

Feb. 13, 1968

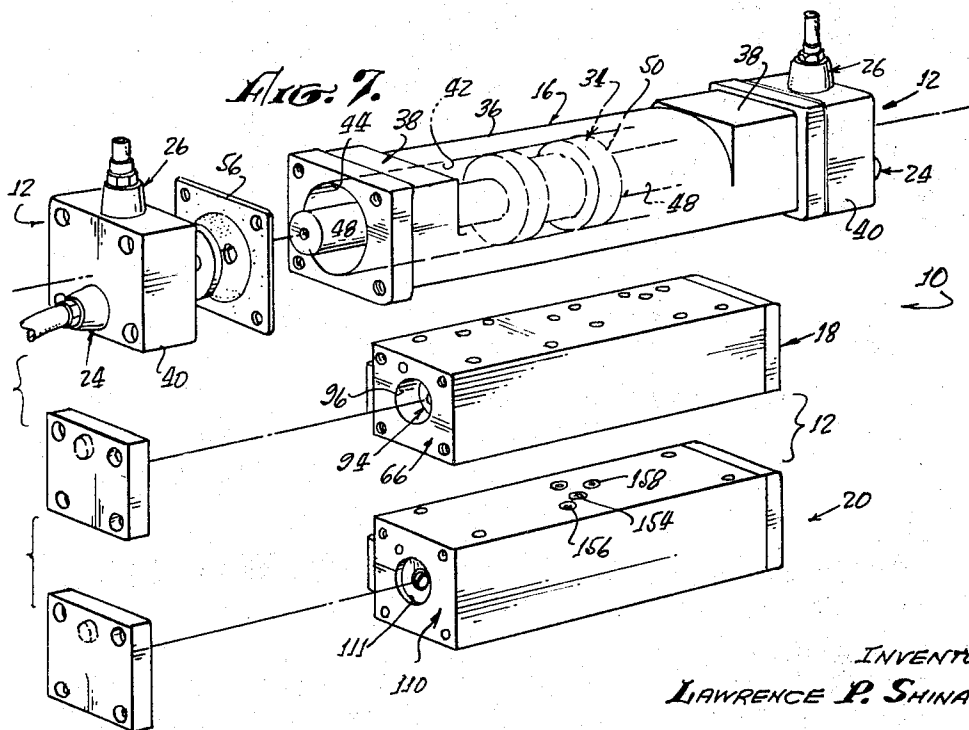
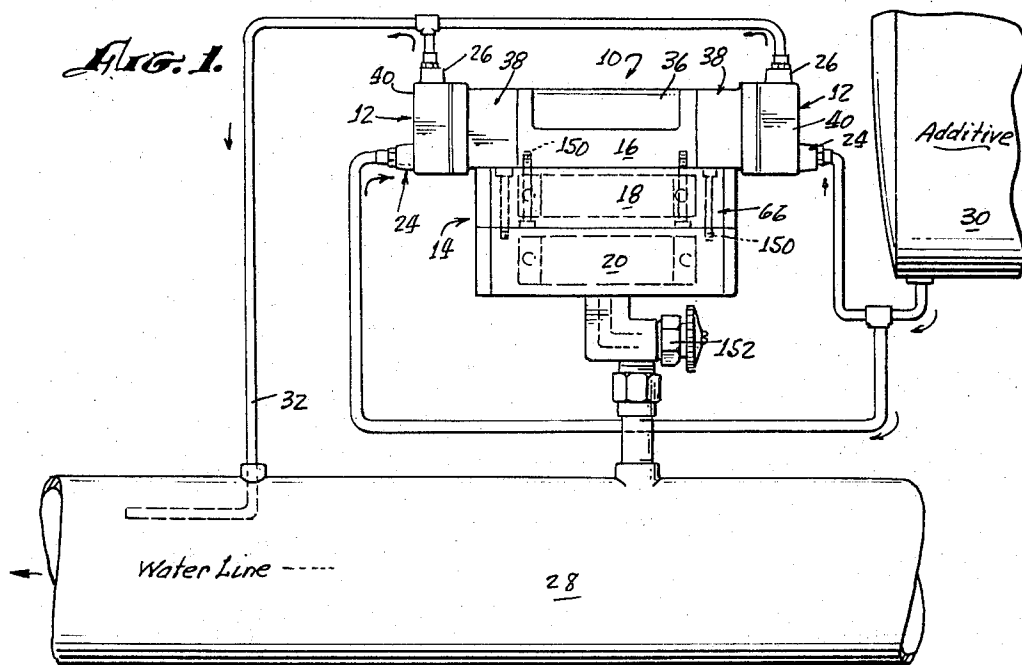
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3,368,458

