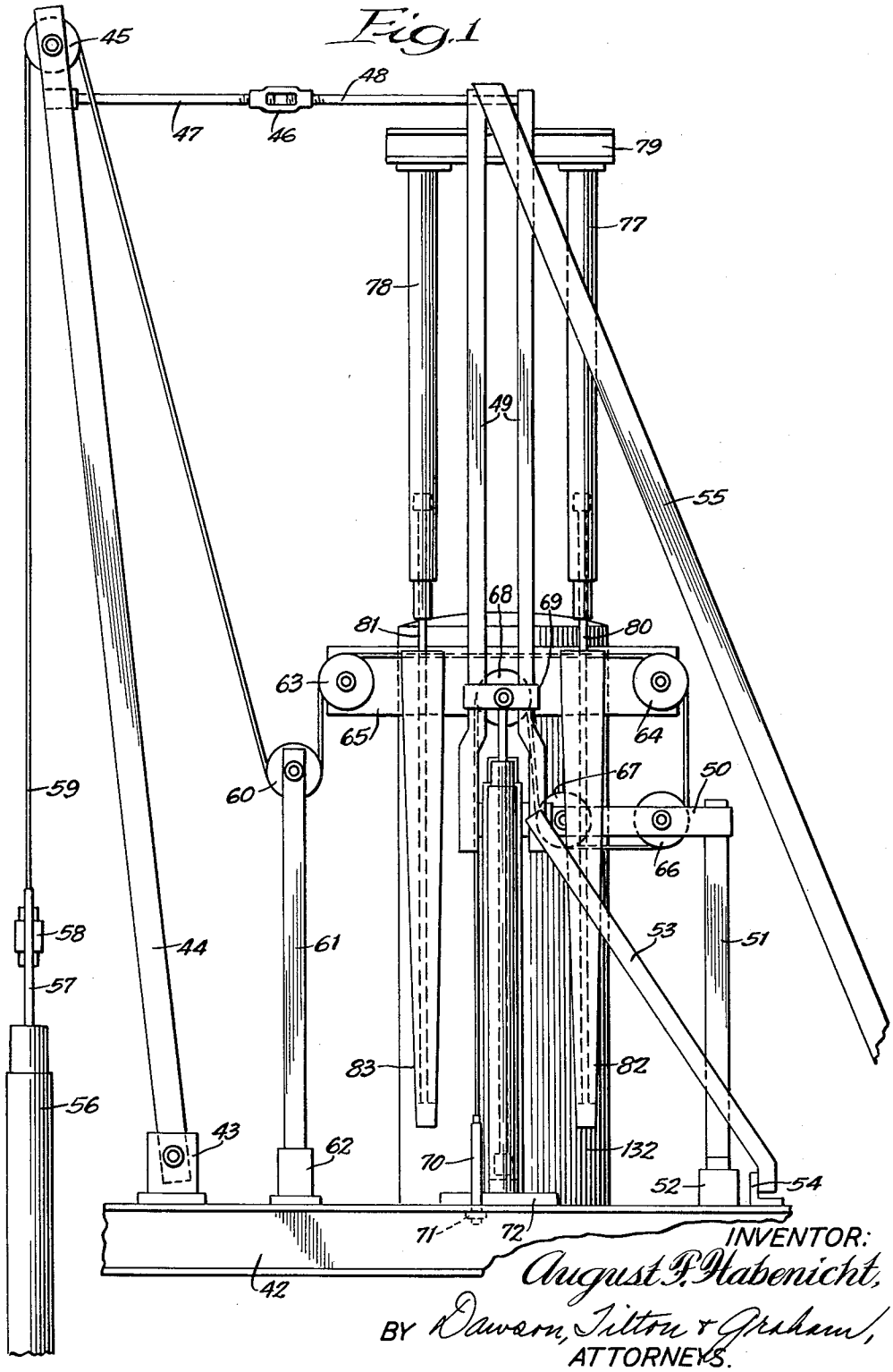
Sept. 12, 1961 A. F. HABENICHT 2,999,360

