United States Patent

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[54] RECIPROCATING PUMP

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[52] **U.S. Cl.**.....**417/400,** 91/321

[51] **Int. Cl.**.....**F04b 17/00,** F04b 35/00, F01b 7/18

[58] **Field of Search**.....417/400, 399, 401, 402, 383, 417/384, 398; 91/321, 345

[56] **References Cited**

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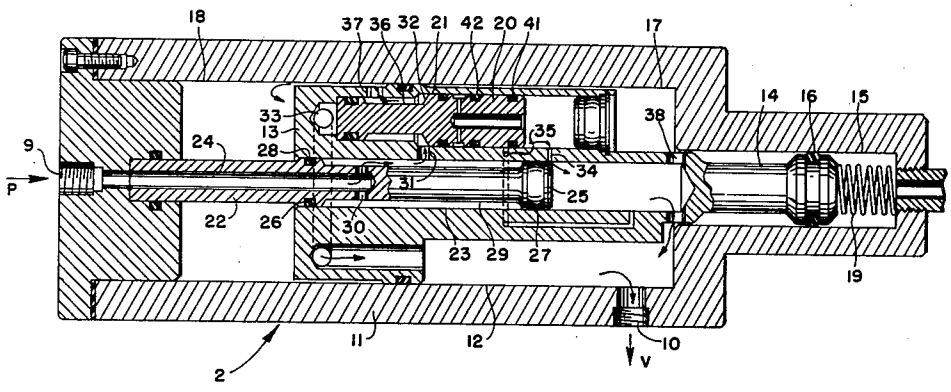
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[57] **ABSTRACT**

Reciprocating pump includes a piston contained in a cylinder which is continuously vented at one end, and the other end is alternately subjected to pressure and vented through a simplified valve and porting arrangement. During the pressure phase, the piston is moved in the direction of the continuously vented end, whereas return movement of the piston is caused by an external applied force upon venting the pressure. The valving is located in the piston for maximum simplicity and most direct porting, and a small diameter fixed porting tube may be used to supply pressure to the valving in the piston through porting. The valving and porting relationships between elements assure against pump stalling.