HYDRAULIC MOTOR

Filed Oct. 24, 1965

4 Sheets-Sheet 1



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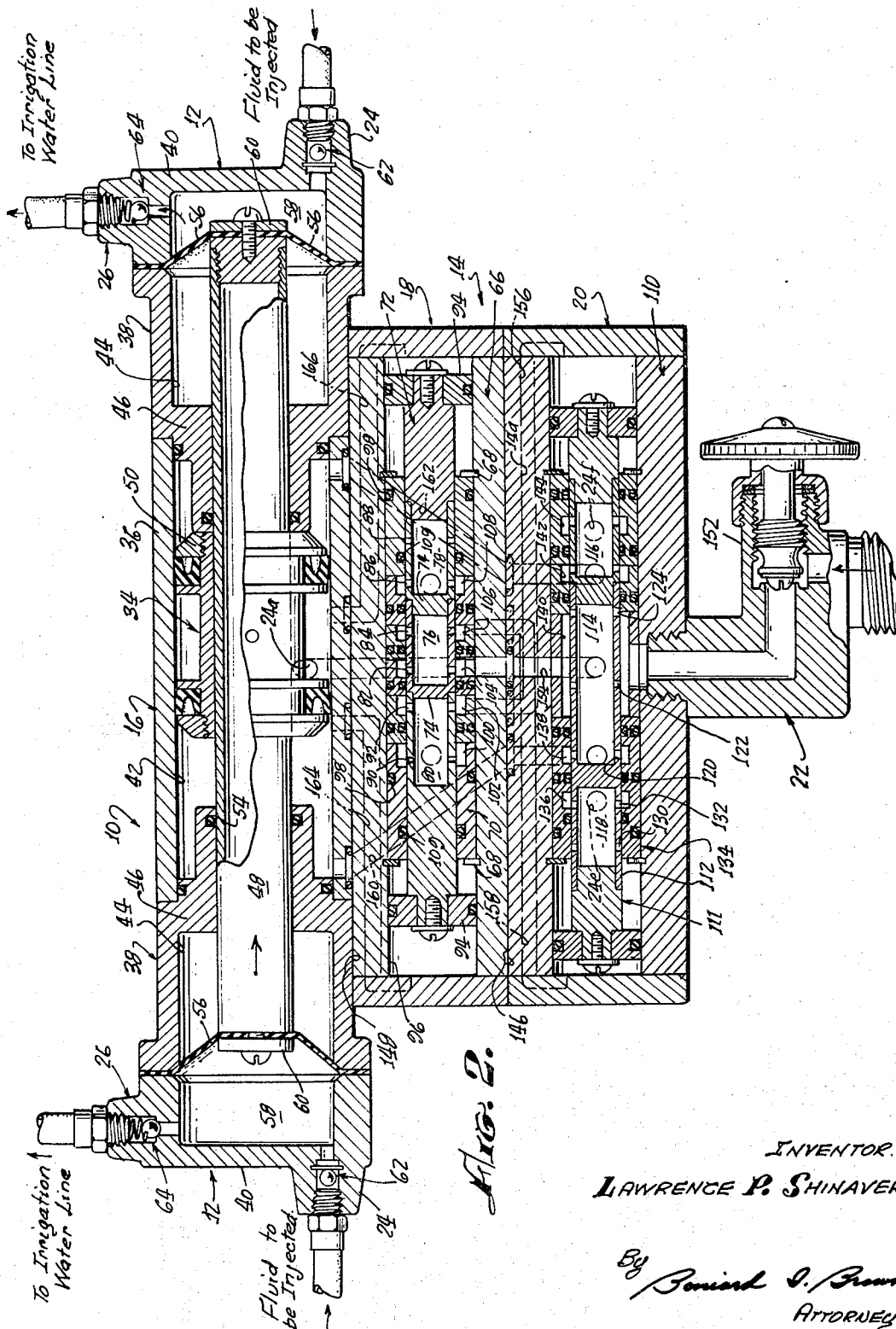


FIG. 2.

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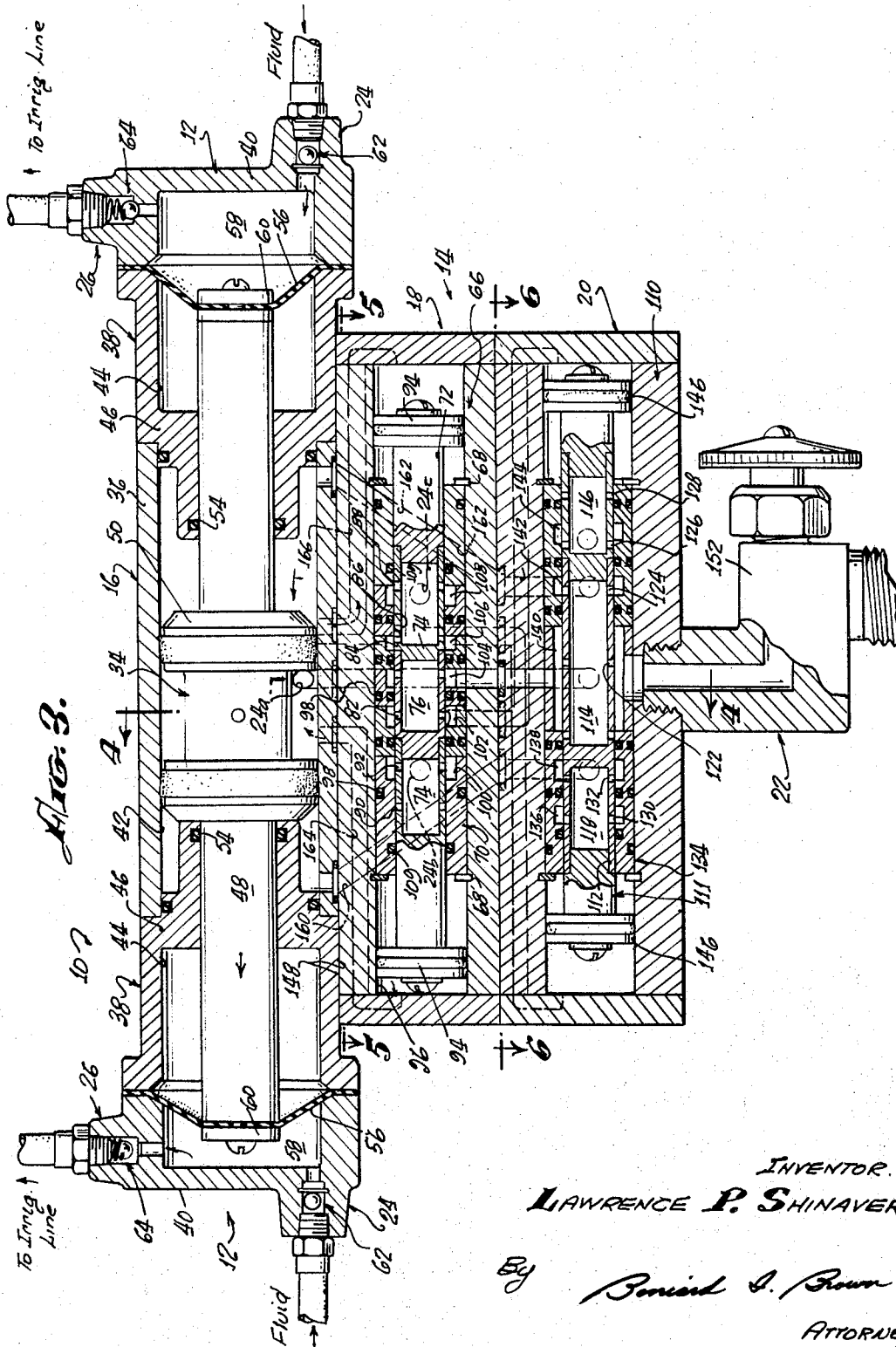
L. P. SHINAVER