HYDRAULIC PUMP APPARATUS

Filed May 26, 1959 2 Sheets-Sheet 1

Fig. 1



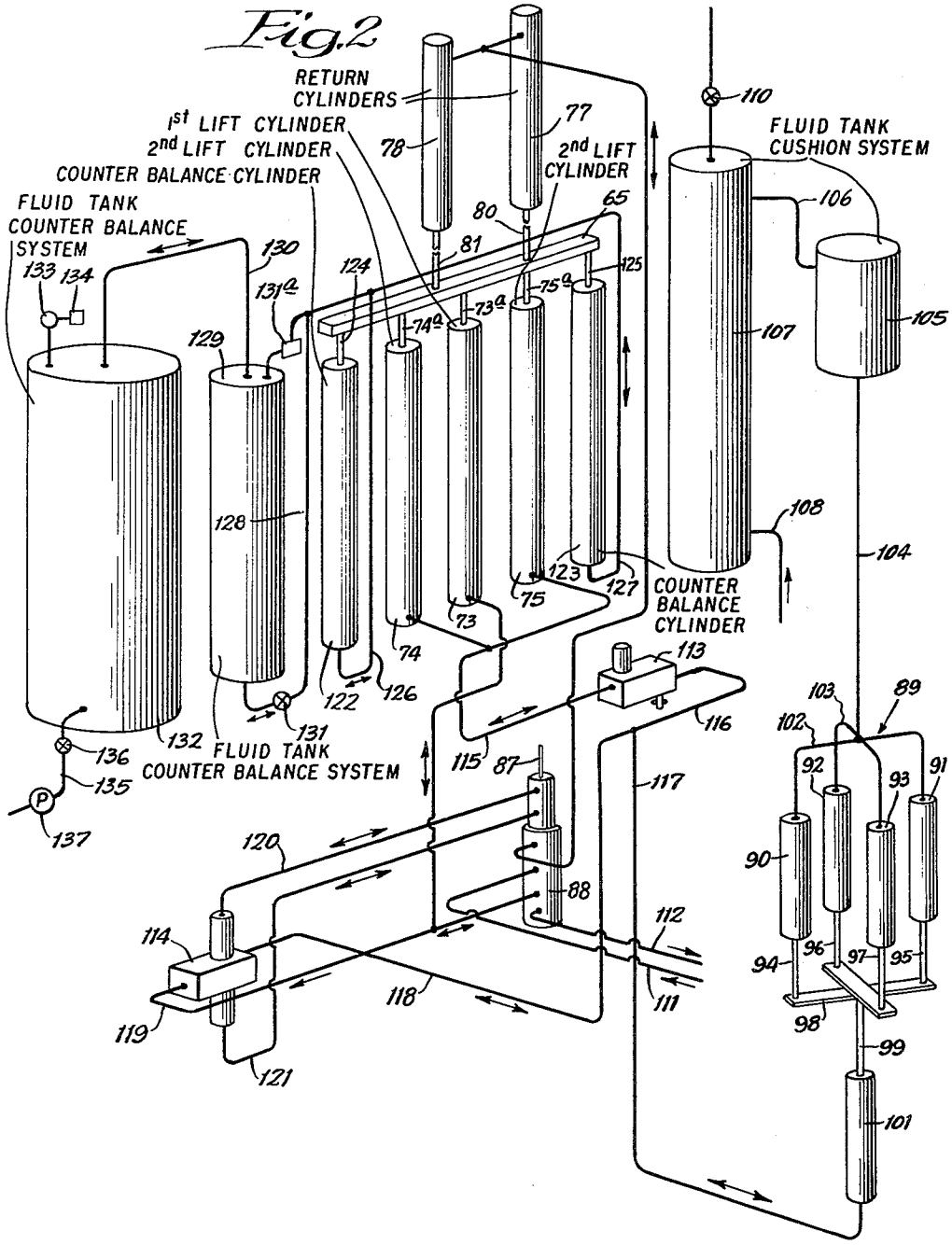
INVENTOR:
August F. Habenicht,
BY Dawson, Tilton & Graham,
ATTORNEYS.

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Fig. 2



INVENTOR:
August F. Habenicht,
BY Dawson, Tilton & Graham,
ATTORNEYS.

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HYDRAULIC PUMP APPARATUS

August F. Habenicht, 17221 67th Court, Tinley Park, Ill.