16 Claims, 11 Drawing Figures



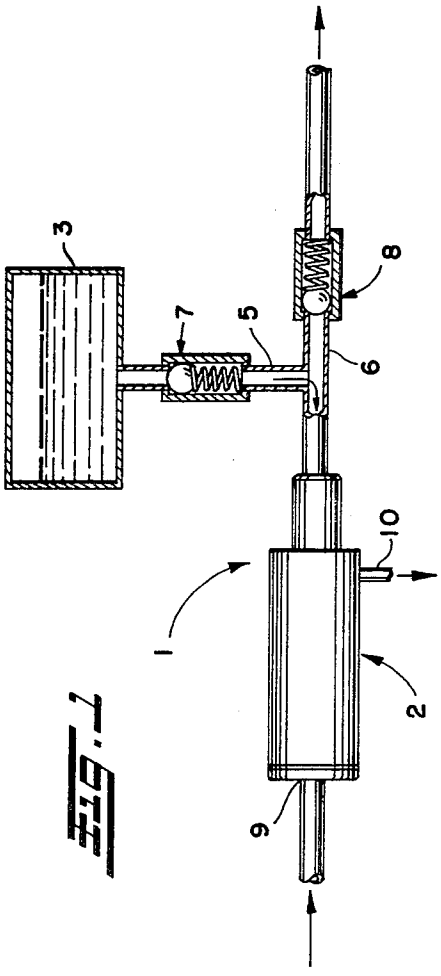


FIG. 1

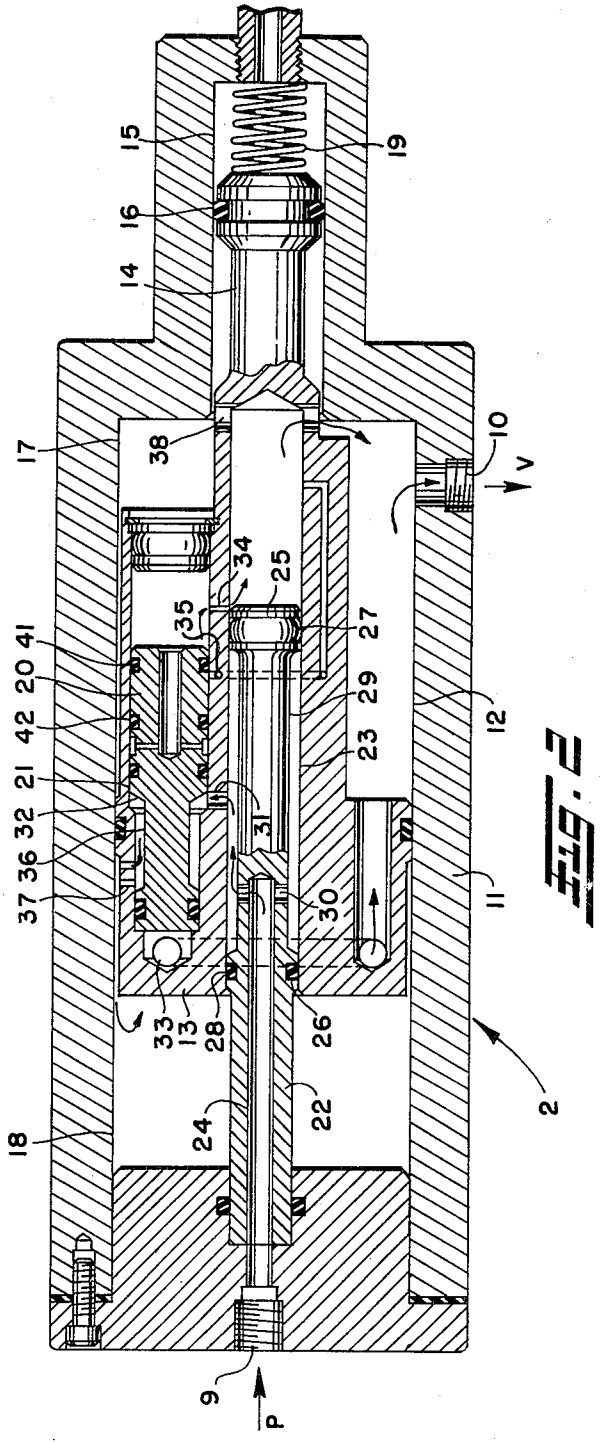


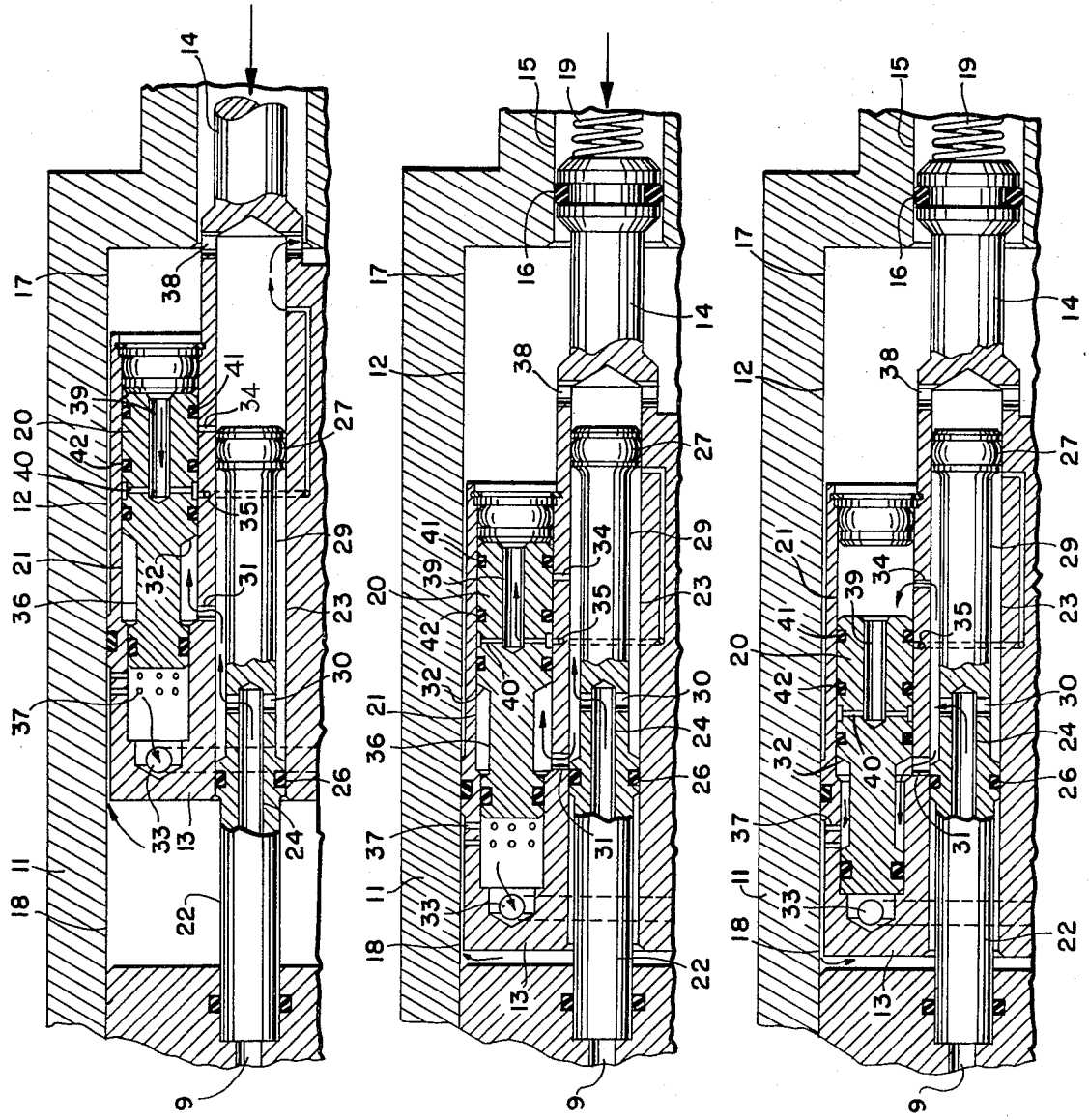
FIG. 2

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FIG. 3

FIG. 4

FIG. 5



