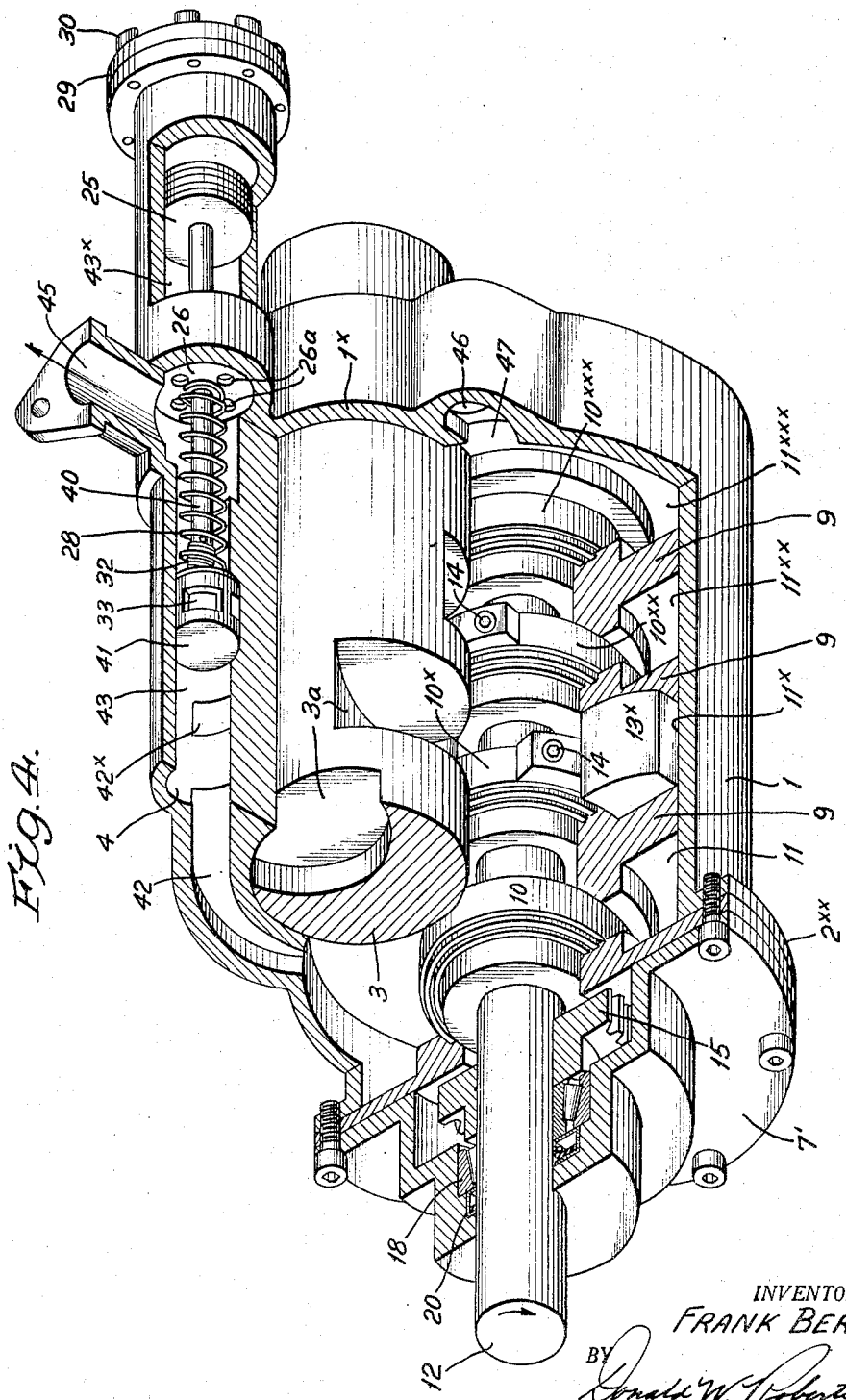


Fig. 4.

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Jan. 2, 1951 F. BERRY 2,536,486