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HYDRAULIC MOTOR

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Feb. 13, 1968

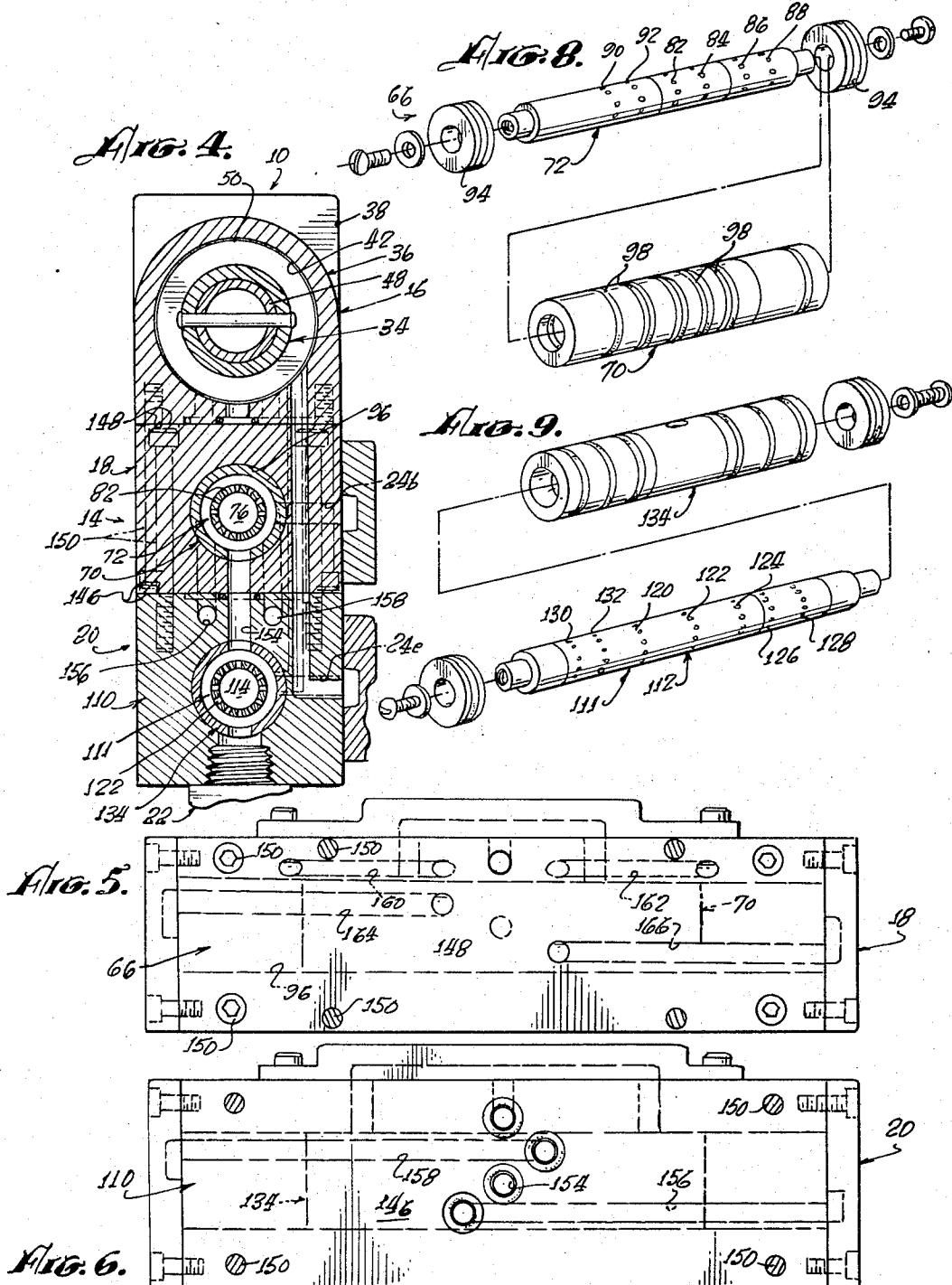
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HYDRAULIC MOTOR

Filed Oct. 24, 1965

4 Sheets-Sheet 4



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3,368,458

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4 Claims. (Cl. 91-308)

ABSTRACT OF THE DISCLOSURE

A reciprocating hydraulic motor having a power cylinder, a main valve cylinder, and a pilot valve cylinder contained in separate cylinder blocks which are releaseably joined with seating faces thereof disposed in sealing contact, and passages communicating the cylinders through communicating ports in the seating faces. A sleeve valve construction for use in the hydraulic motor.

This invention relates generally to fluid motors; more particularly, the invention relates to a novel reciprocating fluid motor assembly and to an improved fluid pump embodying the motor assembly. The invention also relates to an improved slide valve for the motor assembly.

Briefly stated, the invention provides a fluid motor assembly including a reciprocating fluid motor proper, hereinafter referred to as a power unit, a main slide valve for controlling the power unit, and a pilot slide valve for controlling the main valve. The pilot valve, in turn, is controlled by the power unit. The power unit has a power cylinder containing a power piston. Each valve has a cylinder containing valve piston. In this disclosure, the cylinder and piston of the pilot valve are referred to, in places, simply as a pilot cylinder and a pilot piston, respectively, and the cylinder and piston of the main valve are referred to as a main cylinder and a main piston, respectively.

During operation of the motor assembly, the power unit controls the flow of operating fluid to and from the ends of the pilot cylinder in such a way that the pilot piston is reciprocated between its limiting positions in the pilot cylinder in response to movement of the power piston between its limiting positions in the power cylinder. The pilot valve, in turn, controls the flow of operating fluid to and from the ends of the main cylinder in such a way that the main piston is reciprocated between its limiting positions in the main cylinder in response to reciprocation of the pilot piston. Finally, the main valve controls the flow of operating fluid to and from the ends of the power cylinder in such manner that reciprocation of the main piston is effective to cause reciprocation of the power piston. Accordingly, during operation of the motor assembly, the three pistons undergo synchronized reciprocation.