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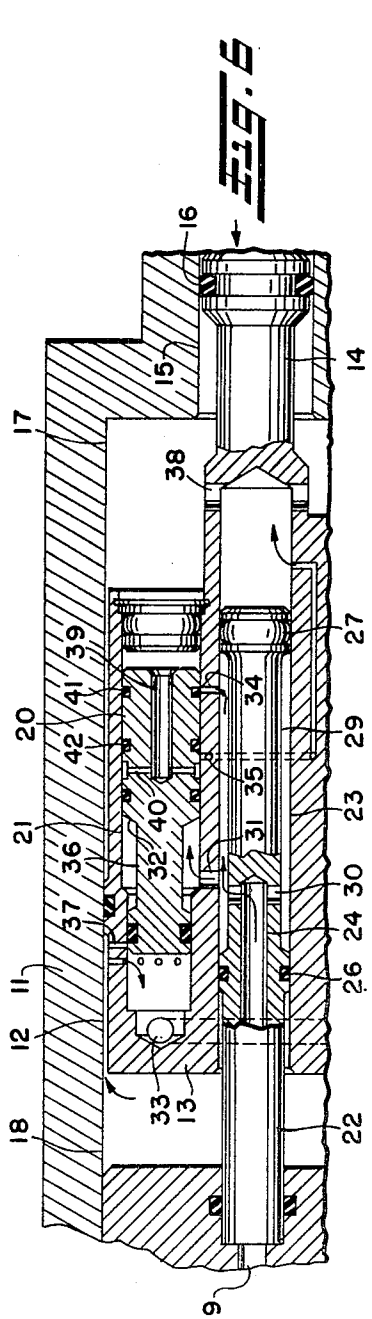


FIG. 6

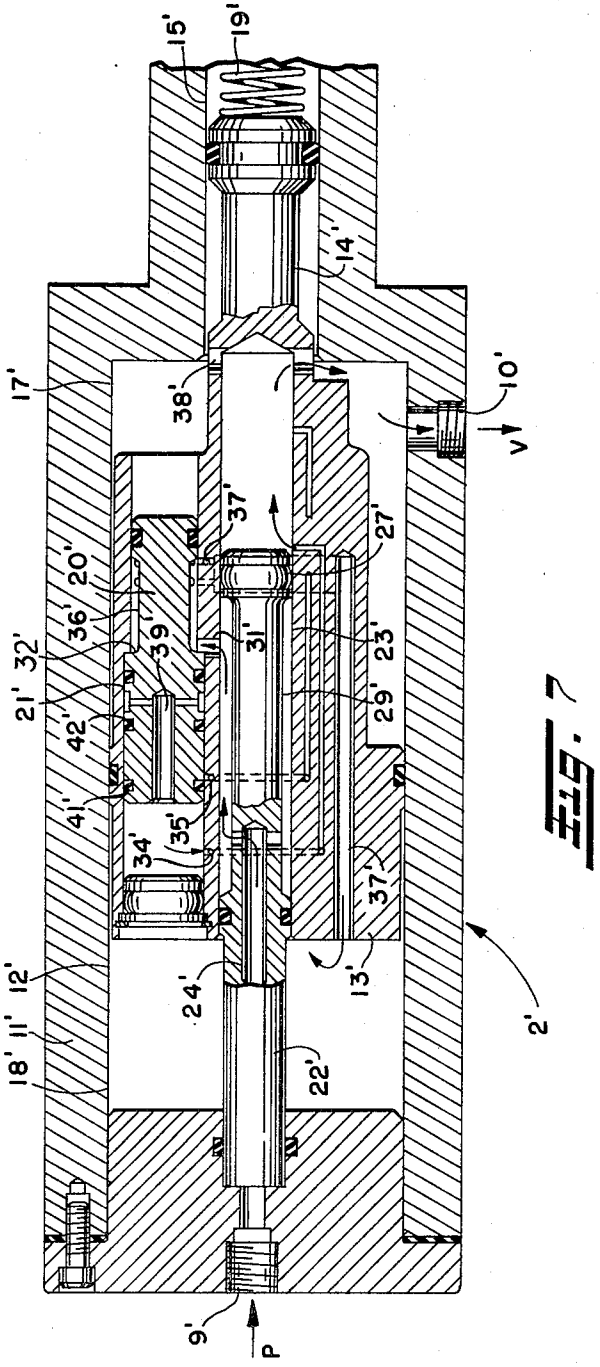


FIG. 7

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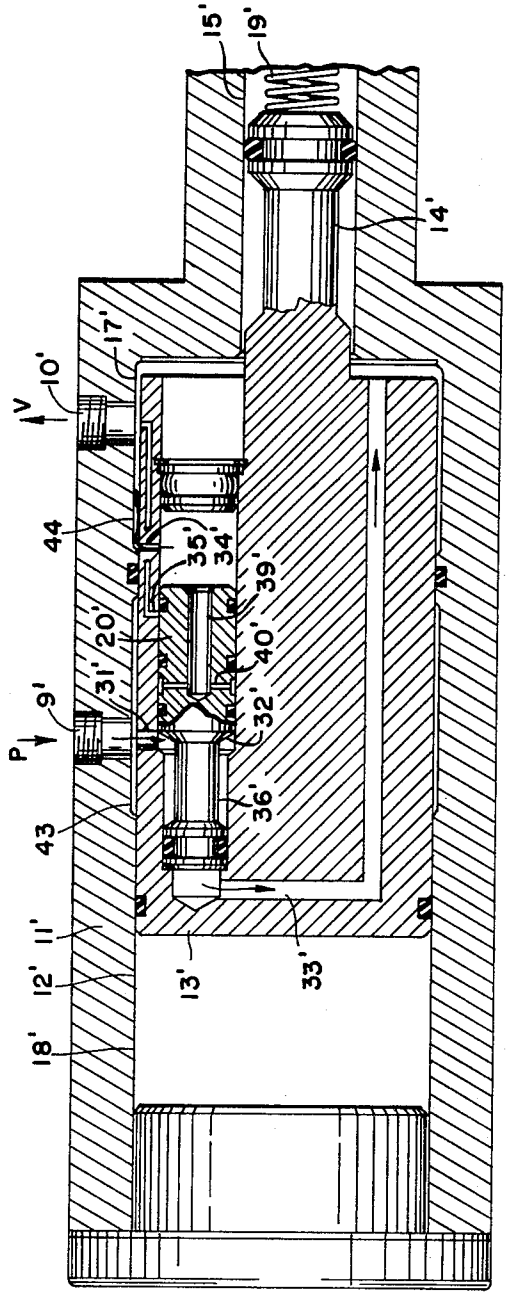