FLUID POWER DEVICE

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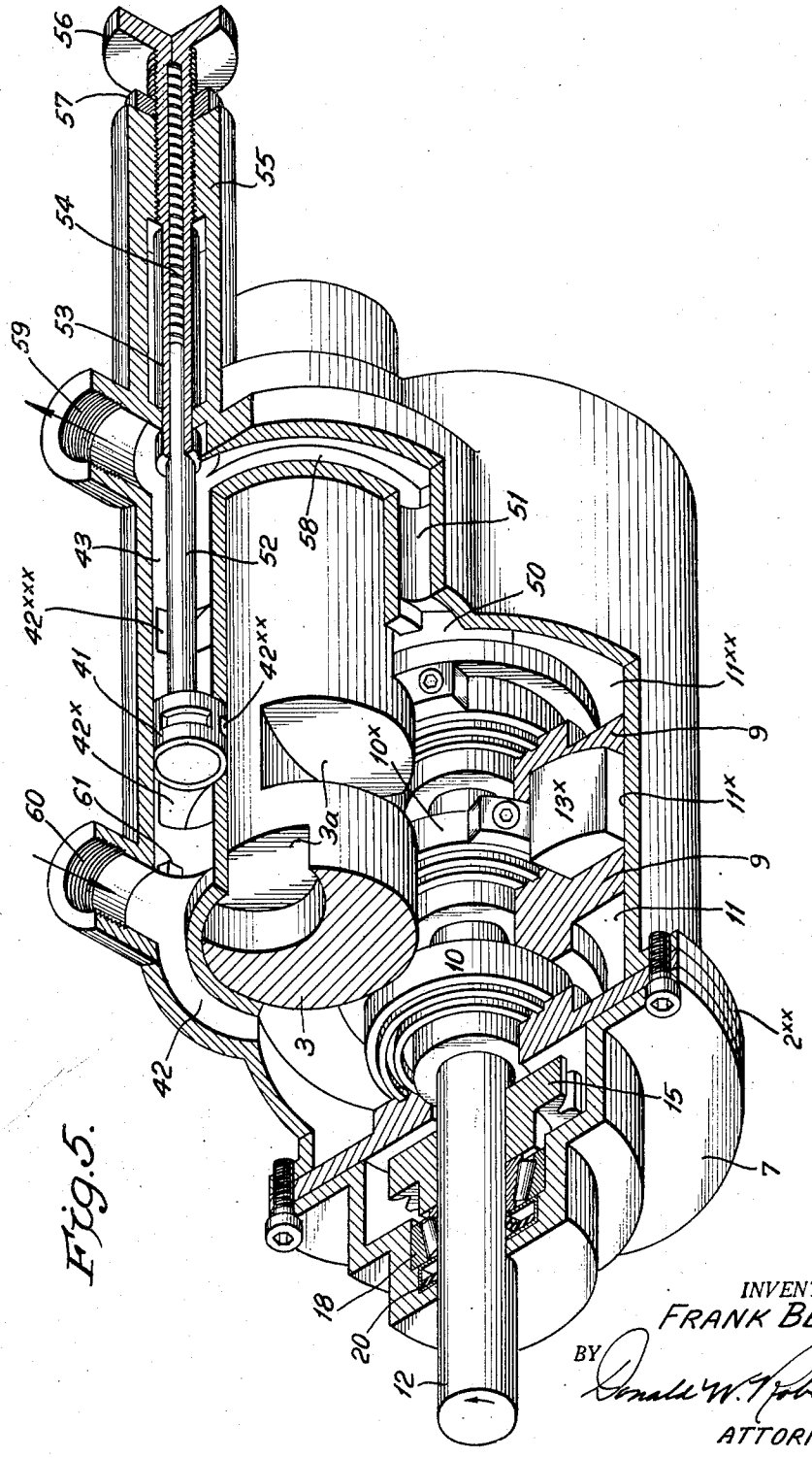


Fig. 5.

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Jan. 2, 1951 F. BERRY 2,536,486

FLUID POWER DEVICE

Filed April 27, 1945 4 Sheets-Sheet 4

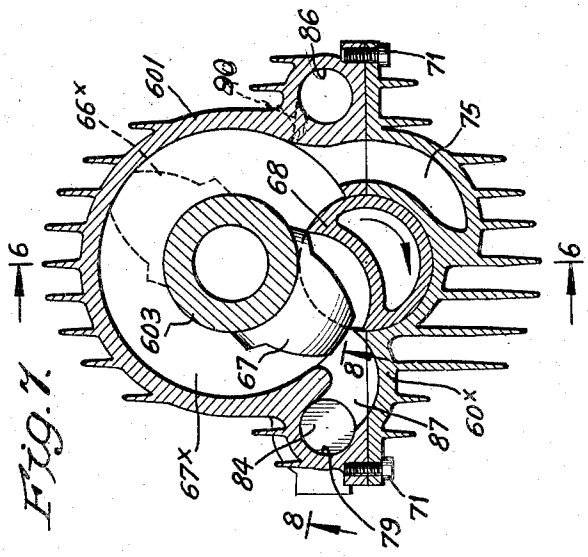


Fig. 1.