Hydraulic motor assemblies of this general type are known in the art. Patent No. 2,920,640, for example, discloses such a motor assembly. The existing motor assemblies, however, including that disclosed in the above-mentioned patent, are deficient in certain respects. One aspect of this invention is concerned with curing these deficiencies.

The power unit and valves of some existing motor assemblies, for example, comprise separate components which are interconnected by fluid conduits. These assemblies, obviously, are relatively large in overall size, difficult and costly to manufacture and assemble, and, in general, are ill suited to many applications. In an attempt to overcome these disadvantages, unitary motor assemblies have been devised in which the power unit, pilot valve, and main valve are constructed as a unitary structure wherein the valve and power cylinders communicate with one another and with an operating fluid inlet and outlet

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through fluid passages which extend through the body of the unitary structure. The patent referred to above discloses a unitary motor assembly of this type. The motor assembly disclosed in the patent, however, is deficient in that the geometry and the arrangement of the fluid passages in the main body of the assembly are extremely intricate. Accordingly, this motor assembly is costly to manufacture. The intricate geometry and passage arrangement of the latter motor assembly are necessitated by the fact that the main body of the assembly is constructed in only two separate parts and by the particular arrangement of the valve and power cylinders in the body. Another deficiency of the patented motor assembly resides in the fact that the pistons of the pilot and main slide valves of the assembly comprise valve spools, the lands of which are sealed to the walls of the respective cylinders by so-called "U-cup" seals which are carried on the lands. It has been found, in practice, that this method of sealing the pilot and main slide valves of the motor assembly is unsatisfactory with certain types of operating fluids, such as the irrigation water which is intended to power the patented motor assembly. This is due to the fact that irrigation water has particles of sand and other solid matter entrained therein, which particles tend to become trapped between the seals and the walls of the cylinders. The seals and cylinders are thus rapidly abraded and the service life of the motor assembly is substantially reduced. Moreover, the metallic sealing surfaces which are thus abraded in the patented motor are the walls of the valve cylinders. Accordingly, the valve cylinders must be periodically re-bored, or the part of the motor body containing these cylinders must be periodically replaced. This, of course, contributes substantially to the operating cost of the motor and results in periodic removal of the motor from service for a substantial period of time. Another disadvantage of the motor disclosed in the patent resides in the fact that the frictional drag between the relatively broad U-cup seals on the valve pistons of the motor valves and the walls of the valve cylinders is relatively high. As a consequence, the patented motor is prone to stalling at relatively slow speed. In addition, the maximum reliable operating speed of the patented motor is relatively low. Because of these disadvantages of U-cup seals, attempts have been made at replacing these seals by O-rings. However, it has been found in practice that O-rings, when installed on a moving part, such as the valve piston of a slide valve, tend to be blown away by the contained fluid pressure.

The fluid motor disclosed in the aforementioned Patent No. 2,920,640 is intended primarily for use in the agricultural industry for injecting measured quantities of liquid fertilizer into irrigation water. To this end, the power unit of the motor is equipped with pump cylinders at opposite ends of the power cylinder. These pump cylinders contain pump pistons which are connected to the power piston in such a way that reciprocation of the power piston drives the pump pistons in a reciprocating pumping motion in their cylinders. The pump cylinders have inlets for connection to a liquid fertilizer tank and outlets for connection to an irrigation pipe line, or the like. Accordingly, during operation of the patented motor and pump assembly, liquid fertilizer is drawn from the fertilizer tank and pumped into the irrigation pipe line for mixing with the irrigation water flowing there-through. As already noted, the motor is intended to be powered by the irrigation water.

The patented pumping apparatus is deficient for the reason that the power and pump cylinders are isolated simply by seal rings which engage the rod or shaft of the power piston. As a result, it has been found in practice that liquid fertilizer leaks from the pump cylinders into

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the power cylinder and produces undesirable deposits in the power cylinder as well as in other portions of the pump and motor assembly.

It is a general object of this invention to provide an improved reciprocating motor of the character described, and an improved fluid pump embodying the motor, which are not subject to the above noted and other deficiencies of the existing motors and pumps of this general class.

Another object of the invention is to provide a fluid motor and pump of the character described wherein the power unit, pilot slide valve, and main slide valve are separately formed and uniquely assembled in such a way as to substantially reduce the complexity and cost, and substantially increase the efficiency, reliability, and service life of both the motor and pump.

Yet another object of the invention is to provide a fluid pump of the character described wherein the pump cylinders, or chambers, are completely isolated from the main power cylinder in such a way as to entirely prevent fluid leakage between the pump chambers and the power cylinder.

A related object of the invention is to provide a fluid pump which is ideally suited to pumping liquids, such as liquid fertilizer, which tend to create undesirable deposits in the wall of the power cylinder, and exhibit other undesirable effects, in the event of leakage of these liquids into the power cylinder.

A further object of the invention is to provide an improved slide valve for fluid motors of the character described, and other fluid operated equipment, which is uniquely designed to increase the service life of the valve, particularly when the latter is employed in a fluid motor powered by an operating fluid containing abrasive particles.

A related object of the invention is to provide an improved slide valve which is ideally suited to use in a fluid motor powered by water, such as irrigation water, which contains entrained sand and the like, whereby the present motor and pump are uniquely adapted to use in the agricultural industry for pumping measured amounts of liquid fertilizer into irrigation water.

Yet a further object of the invention is to provide an improved fluid motor, pump, and slide valve which are relatively simple in construction, reliable in operation, rugged and durable, compact in size, and otherwise ideally suited to their intended purposes.

Other objects, features and advantages of the present invention will become apparent to those versed in the art from a consideration of the following description, the appended claims and the accompanying drawings, wherein:

FIGURE 1 illustrates a system for injecting liquid fertilizer into an irrigation pipe line, which system embodies an improved motor and pump assembly according to the invention;

FIGURE 2 is an enlarged section taken through the motor and pump assembly in FIGURE 1 and illustrating the movable components of the assembly in certain operative positions thereof;

FIGURE 3 is a view similar to FIGURE 2 illustrating the movable components of the motor and pump assembly in other operative positions thereof;

FIGURE 4 is a section taken on line 4—4 in FIGURE 3;

FIGURE 5 is a section taken on line 5—5 in FIGURE 3;

FIGURE 6 is a section taken on line 6—6 in FIGURE 3;

FIGURE 7 is an exploded perspective view of the motor and pump assembly;

FIGURE 8 is an exploded perspective view of certain elements of the pilot valve of the assembly; and

FIGURE 9 is an exploded perspective view of certain elements of the main valve of the assembly.