FIG. 2

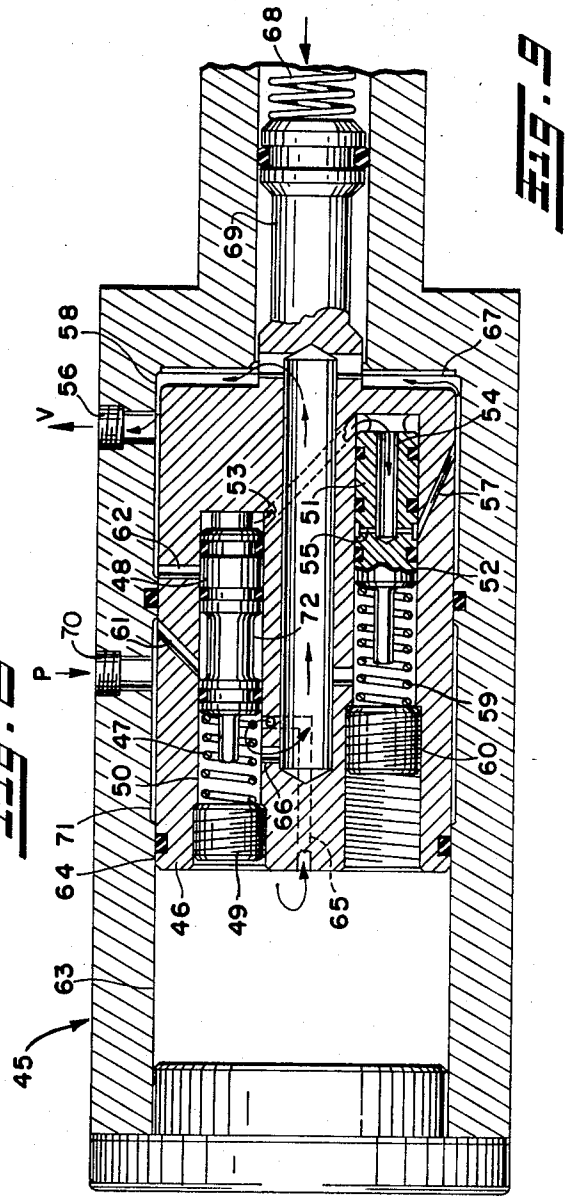


FIG. 5

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Fig. 10

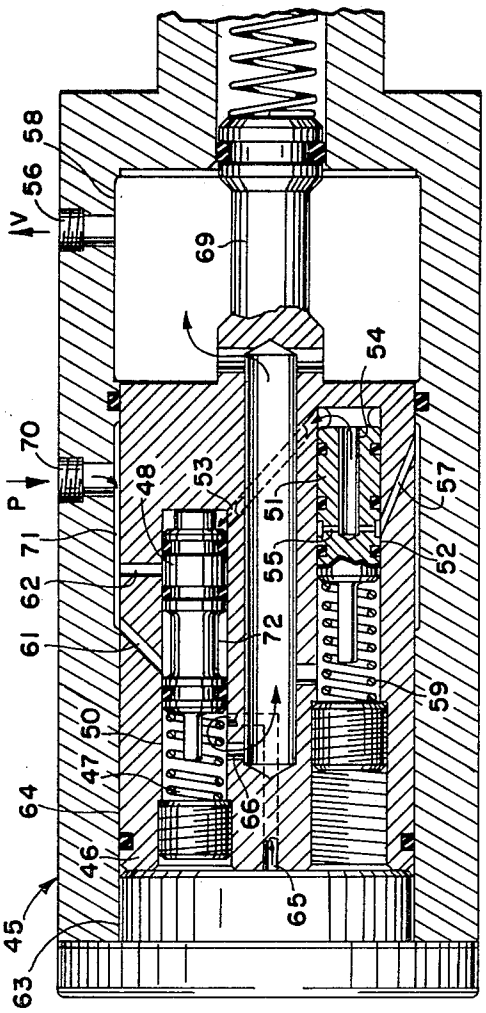
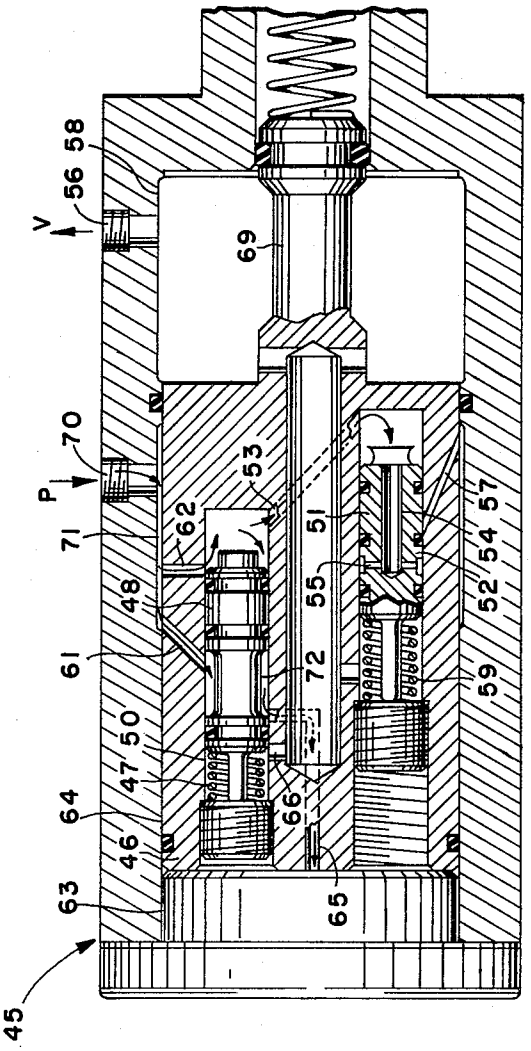


Fig. 11



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RECIPROCATING PUMP

BACKGROUND OF THE INVENTION

This invention generally relates to a reciprocating pump, preferably driven by a regulated gas supply to develop high fluid pressure at the outlet.