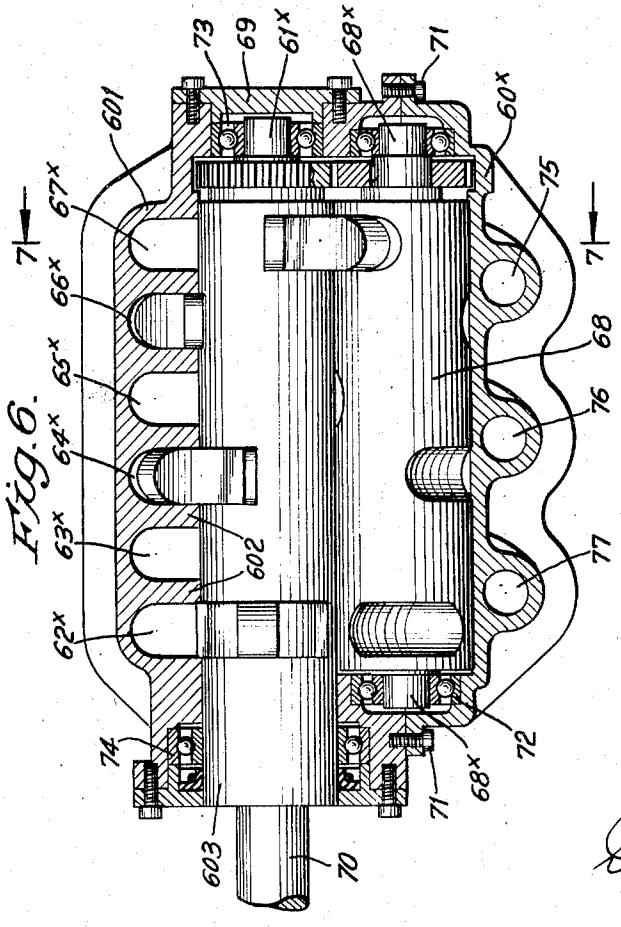


Fig. 6.

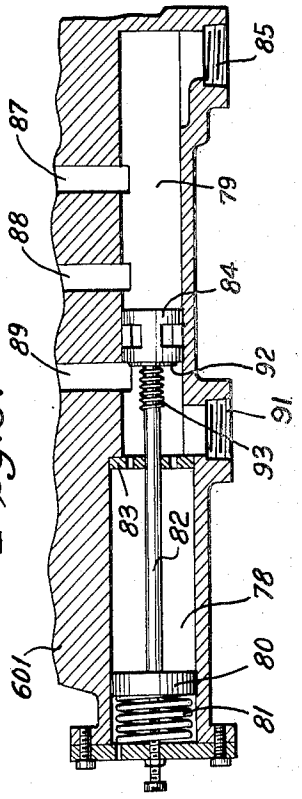


Fig. 8.

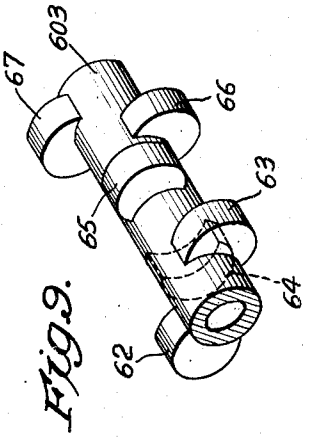


Fig. 9.

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Patented Jan. 2, 1951

2,536,486

UNITED STATES PATENT OFFICE

2,536,486

FLUID POWER DEVICE

Frank Berry, Corinth, Miss., assignor to Berry Motors, Inc., Corinth, Miss., a corporation of Tennessee

Application April 27, 1945, Serial No. 590,543

10 Claims. (Cl. 103—120)

1

This invention relates to hydraulic power devices, such as hydraulic pumps, hydraulic motors and servo-motors, hydraulic transmissions, power connecters, and controls therefor.

One of the objects of the invention is to provide a hydraulic pump or transmission which will deliver a variable volume of fluid under variable pressure to a hydraulic motor to drive it at variable speed under varying loads. A hydraulic pump of these characteristics, together with the driven hydraulic motor making up the transmission unit, would find special application under circumstances, such as in machine tools, where the power supply is constant and the load varies. Another application would be hydraulic transmissions for automobiles where the unit would be further provided with manual control means. The pump would be useful to furnish a variable volume under a constant pressure, as for examples, fuel supply pumps, injectors and the like.

For the attainment of the foregoing and such other objects of invention as may appear or be pointed out herein I have shown several embodiments of my invention in the accompanying drawings, wherein—

Figure 1 is a longitudinal section through a form of multiple cylinder pump in which the cylinders are arranged in parallel and in communication with a common manifold which forms part of a control device for varying the volume delivered to the driven motor of the transmission unit to accommodate varying load conditions;

Figure 2 is a transverse section through one of the cylinders taken on the line 2—2 of Figure 1;

Figure 3 is a perspective view of the piston valve forming part of the control device of the pump unit of Figure 1;

Figure 4 is a perspective view of the pump and control device of Figure 1 with the upper half of the end and the front of the casing removed to expose the interior of both the pump and the control valve;

Figure 5 is a perspective view similar to Figure 4 showing a hydraulic motor implemented with a variable speed device;

Figure 6 is a vertical longitudinal section, on the line 6—6, Figure 7, through a modified form of the device, adapted for use as a double stage variable speed hydraulic transmission;

Figure 7 is a transverse section taken on the line 7—7, Figure 6;

Figure 8 is a longitudinal section on line 8—8 of Fig. 7 through an automatic fluid porting device adapted to control the admission of fluid to

2

the cylinders, similar to those illustrated in Figures 1 and 4.