Generally speaking, the motor and pump assembly 10

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of the invention which has been selected for illustration in the drawings comprises a pair of pumping means 12 and a fluid motor 14 for driving the pumping means. Motor 12 includes a power unit 16, a pilot slide valve 18, and a main valve 20. The pumping means 12 are located at the ends, respectively, of the power unit 16. Motor 14 has a high pressure fluid inlet 22 for connection to a source of operating fluid under pressure and a low pressure fluid outlet 24 for connection to a fluid return line, drain line, or waste facility. During operation of the motor and pump assembly 10, the pilot valve 18 controls the main valve 20, the main valve controls the power unit 16, and the power unit controls the pilot valve, all in such manner that the high pressure operating fluid entering the assembly through the inlet 22 is effective to drive the power piston (not shown in FIGURE 1) contained in the power unit 16 in a reciprocating motion. This reciprocating motion of the power piston drives the pumping means 12, whereby fluid is drawn into the pumping means through their inlets 24 and is expelled from the pumping means through their outlets 26.

As will appear from the ensuing description, the motor and pump assembly 10 may be used for various pumping applications. The particular application illustrated in the drawings involves the injection of liquid fertilizer into irrigation water. In this case, the inlet 22 of the motor and pump assembly is connected to an irrigation pipe line 28 through which irrigation water flows under pressure. The pump inlets 24 of the assembly are connected to a tank 30 containing liquid fertilizer. The pump outlets 26 are connected to a fertilizer discharge line 32 which opens into the pipeline 28. It is evident, therefore, that the motor 14 is powered by the pressure of the irrigation water flowing through the pipe line 28 and thereby drives the pumping means 12 in such manner as to pump measured amounts of liquid fertilizer from the tank 30 into the pipe line 28.

Referring now in greater detail to the motor and pump assembly 10, and referring particularly to FIGURES 2 and 3, it will be observed that the power unit 16 comprises a power cylinder 32 containing a power piston 34. Power cylinder 32 includes a sleeve 36, fixed in the ends of which are generally cylindrical cup-shaped parts 38. End caps 40 are bolted or otherwise rigidly secured to the outer ends of the cup-shaped parts 38. Accordingly, it will be observed that the power unit 16 defines a power cylinder bore 42 containing the power piston 34, chambers 44 at the ends of the power cylinder, and transverse walls 46 separating these chambers from the cylinder bore 42.

Power piston 34 comprises a shaft or rod 48 and an enlarged piston head 50 coaxially fixed to the rod, intermediate its ends. The piston head 50 slides within and is peripherally sealed to the wall of the cylinder bore 42. The piston rod 48 extends slidably through aligned bores in the cylinder end walls 46 and is slidably sealed to these walls by O-rings 54. The ends of the piston rod are disposed within the cylinder end chambers 44.

Extending transversely across the cylinder end chambers 44 are flexible diaphragms 56. The perimetrical edge portion of each diaphragm 56 is clamped between the adjacent cup part 38 and cylinder end cap 40. Accordingly, each diaphragm is peripherally sealed to the wall of its respective cylinder chamber 44 and defines, with the end wall of its adjacent cylinder cap, a pump chamber 58. The center of each diaphragm 56 is fixed, by means 60, to the adjacent end of the power piston rod 48.

It will be observed in FIGURES 2 and 3 that the pump inlets 24 and outlets 26 open into the pump chambers 58, respectively. Disposed within the pump inlets 24 are check valve means 62 which permit fluid flow into and block fluid flow from the respective pump chambers through the inlets. Similar check valve means 64 are mounted in the pump outlet 26 to permit fluid flow from but block fluid flow into the respective pump chambers through the outlets.

At this point, it is evident that reciprocation of the power piston 34 in the power cylinder 32 is effective to drive the diaphragms 56 in a reciprocating pumping motion. This pumping motion of the diaphragms is effective to draw fluid into the pump chambers 58 through their respective inlets 24 and to expell the fluid from the chambers through the respective outlets 26. It is obvious, of course, that the pump means 12 operate in alternate fashion; that is to say, each pump means undergoes its suction stroke during the discharge stroke of the other pump means. It is significant to note at this point that the diaphragms 56, being peripherally fixed, as they are, to the wall of the power cylinder 32, are effective to completely isolate the pump chambers 58 from the power cylinder bore 42 and, thereby, to entirely prevent fluid leakage between the pump chambers and the power cylinder bore.

The pilot valve 18 of the motor and pump assembly 10 comprises a pilot cylinder 66. Fixed within this pilot cylinder, by snap rings 68, is a cylinder liner 70. Slidable in this liner is a pilot valve piston 72. Pilot piston 72 comprises a sleeve-like element which is closed at its ends and includes a pair of internal partitions 74 which define, in the piston sleeve, a central chamber 76 and two outer chambers 78 and 80. Opening into the central chambers 76 are two sets 82 and 84 of circumferentially spaced ports. Opening into the piston chambers 78 are two additional sets 86 and 88 of circumferentially spaced ports. Finally, two sets of circumferentially spaced ports 90 and 92 open into the piston chamber 80. At the ends of the pilot piston 72 are enlarged piston heads 94 which slide in and are peripherally sealed to the wall of the pilot cylinder bore 96, beyond the ends of the cylinder liner 70. The piston sleeve, in the region between the piston heads, slides in the liner.

Cylinder liner 70, which may comprise a number of separate cylindrical sections disposed in end to end abutting relation, as shown, is externally sealed to the wall of the pilot cylinder bore 96 by means of a number of O-rings 98. The liner has a number of internally circumferential, axially spaced grooves 100, 102, 104, 106, and 108. The lands of the liner, between these grooves, are sealed to the outer surface of the pilot piston 72, by O-rings 109.