Previous known pumps and motors of this same general type were usually provided with a differential area piston having a smaller effective area at one end which was continuously subjected to inlet pressure and a larger effective area at the other end which was alternately subjected to inlet pressure and exhaust, causing the piston to reciprocate. To obtain such alternate pressure and exhaust at the larger area end of the piston usually required the use of relatively complicated valve and porting arrangements which not only made the pumps costly to manufacture but they were also usually inefficient and slow acting. Moreover, they were susceptible to stalling under certain operating conditions, particularly during slow startup or when the valve was located in an intermediate position in which the pressure across the valve was balanced, preventing movement.

SUMMARY OF THE INVENTION

A principal object of this invention is to provide a reciprocating pump with an improved and simplified valve and porting arrangement for controlling piston movements. One end of the piston is cylinder continuously vented, and the other end is alternately vented and pressurized by valving which is desirably located in the piston for maximum simplicity and most direct porting. During the pressure phase the piston is caused to move in one direction, and when the pressure is vented the piston is moved in the reverse direction by an external applied force.

In one form of the invention, a small diameter fixed porting tube extending into the center of the piston supplies pressure to the valve while greatly reducing seal friction. Resilient seals are also desirably used on all sealing lands to reduce cost and improve efficiency by substantially eliminating fluid leakage between moving parts. The porting between the porting tube and valve also prevents pump stall-out regardless of the position of parts.

To the accomplishment of the foregoing and related ends the invention, then, comprises the features hereinafter fully described and particularly pointed out in the claims, the following description and the annexed drawings setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but a few of the various ways in which the principles of the invention may be employed.

BRIEF DESCRIPTION OF THE DRAWINGS

In the annexed drawings:

FIG. 1 is a schematic view showing a typical hydraulic system incorporating a reciprocating pump constructed in accordance with the present invention;

FIGS. 2 through 5 are fragmentary longitudinal sections through a preferred form of pump constructed in accordance with this invention showing the various positions of the pump piston and porting and valving mechanism during a complete pump cycle;

FIG. 6 is a fragmentary longitudinal section through the pump of the FIGS. 2–5 embodiment showing the valve plunger in an intermediate position;

FIGS. 7 and 8 are fragmentary longitudinal sections through modified forms of pumps constructed in accordance with the present invention; and

FIGS. 9 through 11 are fragmentary longitudinal sections through yet another form of pump in accordance with this invention, showing the various positions of the piston and porting and valving mechanism during a pump cycle.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now in detail to the drawings and first especially to FIG. 1, there is schematically shown a hydraulic system 1 including a pump 2 and reservoir 3 containing hydraulic fluid which is directed to the pump 2 through a fluid line 5 for discharge from the pump outlet 6 under high pressure. Check valves 7 and 8 may be provided within the fluid lines associated with the reservoir and pump outlets to prevent reverse flow of the fluid. The pump 2 requires a constant low pressure gas supply connected to the pump inlet 9 for operation and develops a high hydraulic pressure which is a function of the relative areas of the piston acted upon by the inlet gas pressure and piston rod acting on the hydraulic fluid. A vent 10 is provided for venting one or both sides of the piston to cause the same to reciprocate, as described hereafter.

One form of pump 2 constructed in accordance with this invention is shown in detail in FIGS. 2 through 6, and includes a housing 11 containing a cylinder 12 in which is axially slidably received a piston 13. The piston rod 14 extends into a pumping chamber 15 to which hydraulic fluid is supplied from the reservoir 3 through the fluid line 5. An external seal 16 on the piston rod 14 prevents leakage of such hydraulic fluid around the piston rod into the rod end 17 of the cylinder 12 which is continuously vented through the vent opening 10.

Reciprocation of the piston 13 is caused by alternately pressurizing and venting the head end 18 of the cylinder 12, in a manner to be more fully described hereinafter. With the head end 18 of the cylinder 12 vented, the piston 13 is caused to move to the left by an external applied force acting on the outer end of the piston rod 14, which may be applied by placing the reservoir fluid under pressure or by disposing an external spring 19 between the piston rod and outer end of the pumping chamber 15 as shown. Movement of the piston 13 in the reverse direction (i.e., toward the right) is caused by supplying the inlet gas pressure to the head end 18 of the cylinder 12 which produces a force acting on the larger area piston 13 substantially greater than the relatively low opposing external applied force acting on the smaller area of the rod 14. In one form of the present invention, a 500 psi gas supply was used to develop 3,000 psi hydraulic pressure during the pressure stroke of the piston rod, and a hydraulic reservoir pressure of 100 psi was used to return the piston when the pressure acting on the head end of the piston was dumped.