Figure 9 is a perspective view showing the relative positions of the pistons on the drive shaft.

In Figures 1 to 4 inclusive is shown an embodiment of my invention which has pressure, volume and torque controls.

Referring especially to Figures 1 to 4, it will be seen that the rotary elements are contained within an outer casing 1. The interior portion of the casing is provided with a long circular bore within which is rotatively mounted a cylindrical abutment rotor 3.

Secured to the outer casing 1, as by means of bolts 8^{x}, Figure 1, and extending radially inwardly are three annularly shaped members 9 which separate the interior of outer casing 1 into four annular cylinders designated from left to right in Figure 1 as 11, 11^{x}, 11^{xx}, and 11^{xxx}. Cylinder separators 9 are of irregular cross-section, see Figure 1, having oppositely facing portions between which are disposed the piston rotors 10, 10^{x}, 10^{xx}, and 10^{xxx}, respectively. Also, the left housing wall 7 has a rightwardly facing portion between which and the leftwardly facing portion of separator 9 is disposed the left piston rotor 10; similarly, the right housing wall 7^{xx} has a leftwardly facing portion between which and the rightwardly facing portion of separator 9 is disposed the right piston rotor 10^{xxx}. The central piston rotors 10^{x} and 10^{xx} are disposed between the oppositely facing portions of three of the separators 9. The piston rotors 10, etc., are secured, as by keys 16, to a drive shaft 12 rotatively mounted in anti-friction bearings 18. The right end of drive shaft 12 is provided with a reduced portion 12' and provided with the inner race of an anti-friction bearing 18.

Pistons 13, 13^{x}, 13^{xx}, and 13^{xxx}, which are slidably received in the annular cylinders, respectively 11, 11^{x}, and 11^{xx} and 11^{xxx}, are fastened to their rotors, respectively, 10, 10^{x}, and 10^{xx} and 10^{xxx} by bolts 14.

Piston drive shaft 12 rotates in synchronism with abutment rotor 3 which is common to all four pistons. For this purpose spur gear 15^{x}, Figure 1, is secured, as by key 16^{x}, to the left spindle 3^{x} of abutment rotor 3, and meshes with a gear 15 secured, as by key 16^{xx}, on drive shaft 12. The spindles of the abutment rotor are mounted on anti-friction bearings 19.

The common abutment rotor 3 is provided with four arcuate cut-outs 3a, each of which provides a space in which a respective one of the four pistons 13, 13^{x}, 13^{xx}, 13^{xxx} clears.

Individual ducts 42, 42x, 42xx, and 42xxx, Figure 1, connect the annular cylinders, respectively, 11, 11x, 11xx, and 11xxx, through the intermediary of a common cylindrical chamber 43. At the right end of cylinder 43 is the outlet 45 of the device while at the left end is a by-pass outlet 44, the purpose of which will be more fully described subsequently.

The device is provided with a common inlet 46, Figure 4, which serves as a manifold from which short passages 47 lead to the individual annular cylinders 11, etc. Co-axial with the cylinder 43, see Figure 1, is a second cylinder 43x of somewhat greater diameter, the two cylinders being separated by a wall 26. Within the smaller cylinder 43 is a piston 41 secured at the left end of a rod 40 which slides in an appropriate hole provided for it in the wall 26. At the right end of piston rod 40 is a second piston 25 which slides in the larger cylinder 43x. A long helical spring 28 encircles piston rod 40 within the smaller cylinder 43 between left piston 41 and separating wall 26. The wall 26 is provided with a number of small holes 26a for the purpose of restricting the fluid flow between cylinder 43 to cylinder 43x, the object being to prevent spasmodic movement of the piston assembly. A cover plate 27 with bleeder hole 29 is fastened by bolts 30 at the right end of cylinder 43x.

A detail of the smaller piston 41 is shown in Figure 3 where it will be seen that the frame constitutes a skeleton piston with openings 33 which are in communication with an annular opening 34 at the piston rod end of the piston. Slidably mounted on piston rod 40 is a disc 31 which serves as a valve to close the annular opening 34, a coil spring 32 being provided to urge disc 31 to closing position.