The main valve 20 is a substantial duplicate of the pilot valve 18 and differs from the latter valve only in arrangement of the valve liner grooves and the valve piston ports. Accordingly, the main valve will not be described in detail. Suffice it to say that the main valve has a cylinder 110 containing a valve piston 111. The main valve piston 111 includes a sleeve 112 with internal chambers 114, 116, and 118, sets 120, 122, and 124 of circumferentially spaced ports opening to the center chamber 114, additional sets 126 and 128 of circumferentially spaced ports opening to the chamber 116, and further sets 130 and 132 of circumferentially spaced ports opening to the chamber 118. The main cylinder liner 134 has internal circumferential grooves 136, 138, 140, 142, and 144.

At this point, it is significant to note that the seal rings which effectively seal the pilot and main valve pistons 72 and 111 to their respective cylinders, i.e., seal rings 109 in the pilot valve, are carried in sealing grooves in the valve liners and slidably engage the exterior surfaces of the valve pistons. The seal rings, therefore, are stationary and the valve pistons move relative to the rings. As will appear presently, this valve seal arrangement has distinct advantages and constitutes one important feature of the invention.

The cylinders of the power unit 16, pilot valve 18, and main valve 20 are separately fabricated and disposed in parallel side by side relation, as shown. The pilot valve is located between the power unit and the main valve. As will appear presently, this arrangement of the power unit and valves has certain distinct advantages and constitutes a second important feature of the invention. The pilot cylinder 66 and the main cylinder 110 have confronting sealing faces 146. The pilot cylinder and the power cylinder

32 have confronting sealing faces 148. The three cylinders are joined by bolts 150 in such a way that the respective confronting sealing faces are urged into fluid sealing relation. The high pressure fluid inlet 22 comprises a fitting threaded in the under side of the main cylinder 110 and containing a shut-off valve 152. The low pressure fluid outlet 24 opens to the center of the power cylinder 32 through a port 24a, to the pilot cylinder grooves 100 and 110 through ports 24b and 24c, respectively, and to the main cylinder grooves 136 and 144 through ports 24e and 24f, respectively.

The pilot valve 18 communicates with the main valve 20 through three fluid passages 154, 156, and 158. Passage 154 extends between the center groove 104 in the pilot cylinder 66 and center groove 140 in the main cylinder 110. The passage in the high pressure inlet 22 also opens to the center groove 140 in the main cylinder. It is evident, therefore, that when the pilot piston 72 occupies its right hand limiting position of FIGURE 2 in the pilot cylinder 66, high pressure fluid entering through the inlet 22 flows to the left hand end of the main cylinder 110 through the passage 154, the pilot piston chamber 76, and the passage 158. Simultaneously, the right hand end of the main cylinder is placed in communication with the low pressure outlet 24 through the passage 156, the pilot piston chamber 80, and the pilot cylinder port 24b. Under these conditions, then, the main piston 111 is urged to the right in its cylinder 110 from its left hand limiting position of FIGURE 2 to its right hand limiting position of FIGURE 3. Assume now that the pilot piston 72 occupies its left hand limiting position of FIGURE 3 in the pilot cylinder 66. In this case, the high pressure fluid inlet 22 communicates to the right hand end of the main cylinder 110 through the fluid passage 154, the center pilot piston chamber 76, and the passage 156. Simultaneously, the left hand end of the main cylinder is placed in communication with the low pressure outlet 24 through the passage 158, the right hand pilot piston chamber 78, and the pilot cylinder port 24c. The main piston 111 is then urged to the left in its cylinder 110 to its left hand limiting position of FIGURE 2. It is evident at this point, therefore, that alternate movement of the pilot piston 72 to its left hand and right hand limiting positions in the pilot cylinder 66 effects reciprocation of the main valve piston in its cylinder 110 between its right and left hand limiting positions, under the action of high pressure fluid entering through the inlet 22. It is significant to note, here, that the fluid passages 154, 156, and 158 which communicate the pilot valve 18 and the main valve 20 extend through the walls of the pilot cylinder 66 and the main cylinder 110 and that these passages open through the intervening confronting sealing faces 146 to define aligned ports in these faces which communicate the portion of each passage in the pilot cylinder 66 with the portion of the corresponding passage in the main cylinder 110. It is also significant to note that the confronting sealing faces 146 on the pilot cylinder 66 and main cylinder 110 are defined by the opposing faces of the confronting wall portions of these cylinders and that the passages extend through these confronting wall portions, thereby minimizing the overall length of these passages.

The grooves 138 and 142 in the main cylinder 110 communicate with opposite ends of the power cylinder 32 through fluid passages 160 and 162. When the main piston 111 occupies its left hand limiting position in the main cylinder 110, the high pressure fluid inlet 22 communicates to the left hand end of the power cylinder 32 through the center chamber 114 of the main piston 111 and the fluid passage 160. The right hand end of the power cylinder communicates to the low pressure outlet 24 through the passage 162 and the main cylinder port 24f. Under these conditions, then, the power piston 34 is driven to its right hand limiting position of FIGURE 2 in the power cylinder 32 under the action of the high pressure fluid

entering through the inlet 22. Assume now that the main piston 111 is shifted to its right hand limiting position of FIGURE 3 in the main cylinder 110. In this case, the high pressure fluid inlet 22 communicates to the right hand end of the power cylinder 32 through the center chamber 114 in the main piston 111 and the passage 162. The left hand end of the power cylinder communicates to the low pressure outlet 24 through the passage 160, the left hand chamber 118 of the main piston 111, and the main cylinder port 24e. Accordingly, the power piston 34 is driven to its left hand limiting position in the power cylinder.

It is now obvious, therefore, that reciprocation of the pilot piston 72 in the pilot cylinder 66 is effective to cause reciprocation of the main piston 111 in the main cylinder 110, and that this reciprocation of the main piston in the main cylinder is effective to cause reciprocation of the power piston 34 in the power cylinder 32.