For alternately venting and pressurizing the head end 18 of the cylinder 12, a valve plunger 20 is provided,

desirably contained within a bore 21 in the piston 13 for maximum simplicity, more direct porting, and minimum cost and weight. Supply pressure is fed to the valve bore 21 through a relatively small diameter porting tube 22 extending from the head end of the cylinder into a central longitudinal bore 23 in the piston 13 and piston rod 14. The porting tube 22 is fixed and has a longitudinal passage 24 therein communicating with the gas supply inlet 9 to the pump housing 11. A pair of longitudinally spaced external grooves 25 and 26 in the outer surface of the porting tube 22 contain annular seals 27 and 28 which remain in sealed engagement with the central bore 23 of the piston 13 during reciprocation thereof. Between the annular seals 27 and 28 the porting tube 22 is externally grooved at 29 for a substantial length and there is a transverse passage 30 in the porting tube for supplying pressure from the longitudinal passage 24 to the external groove 29. A port 31 in the piston 13 provides communication between the groove 29 and valve bore 21 for supplying pressure to the valve bore 21 for all portions of the piston 13 within the cylinder 12.

The valve plunger 20 is stepped as shown to provide a differential pressure area 32 intermediate its length which is acted on by the supply pressure entering the valve bore 21 through the port 31, urging the valve plunger 20 toward the right. The left end of the valve bore 21 is always vented through a passage 33 in the piston 13 communicating with the rod end 17 of the cylinder 12 which is continuously vented through the vent opening 10 as aforesaid. The right end of the valve bore 21, on the other hand, is pressurized or vented depending on the relative position of the valve plunger 20 with respect to two longitudinally spaced trigger ports 34 and 35 extending between the valve bore 21 and piston bore 23 containing the porting tube 22. When the right end of the valve bore 21 is vented, the valve plunger 20 is caused to move to the right by the supply pressure acting on the differential area 32, whereas when the right end of the valve bore 21 is pressurized, the valve plunger 20 is caused to move to the left because of the larger area at the right end of the valve plunger 20 acted upon by supply pressure.

With the valve plunger 20 in the extreme left portion shown in FIG. 2, supply pressure entering the valve bore 21 is ported to head end 18 of the cylinder 12 through an external groove 36 in the valve plunger 20 and additional ports 37 leading to the head end of the piston, whereby the piston is caused to move to the right against the bias of the external force acting on the outer end of the piston rod 14. As the piston 13 approaches its extreme right position as further shown in FIG. 2, the first trigger port 34 passes over the porting tube seal 27 and vents the right end of the valve bore 21 through the right end of the piston tube bore 23, vent passages 38, and rod end of the cylinder 12. This allows the supply pressure acting on the differential area 32 of the valve plunger 20 to snap the valve plunger to the extreme right position shown in FIG. 3 for venting the cylinder head pressure through the small port hole pattern 37 and vent passage 33 in the piston 13. The second trigger port 35 was opened to the vented end of the porting tube bore 23 prior to the first trigger port 34 during movement of the piston 13 to the right, but the second trigger port 35 was precluded from venting the right end of the valve bore 21 by the valve plunger 20 itself. When the valve plunger 20 reaches its extreme right position shown in FIG. 3, the right end of the valve bore 21 is continued to be vented through passages 39 and 40 in the valve plunger which communicate the right end of the valve bore with the second trigger port 35.

Venting of the head end 18 of the cylinder 12 soon causes the pressure to drop below a level at which the external applied force of the low hydraulic return pressure or return spring 19 is sufficient to return the piston 13 to the left as shown in FIG. 4. During such leftward movement of the piston 13, the first trigger port 34 passes back over the outer porting tube seal 37 into communication with the supply pressure groove 29 prior to the second trigger port 35, but pressure flow to the right end of the valve bore 21 through the first trigger port 34 is initially blocked by the valve plunger. However, when the piston 13 reaches its extreme left position shown in FIG. 4, the second trigger port 35 is pressurized by communication with the pressure groove 29 thus pressurizing the right end of the valve bore 21 which forces the valve plunger 20 to the left as shown in FIG. 5. When this occurs, pressure is again supplied to the head end 18 of the cylinder 12 through the valve plunger groove 36 and aligned piston ports 37 to cause the piston 13 to move back to the right as shown in FIG. 2, and so on. The stroke of the piston 13 is determined by the spacing between the trigger ports 34 and 35 where they communicate with the porting tube bore 23, and such trigger ports are desirably located so that the piston does not bottom during movement in either direction.

The relative spacing between the trigger ports 34 and 35 in the valve bore 21 and spaced apart fluid seals 41 and 42 on the valve plunger 20 which isolate the trigger ports from each other is also important to prevent pressure lock of the valve plunger and stall-out of the pump under all operating conditions. As best seen in FIG. 6, the trigger ports 34 and 35 in the valve bore 21 are dimensionally positioned somewhat further apart then the valve plunger seals 41 and 42 to allow a small amount of flow to pass through the trigger ports when the valve plunger 20 is in the intermediate position shown. At that time, the head end 18 of the cylinder 12 is open to the vent passage 33 at the left end of the valve bore 21, allowing the piston 13 to be moved to the left by the external applied force. Accordingly, even though the valve plunger 20 may be in a pressure-balanced position preventing movement of the valve plunger 20 during initial start-up of the pump, when the piston 13 reaches the end of its stroke, both trigger ports 34 and 35 will be pressurized, whereby pressure will leak past both valve plunger seals 41 and 42 and pressurize the right end of the valve bore 21, causing the valve plunger 20 to move to the left. At that time normal operation of the pump will be resumed.

In FIG. 7 there is shown a modified form of pump 2' which is substantially identical to the pump 2 of the FIGS. 2 through 6 embodiment and accordingly the same reference numerals followed by a prime symbol are used to designate like parts. The only significant difference is that the valve plunger 20' has been reversed and porting modified to permit direct venting of the right end of the valve bore 21' to the continu-

ously vented rod end 17' of the cylinder 12'. Otherwise, the details of construction and operation are substantially the same.