The strength of coil spring 28 is such that under no-load or idling conditions the piston 41 is held by the spring in its leftmost position shown in Figure 1 with the piston entirely clear of by-pass outlet 44. The fluid, which is fed to the unit through common inlet or manifold 46 and via the passages 47 to the different annular cylinders 10, 10x, 10xx, and 10xxx, is forced by the pistons 13, 13x, 13xx, and 13xxx thereof through the individual ducts 42, 42x, 42xx, and 42xxx leading from the respective cylinders into the common cylinder 43. From common cylinder 43 the fluid is forced, through the un-blocked by-pass outlet 44 to a storage tank or accumulator (not shown) which has a return leg to the inlet 46. Within this fluid circuit through the annular cylinders of the pump, their individual ducts 42, etc., common cylinder 43, by-pass outlet 44, the storage tank and back to the pump inlet 46, a predetermined volume of fluid will flow at a predetermined low fluid velocity under idling conditions. As the pump unit is speeded up, by increasing the driving energy thereto, a greater volume of fluid will be circulated in the said circuit, resulting in building up the pressure within the cylinders 43 and 43x. In this connection it will be recalled that the openings 26a in wall 26 separating cylinders 43 and 43x cause the pressure within cylinder 43 to be transmitted to cylinder 43x. The pressure within cylinders 43 and 43x exerts forces on their respective pistons 41 and 25, operating in opposite directions and proportional to the areas of the pistons. Since the area of control piston 25 is greater than that of by-pass piston 41, the piston assembly is caused to move rightwardly, as viewed in Figure 4, in opposition to the coil spring 28. Rightward movement of piston 41 causes a gradual closing of by-pass outlet 44 and an increase in the proportion of the fluid flow through outlet 45 as compared with the flow through by-pass outlet 44.

The pump unit of Figures 1–4 is particularly designed to supply fluids under varying volumes and pressures to fluid motors or drives which operate under varying load conditions, such as experienced in automobile propulsion, machine tool operation and the like. Hence it is understood that the pump outlet 45 is connected to the driven fluid motor (not shown) from which a leg returns to the pump inlet 46. The increased flow through pump outlet 45—resulting from a speeding up of the pump, in the manner described above—will cause a speeding up of the driven fluid motor. Should an increased load be placed on the driven fluid motor, or should resistance be placed in the circuit leading from pump outlet 45, the pressure in cylinders 43 and 43x will rise still higher and cause a still further rightward movement of the piston assembly until left piston 41 finally closes the first or leftmost individual duct 42, thus shutting off the first annular cylinder 11 from the pumping operation. This results in the supplying of a smaller volume of fluid to the driven fluid motor at a higher pressure, thus generating a greater torque at slower speed, as would be required to overcome the increased load. The rightward movement of the piston assembly continues with increase in load until piston 41 passes to the right of the first or leftmost duct 42 in which case the fluid discharged from the first or leftmost annular cylinder 10 flows through outlet 44 and the by-pass circuit, which circuit as described above does not include the driven fluid motor. Still further load increase causes further rightward movement of the piston assembly with successive closing and passing of the individual ducts 42x, and 42xx, these ducts contributing their flow, together with the flow from the first duct 42, to the by-pass circuit. In the rightmost position of the piston assembly, defined by the abutting of control piston 25 with end plate 27, only the last or rightmost duct 42xxx remains opened and included in the circuit to the driven fluid motor. With decrease in load and resultant decrease in pressure in the inter-communicating cylinders 43 and 43x, spring 28 causes a leftward movement of the piston assembly, which causes a successive inclusion of the ducts 42xx, 42x, and finally 42 in the circuit to the driven fluid motor, thus resulting in a circulation of a larger fluid volume at a lower pressure (which means a greater fluid velocity and motor speed).

The bleeder hole 29 in the end plate 27 has a pipe connection for a storage or accumulator tank (not shown) to remove any fluid that might have trickled past the piston rings to the right of control piston 25. The purpose of the valve disc 31, Figure 3, of by-pass piston 41 is to pass the fluid to the right of the piston at such times as it covers the openings 42, 42x, 42xx and 42xxx by permitting some fluid to pass through annular opening 34, as excess pressure generated in the cylinders overcomes spring 32.

In Figure 5 is shown an embodiment of the invention, similar to that described above in connection with Figures 1–4, having a control adapting it for use as a variable speed drive or transmission. The particular control unit illustrated particularly adapts the unit as a four speed hydraulic power converter. The right end portion of piston rod 52 is slidable within a sleeve 53, the

right end portion of which is provided with external threads screwed into a tapped hole provided in housing 55. At its right end protruding from housing 55, threaded sleeve 53 is provided with a handwheel 56 and a lock-nut 57. Within the bore of sleeve 53 and between the right end of piston rod 52 and the floor of the bore is a coiled compression of spring 54. By means of handwheel 56 the compression of spring 54 may be varied as desired, for a purpose soon apparent.