As noted earlier, the power unit 16 functions as a valve mechanism for controlling the pilot valve 18. To this end, the power cylinder 32 communicates to opposite ends of the pilot cylinder 66 through passages 164 and 166. When the power piston 34 occupies its right hand limiting position of FIGURE 2 in the power cylinder 32, the passage 164 which extends to the left hand end of the pilot cylinder 66 communicates, through the power cylinder 32, to the passage 160. The passage 166 which extends to the right hand end of the pilot cylinder 66 communicates to the power cylinder exhaust port 24a. When the power piston occupies its left hand limiting position of FIGURE 3 in the power cylinder, the passage 166 extending to the right hand end of the pilot cylinder 66 communicates to the passage 162 and the passage 164 extending to the left hand end of the pilot cylinder communicates to the power cylinder exhaust port 24a. Assume now that the pilot and main pistons 72 and 111 occupy their limiting positions of FIGURE 2. As noted earlier, in these positions of the valve pistons, high pressure operating fluid flows from the inlet 22 through the passage 160 to the left hand end of the power cylinder 32 and low pressure fluid flows from the right hand end of the power cylinder, through the passage 162, to the low pressure fluid outlet 24, thereby effecting right hand movement of the power piston to its right hand limiting position of FIGURE 2. As the power piston approaches this limiting position, the piston head 50 uncovers the passages 164 and 166 leading to the ends of the pilot cylinder 66 in such a way as to permit high pressure fluid flow from the left hand end of the power cylinder to the left hand end of the pilot cylinder, through the passage 164, and flow of low pressure fluid from the right hand end of the pilot cylinder to the power cylinder exhaust port 24a through the passage 166, thereby effecting right hand movement of the pilot piston 72 to its right hand limiting position of FIGURE 2. As noted earlier, movement of the main piston 111 to its right hand limiting position of FIGURE 3 effects left hand movement of the power piston 34 to its left hand limiting position of FIGURE 3. During this left hand movement of the power piston, the piston head 50 uncovers the passages 164 and 166 in such a way as to permit high pressure fluid flow from the right hand end of the power cylinder 32 to the right hand end of the pilot cylinder 66 through the passage 166 and flow of low pressure fluid from the left hand end of the pilot cylinder to the power cylinder exhaust port 24a through the passage 164, thereby to effect left hand movement of the pilot piston to its left hand limiting position of FIGURE 3.

It is now evident, therefore, that reciprocation of the pilot piston 72 between its limiting positions in the pilot cylinder 66 is effective to cause synchronized reciprocation of the main piston 111 between its limiting positions in the main cylinder 110. Reciprocation of the main piston between its limiting positions, in turn, is effective to cause synchronized reciprocation of the power piston 34

between its limiting positions in the power cylinder 32. Finally, reciprocation of the power piston between its limiting positions in the power cylinder is effective to cause synchronized reciprocation of the pilot piston between its limiting positions. Thus, when the high pressure inlet 22 of the fluid motor 14 is connected to a source of operating fluid under pressure, such as the irrigation pipe line 28, the three motor pistons 34, 72, and 111 undergo synchronized reciprocation. Reciprocation of the power piston is effective to drive the diaphragms 56 in a reciprocating pumping motion, thereby to effect pumping of liquid fertilizer from the tank 30 into the irrigation pipe valve 20 have certain distinct advantages and constitutes line 28.

As noted earlier, the disclosed parallel side by side arrangement of the power unit 16, pilot valve 18, and main an important feature of the invention. Thus, the pilot valve 18, which is controlled by the power unit 16 and controls the main valve 20, is located in close proximity to both of these components because of the location of the pilot valve between the power unit and main valve. Accordingly, the required communicating fluid passages between these components are greatly simplified and reduced to an absolute minimum in length. The fact that the cylinders of the power unit, pilot valve, and main valve are separately formed and the fact that the passages in these components communicate through aligned ports further simplifies the arrangement of passages in the motor 14 and, in addition, simplifies the initial formation of these passages at the time of manufacture of the motor.

The sealing arrangement of the pilot valve 18 and the main valve 20 has certain distinct advantages and constitutes a second important feature of the invention. Thus, it will be observed that in contrast to conventional slide valve with externally grooved valve spools, the fluid flow through the present motor valves occurs through the interiors of the valve pistons 72 and 111. The seal rings 109 which seal these pistons to the respective cylinders are stationary and slidably engage the exterior surfaces of the pistons. It has been found that this sealing arrangement is highly effective in minimizing or eliminating abrasion of the sealing surfaces by particles of sand and other solid matter entrained in the irrigation water, or other fluid which powers the motor. Accordingly, the operating life of the motor is substantially increased. Moreover, there is little if any tendency for such particles to become trapped between the O-rings in the external surfaces of the valve sleeves. In addition, it is significant to note that the metallic parts of the pilot and main valves 18 and 20 which are subject to abrasion by entrained particles in the operating fluid are the sleeves of the valve pistons 72 and 111. Accordingly, even if abrasion does occur in the valve, the latter may be quickly and economically reconditioned by simply replacing the valve sleeves. This is in contrast to the more complicated and costly method required to recondition the valves of the aforementioned patent, for example, wherein the metallic parts which are subject to abrasion and which must be replaced if excessive abrasion occurs are the valve cylinders. The use of liners in the present pilot valve 18 and main valve 20 is also advantageous since these liners, if they become excessively abraded, may be replaced in minimum time and at minimum cost.

As noted earlier, a third important feature of the invention resides in the arrangements of the pump means 12. Thus, the pump diaphragms are effective to completely eliminate any possibility of leakage of liquid fertilizer from the pump chambers 58 into the power cylinder 32, and, thereby, to entirely prevent the liquid fertilizer from producing undesirable deposits in the power cylinder.

According, the invention herein described and illustrated is fully capable of attaining the several objects and advantages preliminarily set forth.

Although a specific embodiment of the present invention has been illustrated and described herein, it will be

understood that the same is merely exemplary of presently preferred embodiments capable of attaining the objects and advantages hereinbefore mentioned, and that the invention is not limited thereto; variations will be readily apparent to those versed in the art, and the invention is entitled to the broadest interpretation within the terms of the appended claims.