By using the small diameter porting tube 22 extending into the center of the piston 13 as previously described, the frictional seal forces developed during pump operation are greatly reduced. Moreover, using resilient seals on all sealing lands rather than lap fits reduces cost and improves efficiency by virtually eliminating leakage between moving parts. To insure adequate seal life, relatively small holes with controlled corner breaks may be used for the ports 34, 35 and 37 which cross over seals and teflon capstrips may be used over the seals to resist abrasion.

However, it will be apparent that lap fits may be used between moving parts if desired. Moreover, it will also be apparent that the fixed porting tube despite its advantages may be eliminated and annular grooves 43 and 44 provided in the inner wall of the main cylinder 12', one of which is pressurized and the other vented as shown in FIG. 8 to alternately pressurize and vent the head end 18' of the cylinder 12' during shutting of the valve plunger 20' as before, Otherwise, the details of construction and operation of the pump of the FIG. 8 embodiment are substantially identical to the pump 2 previously described, and the same reference numerals followed by a prime symbol are used to designate like parts. Of course, when the gas is ported to the valve plunger 20' through the main piston 13' diameter as shown in FIG. 8, the seal frictional forces are much greater unless the parts are lap-fitted at additional expense.

In FIGS. 9 through 11 there is shown still another form of pump 45 in accordance with this invention which is ported through the main piston 46 diameter as in the FIG. 8 embodiment rather than through a central fixed porting tube, and in addition, a spring 47 is utilized for return movement of the main porting valve plunger 48 to eliminate having to use a differential area plunger. The return spring 47 is interposed between the left end of the main vale plunger 48 and a plug 49 in the left end of the main valve bore 50.

When the main piston 46 is in its extreme right position shown in FIG. 9, the right end of the main valve bore 50 is vented through a supplemental valve plunger 51 contained in a supplemental valve bore 52 in the piston 46. The right ends of both valve bores 50 and 52 are interconnected by a passage 53 in the main piston 46, and the supplemental valve plunger 51 has longitudinal and radial passages 54 and 55 therein which provide communication between the right end of the supplemental valve bore 52 and the vent port 56 through a further passage 57 in the main piston 46 and vent groove 58 when the supplemental valve plunger 51 is in its extreme right position where it is biased by a spring 59 interposed between the left end of the supplemental valve plunger 51 and a plug 60 in the left end of such bore. The spring 47 is lighter than the spring 59, for a purpose to be subsequently described.

With the right end of the main valve bore 50 vented, the main valve plunger 48 is biased to its extreme right position shown in FIG. 9 by the return spring 47, blocking both of the trigger ports 61 and 62 and permitting venting of the head end 63 of the main cylinder 64 through a first passage 65 in the main piston 46 communicating the head end of the cylinder with the main valve bore 50 and a second passage 66 in the piston 46 communicating the main valve bore 50 with the rod end 67 of the cylinder which is continuously vented. When the pressure in the head end of the cylinder reaches a low enough level, the piston 46 will be caused to move to the left by the external applied force of the hydraulic return pressure or return spring 68 acting on the outer end of the piston rod 69 as before.

FIG. 10 shows the piston 46 at its extreme left position at which time supply pressure at the inlet 70 is ported to the right end of both valve plunger bores 50 and 52 by way of the pressure groove 71 and communicating passages 57, 53, 54 and 55 in the piston 46 and supplemental valve plunger 51. Both ports 61 and 62 were opened to supply pressure prior to the passage 57, but flow therethrough was blocked by the main valve plunger 48.

With supply pressure at the right end of the main valve bore 50, the main valve plunger 48 is caused to move to the extreme left position shown in FIG. 11, at which time port 61 is connected to the head end 63 of the cylinder 64 through an annular groove 72 in the main valve plunger 48 and passage 65 running between the head end of the piston and the main valve bore 50. Venting of the head end of the cylinder 64 through the passage 66 at that time is prevented by the main valve plunger 48 which blocks communication between the passages 66 and 65.

The supplemental valve plunger 51 is also urged to the left by the pressure in the right end of its associated bore 52, but not before the main valve plunger 48 has reached its extreme left position due to the lighter spring 47 has reached its extreme left position due to the lighter spring 47 acting thereon so that supply pressure is continued to be supplied to the right ends of both valve bores 50 and 52 through the trigger port 62 prior to the trigger port 57 being blocked by movement of the supplemental valve plunger 51. Pressure buildup in the head end 63 of the cylinder 64 will cause the piston 46 to move once again to the right to complete the cycle, and the cycle will be repeated until the supply pressure is interrupted.

From the foregoing, it will now be seen that each of the pump designs disclosed herein includes a simplified valve and porting arrangement which permits efficient and reliable operation of the pump without chance of pump stall out. The valving for the pump is desirably completely contained within the piston for maximum simplicity and most direct porting of the head end of the cylinder, and the rod end of the cylinder is desirably always vented. A lowe external force continuously applied to the piston rod causes return movement of the piston during venting of the head end of the cylinder, and a simplified porting tube may be utilized to supply pressure to the valve which greatly reduces seal friction.

I, therefore, particularly point out and distinctly claim as my invention:

1. A reciprocating pump comprising a housing containing a cylinder including a rod end and a head end, a piston reciprocable within said cylinder, a rod extending from said piston through the rod end of said cylinder, valve means for supplying pressure to the

head end of said cylinder when said piston is adjacent said head end to cause movement of said piston toward the rod end and for venting said head end when said piston is adjacent the rod end of said cylinder, and means for returning said piston toward said head end of said cylinder when said head end is vented as aforesaid, said valve means being contained in a valve bore in said piston, and a porting tube extending from the head end of said cylinder into an opening in said piston, said porting tube and piston having communicating passages therein for supplying pressure through said porting tube to said valve bore.