Fluid from a constant pressure source, such as a pump, is conducted to the transmission unit shown in Figure 5, entering at inlet 60 which leads into cylinder 43. From common cylinder 43, individual ducts 42, 42x, etc. conduct the pressure fluid to their respective annular cylinders 11, 11x, etc., from which the fluid is discharged through individual passages 50 into a discharge manifold 51 which is connected by passage 58 to cylinder 43 and thence to outlet 59. A stop 61 is provided within the cylinder 43 at a point near the first outlet duct 42 adapted to stop the leftward movement of the piston 41 so that the first annular cylinder is at all times open to cylinder 43. In the position of piston 41 shown in Figure 5 only the first and second ducts, 42 and 42x are to the left of piston 41 and effective to conduct the pressure fluid to their respective annular cylinders to drive the pistons thereof and deliver power at shaft 12. As the load imposed on shaft 12 lightens, the pressure within the cylinder 43 to the left of piston 41 decreases, permitting compression spring 54 to move the piston leftward thus cutting duct 42x off from communication with the left end or pressure end of cylinder 43. Hence the load will be carried by the single cylinder 11. The reduction in capacity from two cylinders to a single cylinder reduces the volume accepted by the motor from the pressure fluid source per revolution, with the result of increasing the fluid velocity through the motor and the speed of rotation of the shaft. On the other hand, as the shaft load is increased, the pressure within cylinder 43 increases and causes a rightward movement of piston 41 against a predetermined pressure imposed on spring 54, placing more of the annular cylinders 11, etc., in communication with the pressure cylinder 43, with the result that the torque delivered to shaft 12 is increased and the speed decreased. By regulating the spring 54 by manipulation of handwheel 56 these conditions may be controlled as desired.

In the construction shown in Figures 6 to 9, the casing is formed with an upper annular portion 601 divided by webs 602 into a plurality of cylinders, these cylinders being six in number, 62x to 67x, respectively, in the present embodiment. Extending longitudinally and intersecting the cylinders is a piston rotor 603, provided with six pistons 62, 63, 64, 65, 66, and 67 (Figure 9). Extending in parallelism with piston rotor 603 is an abutment rotor 68 formed with a plurality of clearances one for each of the pistons. The right hand end of the upper casing section is closed by a cap 69 and the left hand end of said casing section is open for the projection of a drive shaft 70 which is received within the piston rotor 603, and connected for its rotation as by splines. The lower portion 60x of the casing is preferably separable, being secured to the upper portion by cap screws 71.

The abutment rotor 68 is provided with spindles 68x which are received within ball bearings 72. The piston rotor 603 is formed with a spindle 61x received within a ball bearing 73, and at its left-end portion the piston rotor is received within a second ball bearing 74.

Viewing Figure 7 it will be seen that the lower section of casing 601 is formed with a deep passage at 75, and this passage will be preferably formed in a progressive curve extending at such an angle as to bring into communication two adjacent cylinders, in this case cylinders 67x and 66x. There being six cylinders in the present embodiment, three of said passages are provided as shown at 75, 76, and 77. Thus passage 75 will afford communication between the cylinders for pistons 67 and 66; passage 76 will afford communication between the cylinders 65x and 64x for pistons 65 and 64; and passage 77 will afford communication between cylinders 63x and 62x for pistons 63 and 62.

The upper casing section at the lower left-hand, viewing Figure 6 is formed with an elongated chamber which is shown in Figure 8, which chamber has a larger cylindrical area at 78 communicating with an elongated cylindrical area of lesser diameter as shown at 79. Within cylinder 78 is a piston 80 behind which is a pre-loaded spring 81. The piston carries a piston rod 82, which passes through a perforated diaphram 83 and extends within cylinder section 79. Piston rod 82 carries a slotted piston 84 which is similar to that shown in detail in Figure 3. Cylinder section 79 is provided with a by-pass duct at 85 which is adapted for communication (as by a pipe not shown) with the by-pass and inlet passage 86, Figure 7. Cylinder 79 also is provided with ducts at 87, 88, and 89 for communication respectively with cylinders 67x, 65x, and 63x, according to the arrangement indicated in Figure 7.

In the operation of the device illustrated in Figures 6 to 8, which device may be described as a fluid power generator and automatic variable fluid transmitter, rotation of shaft 70 by any suitable source of power will cause the abutment to move in the direction of the arrow Figure 7, and the pistons will move through the abutment clearances in counter-clockwise direction. The fluid will move under pressure from right to left of the structure shown in Fig. 6 and will have the following effect upon the automatic variable control shown in Figure 8:

Bearing in mind that the inlet and by-pass 86 will communicate with an accumulator or other reservoir containing fluid, and this in addition to its communication with by-pass 85, for cylinder section 79, and also bearing in mind that the inlet and by-pass 86 extends longitudinally of the casing and is formed with openings (such as that shown by dotted lines at 90, Figure 7) for communication with each of the alternate cylinders 66x, 64x and 62x, the operation of the generator in conjunction with the automatic control is governed in the following manner:

It is assumed that the unit is driven by a variable speed power supply such as an air motor or an internal combustion engine that may be accelerated or decelerated. The preloading spring 81 is under the proper tension to retain the piston 84 at a point past the by-pass opening 85 in the cylinder 79 during the idling speed of the driving unit. As said driving unit is accelerated a pressure will be built up within the cylinders 78 and 79 and will begin to react on pistons 80 and 84 so that piston 84 will successively pass the ducts 87, 88, and 89 as the volume and pressure requirements through the discharge opening 91 demand. The discharge from said opening 91 will

be employed for the propulsion of a fluid motor or other device operated by a fluid having varying volumes and pressures. It will be noted that piston 84 is a skeleton piston having a check valve 92 controlled by a spring 93 for the purpose of passing the fluid to the left of the piston at such times as it covers the openings 87, 88, and 89. As the pressure requirements of the load decrease, the preloaded spring will move the pistons toward the by-pass opening until the proper volume and pressure requirements have been fulfilled. It will be noted from Figure 7 that pistons 66 and 67 are timed 180° apart and operate as a joint unit. Piston 66 will first take in a charge of fluid through inlet-and-by-pass 86 and duct 90, and will force a charge around its cylinder 66^x through the connecting deep cylindrical passage 75 and directly into cylinder 67^x where it is received by piston 67 and forced around said cylinder, then discharged through duct 87 into the cylinder 79 of the automatic control, thus completing a cycle. It will be noted that at such time as one of the pistons 66 or 67 is passing through its appropriate abutment clearance, or otherwise becomes idle, the other piston will supply the column of fluid to the automatic control, thus maintaining a constant column of the fluid at all times and assuring smooth operation of the device.

I claim:

1. In a control device for a multiple cylinder pump, the combination of an elongated cylinder connected by individual ducts to the pump cylinders, a by-pass outlet at one end of the said elongated cylinder, a discharge outlet at the other end of the elongated cylinder, a piston slidable in the said elongated cylinder and spring pressed beyond the said by-pass outlet whereby the fluid is by-passed therethrough, said piston adapted upon increasing the power supplied to the pump to move in a direction against its said spring to close the said by-pass outlet whereby the fluid is pumped through the said discharge outlet, the said means being further adapted upon the imposition of load on the pump to move the piston further in the said direction to open the said by-pass outlet and to place successive ones of the said outlet ducts from the plurality of pump cylinders on the by-pass side of the piston and shut such cylinders from communication with the said discharge outlet whereby a smaller volume is delivered to develop a greater torque at reduced speed, said piston being of skeleton form with peripheral openings and with its end facing the said discharge outlet of the elongated cylinder open, the said open end of the piston being in communication with the said peripheral openings, a disc slidably mounted on the piston rod and spring pressed toward the piston to close its said open end, whereby excessive pressure in the particular one of the pump cylinders the outlet of which is blocked by the said piston, will be relieved through the said peripheral piston openings and the said open end thereof.

2. The combination according to claim 1, in which the device is adapted as a fluid power generator and automatic variable fluid transmitter, and said device being provided with a plurality of pairs of annular pump cylinders, the cylinders of each pair communicating with each other and with a fluid inlet, and one cylinder of each pair having an outlet duct, each cylinder receiving a rotary piston, and one cylinder of each pair discharging into that cylinder of the pair having the outlet duct, the outlet duct leading to the elongated cylinder of the control.

3. The combination according to claim 1, in which the device is adapted as a fluid power generator and automatic variable fluid transmitter, the said device being provided with a plurality of pairs of annular pump cylinders, the cylinders of each pair communicating with each other and one with a fluid inlet, and one cylinder of each pair having an outlet duct, each cylinder receiving a rotary piston, the pistons of each pair of cylinders being spaced circumferentially on the piston shaft about 180° and the pistons of an adjacent pair of cylinders having like relative spacing but being circumferentially offset from the cylinders of the first named pair, one cylinder of each pair having the outlet duct leading to the control.

4. The combination according to claim 1, in which the device is adapted as a fluid power generator and automatic variable fluid transmitter, the said device being provided with a plurality of pairs of annular pump cylinders, the cylinders of each pair communicating with each other and with a fluid inlet, and one cylinder of each pair having an outlet duct, each cylinder receiving a rotary piston, and one cylinder of each pair discharging into that cylinder of the pair having the outlet duct, the outlet duct leading to the elongated cylinder of the control, the communication between the cylinders of each pair consisting of a tubular semi-circular passageway of substantially constant cross sectional area directed in opposition to the annular cylinders, an abutment rotor intermediate the passageway and the annular cylinders, said abutment rotor being formed with clearances for the pistons and being partially encircled by the walls of said passageway.