The inventor claims:

1. A slide valve comprising:

a cylinder having first and second axially spaced internal circumferential grooves, a first fluid port opening to said first groove, and a second fluid port opening to said second groove,

a relatively thin walled valve sleeve slidable in said cylinder and having an internal chamber at least equal in length to the axial spacing between said cylinder grooves, a number of first fluid ports in the wall of said sleeve circumferentially spaced about and opening to said chamber adjacent one end thereof, and a number of second fluid ports in the wall of said sleeve circumferentially spaced about and opening to said chamber adjacent the other end thereof, the axial spacing between said first and second sleeve ports being substantially equal to the axial spacing between said cylinder grooves,

said valve sleeve being axially movable in said cylinder between a first position wherein said first and second sleeve ports are aligned with said first and second cylinder grooves, respectively, thereby to permit fluid flow between said cylinder ports, and a second position wherein said sleeve blocks fluid flow between said cylinder ports, and

a number of resilient seal rings contained within internal circumferential sealing grooves in said cylinder and disposed in sliding sealing engagement with the external surface of said valve sleeve for blocking fluid leakage between said cylinder ports externally of said sleeve.

2. A slide valve comprising:

a cylinder having first and second axially spaced, internal circumferential grooves and an intervening internal circumferential groove located approximately midway between said first and second grooves, a first fluid port opening to said first groove, a second fluid port opening to said second groove, and an intervening fluid port opening to said intervening groove,

a relatively thin walled valve sleeve slidable in said cylinder and having an internal chamber, a number of first fluid ports in the wall of said sleeve circumferentially spaced about and opening to said chamber adjacent one end thereof, a number of second fluid ports in the wall of said sleeve circumferentially spaced about and opening to said chamber adjacent the other end thereof, and a number of intervening ports in the wall of said sleeve circumferentially spaced about and opening to said chamber approximately midway between said first and second sleeve ports,

the axial spacing between said first and second sleeve ports being less than the axial spacing between said first and second cylinder grooves, whereby said valve sleeve is movable between a first position wherein said first sleeve ports are aligned with said first cylinder groove and said second sleeve ports are axially spaced from said second cylinder groove and a second position wherein said second sleeve ports are aligned with said second cylinder groove and said first sleeve ports are axially spaced from said first cylinder groove,

the axial width of said intervening cylinder groove being at least equal to the axial travel of said valve sleeve between said first and second positions and said intervening cylinder groove being in constant communication with said intervening sleeve ports

throughout the range of travel of said valve sleeve between said first and second positions, whereby movement of said valve sleeve to said first position conditions said slide valve for fluid flow between said first and intervening cylinder ports and movement of said valve sleeve to said second position conditions said slide valve for fluid flow between said second and intervening fluid ports, and

a number of resilient seal rings contained within internal circumferential sealing grooves in said cylinder and disposed in sliding sealing engagement with the external surface of said valve sleeve for blocking fluid leakage between said cylinder ports externally of said sleeve.

3. A reciprocating fluid motor assembly comprising: a power unit including a cylinder and a power piston movable in the bore of said cylinder,

a pilot slide valve including a pilot valve cylinder and a pilot valve piston movable in the bore of said pilot cylinder,

a main slide valve including a main valve cylinder and a main valve piston movable in the bore of said main cylinder,

said cylinders being separately formed and disposed in parallel side by side relation,

the adjacent cylinders having confronting sealing faces, means joining said cylinders in such a way as to retain the respective confronting sealing faces in fluid sealing relation,

said pistons being movable between first and second limiting positions in their respective cylinder bores, one cylinder having a high pressure fluid inlet and one cylinder having a low pressure fluid outlet,

there being first passages in said cylinders communicating the ends of said main cylinder bore to said inlet and outlet through said pilot valve in such manner that movement of said pilot piston to its first position conditions said main valve for movement of said main piston to its first position under the action of high pressure fluid entering through said inlet and movement of said pilot piston to its second position conditions said main valve for movement of said main piston to its second position under the action of said entering fluid,

there being second passages in said cylinders communicating the ends of said power cylinder bore to said inlet and outlet through said main valve in such manner that movement of said main piston to its first position conditions said power unit for movement of said power piston to its first position under the action of said entering fluid and movement of said main piston to its second position conditions said power unit for movement of said power piston to its second position under the action of said entering fluid,

there being third passages in said cylinders communicating the ends of said pilot cylinder bore to said inlet and outlet through said power cylinder bore in such manner that movement of said power piston to its first position conditions said pilot valve for movement of said pilot piston to its second position under the action of said entering fluid and movement of said power piston to its second position conditions said pilot valve for movement of said pilot piston to its first position under the action of said entering fluid, whereby admission of high pressure fluid to said inlet effects synchronized reciprocation of said pistons between said positions thereof,

the communicating passages in adjacent cylinders communicating with one another through ports in the intervening confronting sealing faces, each of said valve pistons comprising a sleeve which is ported in such manner that fluid flow through the respec-

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tive valve occurs through the interior of said valve sleeve, and
 resilient seal rings contained in internal circumferential sealing grooves on each valve cylinder and disposed in sliding sealing engagement with the external surface of the respective valve sleeve for blocking fluid leakage between the sleeve and the wall of its respective cylinder. 5
 4. A reciprocating fluid motor assembly comprising:
 a power unit including a first cylinder block containing a power cylinder bore and a power piston movable in said cylinder bore, 10
 a pilot slide valve including a second cylinder block containing a pilot valve cylinder bore and a pilot valve piston movable in said pilot cylinder bore, 15
 a main slide valve including a third cylinder block containing a main valve cylinder bore and a main valve piston movable in said main cylinder bore, 20
 said cylinder blocks being separately formed and disposed in parallel side by side relation, and the adjacent cylinder blocks having confronting seating faces, 25
 means joining said cylinder blocks with the respective confronting seating faces thereof in fluid sealing relation,
 said motor assembly having a high pressure fluid inlet and a low pressure fluid outlet, and passage means

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communicating said inlet, outlet, and cylinder bores in such manner that said main valve piston is positioned in said main cylinder bore in response to positioning of said pilot valve piston in said pilot cylinder bore, said power piston is positioned in said power cylinder bore in response to positioning of said main valve piston in said main cylinder bore, and
 said pilot valve piston is positioned in said pilot cylinder bore in response to positioning of said power piston in said power cylinder bore, and
 said passage means including communicating passages in the adjacent cylinder blocks which communicate through aligned ports in the intervening cylinder block seating faces.

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