2. The pump of claim 1 further comprising vent means for continuously venting said rod end of said cylinder.

3. The pump of claim 1 wherein said means for returning said piston toward said head end of said cylinder comprises a spring acting on the outer end of said piston rod.

4. The pump of claim 1 wherein said means for returning said piston toward said head end of said cylinder comprises the hydraulic fluid to be pumped which is maintained under low pressure.

5. The pump of claim 1 wherein said porting tube has a pair of longitudinally spaced external seals in sealing engagement with the wall of said opening in said piston, and an external groove between said seals, said porting tube also having a passage therein extending from the head end of said cylinder to said groove for supplying pressure to said groove, said piston having a first port between said valve bore and opening which provides communication between said groove in said porting tube and said valve bore, a vent passage communicating with said valve bore, and a second port extending from the head end of said piston to said valve bore, said valve means when disposed at one end of aid valve bore providing communication between said second port and said vent passage for venting the head end of said cylinder, and when positioned at the other end of said valve bore estabiishing communication between said first and second ports for supplying pressure to said head end of said cylinder, and means for moving said valve mans from one end of said valve bore to the other when said piston reaches the ends of its stroke.

6. The pump of claim 5 wherein said means for moving said valve means as aforesaid comprises a pair of longitudinally spaced trigger ports in said piston connecting said valve bore with said opening for said porting tube said trigger ports being positioned to supply pressure from said external groove in said porting tube to one end of said valve bore when said piston is at the rod end of its stroke for moving said valve means to the other end of said valve bore, and also positioned to vent said one end of said valve bore to the inner end of said opening in said piston when said piston is at the head end of its stroke, a passage in said piston venting the inner end of said opening to the rod end of said cylinder, and means for moving said valve means to said one end of said valve bore upon venting said one end.

7. The pump of claim 6 wherein said means for moving said valve means to said one end of said valve bore comprises a differential area on said valve means less than the area of said one end of said valve means, and porting in said piston for supplying pressure to said valve bore which acts on said differential area.

8. The pump of claim 6 wherein said means for moving said valve means to said one end of said valve bore comprises a spring interposed between said valve means and the other end of said valve bore.

9. A reciprocating pump comprising a housing containing a cylinder including a rod end and a head end, a piston reciprocable within said cylinder, a rod extending from said piston through the rod end of said cylinder, valve means for supplying pressure to the head end of said cylinder when said piston is adjacent said head end to cause movement of said piston toward the rod end and for venting said head end when said piston is adjacent the rod end of said cylinder, and means for returning said piston toward said head end of said cylinder when said head end is vented as aforesaid, said valve means being contained in a valve bore in said piston, and a pair of longitudinally spaced trigger ports in said piston which alternately vent and pressurize one end of said valve bore at opposite ends of the stroke of said piston to cause movement of said valve means for alternately venting and pressurizing the head end of said cylinder.

10. The pump of claim 9 wherein said valve means has a pair of longitudinally spaced seals which isolate said trigger ports from each other for all positions of said valve means, said valve means when in a pressure balanced position with respect to said trigger ports causing venting of the head end of said cylinder to permit movement of said piston toward the head end of said cylinder by the external applied force, the relative spacing between said trigger ports in said valve bore being somewhat greater than the relative spacing between said seals in said valve means, whereby when said piston reaches the head end of said cylinder, pressure is supplied to both of said trigger ports and is permitted to leak past both of said seals to said one end of said valve bore, causing movement of said valve means toward the other end of said valve bore.

11. The pump of claim 9 wherein said valve means is caused to move to the other end of said valve bore in response to pressure applied to said one end of said valve bore, and means are provided for moving said valve means to said one end of said valve bore upon venting said one end.

12. The pump of claim 11 wherein said means for moving said valve means to said one end of said valve bore comprises a differential area on said valve means less than the area of said one end of said valve means, and porting in said piston for supplying pressure to said differential area.

13. The pump of claim 11 wherein said means for moving said valve means to said one end of said valve bore comprises a spring interposed between said valve means and the other end of said valve bore.

14. A reciprocating pump comprising a housing containing a cylinder including a rod end and a head end, a piston reciprocable within said cylinder, a rod extending from said piston through the rod end of said cylinder, valve means for supplying pressure to the head end of said cylinder when said piston is adjacent said head end to cause movement of said piston toward the rod end and for venting said head end when said piston is adjacent the rod end of said cylinder, and means for returning said piston toward said head end of said cylinder when said head end is vented as aforesaid, said piston containing a first valve bore for receipt of

said valve means, and a second valve bore for receipt of a supplemental valve means through which one end of said valve means is alternately pressurized and vented when said piston reaches the ends of its stroke, the pressurizing of said one end of said first valve bore causing said valve means to move to the other end of said first valve bore for pressurizing the head end of said cylinder, and means for moving said valve means to said one end of said first valve bore for venting the head end of said cylinder upon venting said one end of said first valve bore.

15. The pump of claim **14** wherein said last-mentioned means comprises a spring interposed between said valve means and the other end of said first valve bore.

16. The pump of claim **15** wherein said supplemental valve means is movable by the pressure supplied to said one end of said first valve bore to a position blocking further pressure flow therethrough, and a further spring stronger than the spring acting on said valve means resists such movement of said supplemental valve means until said valve means has moved to a position permitting pressure to be supplied to said one end of said first valve bore through a trigger port in said piston.

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