5. In a multiple cylinder power converter, a casing provided with a plurality of annular cylinders, a shaft disposed centrally of the annular cylinders having fixed for rotation therewith a piston slidably received in each annular cylinder, a cylindrical abutment extending parallel to the piston shaft and having openings at the annular cylinders wherein the respective pistons clear, the terminal portions of each of the annular cylinders being provided with openings on each side of the abutment, a cylinder connected by individual ducts to the terminal openings on one side of the abutment, said individual ducts communicating with the last-named cylinder at openings spaced longitudinally of said cylinder, a manifold connected to the terminal openings on the other side of the abutment, a piston slidable in said last-named cylinder, and resilient means for resisting movement of the piston lengthwise of said cylinder in one direction, said piston being of a length sufficient to cover each of said spaced openings as it passes them in turn, said piston having a lateral opening for communication with said spaced openings and a check valve in communication with said lateral opening, and said piston being movable against said resilient means upon increased loading of the power converter by increased pressure in said last-named cylinder produced by the increased loading whereby the piston successively passes the spaced openings in said cylinder to automatically regulate the number of annular cylinders operating in the power cycle and thus increase the mechanical advantage through lowering the rate of work output.

6. In a control device for a multiple annular cylinder power converter, the combination of a control cylinder connected by individual ducts to

terminal openings at one end of each annular cylinder, said individual ducts communicating with the control cylinder at openings spaced longitudinally of the control cylinder, a manifold connected to terminal openings at the other end of each annular cylinder, a piston slidable in the control cylinder, and resilient means for resisting movement of the piston lengthwise of the control cylinder, said piston being of a length sufficient to cover each of said spaced openings as it passes them in turn, said piston having a lateral opening for communication with said spaced openings and a check valve in communication with said lateral opening, and said piston being movable against said resilient means upon increased loading of the power converter by increased pressure in the control cylinder produced by the increased loading whereby the piston successively passes the spaced openings in the control cylinder to automatically regulate the number of annular cylinders operating in the power cycle and thus increase the mechanical advantage through lowering the rate of work output.

7. In a control device for a multiple annular cylinder fluid pump, the combination of a control cylinder connected by individual ducts to terminal openings at one end of each annular cylinder, said individual ducts communicating with the control cylinder at openings spaced longitudinally of the control cylinder, a manifold connected to terminal openings at the other end of each annular cylinder, a piston slidable in the control cylinder against resilient pressure, said piston being of a length sufficient to cover each of said spaced openings as it passes them in turn, said piston having a lateral opening for communication with said spaced openings and a check valve in communication with said lateral opening, and said piston being movable against said resilient pressure upon increased loading of the pump by increased pressure in the control cylinder produced by the increased loading whereby the piston successively passes the spaced openings in the control cylinder to regulate automatically the number of annular cylinders operating in the pump and thus increase the mechanical advantage through lowering the volume of fluid delivered per revolution.

8. A control device of the character described in claim 7, in which the control cylinder has an adjoining cylinder coaxial therewith and an apertured wall separating the said two cylinders, a piston slidable in said adjoining cylinder and connected to the piston of the control cylinder, a by-pass outlet near one end of the control cylinder, a compression coil spring in the control cylinder to provide said resilient pressure, said spring holding the control cylinder piston beyond the by-pass outlet when the pump is turning at idling speed whereby the fluid is pumped through the by-pass outlet, said two pistons having different areas so that upon increasing the speed of the pump the pistons move in a direction against said spring to close the by-pass outlet.

9. In a control device for a multiple annular cylinder power converter, the combination of a control cylinder connected by individual ducts to terminal openings at one end of each annular cylinder, said individual ducts communicating with the control cylinder at openings spaced longitudinally of the control cylinder, a piston slidable in the control cylinder, a manifold connected to terminal openings at the other end of each annular cylinder, said manifold connection to each cylinder remaining open irrespective of the position of said piston, and resilient means for resisting movement of the piston lengthwise of the control cylinder, said piston being of a length sufficient to cover each of said spaced openings as it passes them in turn, said piston having a lateral opening for communication with said spaced openings and a check valve in communication with said lateral opening, and said piston being movable against said resilient means upon increased loading of the power converter by increased pressure in the control cylinder produced by the increased loading whereby the piston successively passes the spaced openings in the control cylinder to automatically regulate the number of annular cylinders operating in the power cycle and thus increase the mechanical advantage through lowering the rate of work output.

10. In a control device for a multiple annular cylinder power converter, the combination of a control cylinder connected by individual ducts to terminal openings at one end of each annular cylinder, said individual ducts communicating with the control cylinder at openings spaced longitudinally of the control cylinder, a manifold connected to terminal openings at the other end of each annular cylinder, a piston slidable in the control cylinder, and resilient means for resisting movement of the piston lengthwise of the control cylinder, said piston being of a length sufficient to cover each of said spaced openings as it passes them in turn, said piston having a lateral opening for communication with said spaced openings and a check valve in communication with said lateral opening, said check valve being arranged to permit discharge from the control cylinder through said lateral opening when the piston is in positions covering said spaced openings, and said piston being movable against said resilient means upon increased loading of the power converter by increased pressure in the control cylinder produced by the increased loading whereby the piston successively passes the spaced openings in the control cylinder to automatically regulate the number of annular cylinders operating in the power cycle and thus increase the mechanical advantage through lowering the rate of work output.

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