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4 Claims. (Cl. 60—51)

This invention relates to a hydraulic power unit, and more particularly to hydraulic pump apparatus especially useful in connection with deep wells.

In my copending application, Serial No. 560,179, filed January 19, 1956, now Patent No. 2,887,846, of which this is a continuation-in-part, I disclose a hydraulic pump that while being useful in connection with both shallow and deep wells, is especially suited for use in the latter instance. In deep wells that are often greater in depth, for example, than 5,000 feet, the weight of the pump rod is a significant factor since steel sections extending to such depths are obviously quite heavy. This rod when it is at the bottom of its stroke, plus the weight of the fluid to be lifted during the upward stroke thereof, and the frictional resistance to movement provided by the various pump parts, combine to offer considerable inertia or resistance to upward movement that must be overcome by the power apparatus used to reciprocate the pump rod. It is common in such installations to employ weights for counter-balancing such forces, which afford the advantage of permitting the use of power units of lesser capacity than one which would be required if the entire magnitude of these forces were to be lifted thereby.

However, the use of counter-weights has a number of disadvantages, among which are the tremendous additional inertia added to the system and which must be overcome upon each movement thereof, and the danger to personnel and pump parts, etc. that accompanies the movement of such heavy weights. It is apparent then that though mechanical counter-weights afford certain advantages, they inherently introduce into the system certain disadvantages. As a result, an improved arrangement providing the advantages of a mechanical counter-weight, but not the disadvantages thereof, would serve a useful function in this art, and it is accordingly an object of this invention to provide such an arrangement.

Another object to this invention is to provide in a structure of the character described, a means for counter-balancing a heavy pump rod or other heavy object that must be lifted without introducing additional inertia into the system, and without otherwise materially resisting movement of such pump rod. Still another object is that of providing a fluid counter-balancing arrangement operative to counter-balance a heavy weight during movement thereof in one direction (lifting, for example), but being ineffective to influence movement of such weight in the opposite direction.

Yet another object is to provide a fluid pressure counter-balancing system in a structure of the character described which employs a gaseous medium such as air having a pressure of sufficient magnitude to counter-balance the heavy weight, and having also a volume sufficiently large so that movement of the weight which will alter the volume of the air will not materially change the pressure thereof, whereby the counter-balancing pressure is substantially constant. Yet a further object is to provide a constant fluid pressure counter-balancing system employing piston and cylinder structures, the pistons being connected to the weight to be counter-balanced and being oriented in a direction to effectively counter-balance the same, and the cylinders either providing themselves or being connected with a tank volume of such capacity that reciprocation of the piston, as caused by movement of the counter-balanced weight, results in substantially no change in pressure in the counter-balancing system. Additional objects and advantages will appear as the specification develops.

An embodiment of the invention is illustrated in the accompanying drawings, in which—

FIGURE 1 is a broken side view in elevation of hydraulic pump apparatus embodying the invention; and

FIGURE 2 is a diagrammatic view showing the hydraulic flow circuit.

From the disclosure heretofore presented it is apparent that the apparatus or system is particularly suited for use as an operating means for a hydraulic pump, and is operative to reciprocate a pump rod which carries the plunger of a foot valve or foot pump positioned within the depths of the well. When the rod is reciprocated, the foot valve is necessarily reciprocated and functions to pump liquid from the well to the surface of the earth. The general structural arrangement is illustrated most clearly in FIGURE 1.

Generally, in a hydraulic pump system there are a number of advantages realized when the various cylinders are short—one of which is minimizing the difficulties encountered in maintaining bearing supports for the reciprocable pistons of those cylinders. Further, cylinders that are short are less expensive and the problems of structural strength which are magnified when cylinder length is increased, are obviated. However, it is frequently necessary to reciprocate a pump rod through a considerable distance, and if this is to be accomplished while employing short lift cylinders, some means must be provided for multiplying at the pump rod the distance through which the pistons reciprocate.

In the form of the invention illustrated in FIGURE 1, a distance multiplication of such type is provided in the pulley system to be described in detail hereinafter, and this multiplication factor may be 2, 4, 6, 8, etc., as desired.

In the apparatus, support beams **42** are provided, and these beams are adapted to rest upon the ground or other stable support medium and they carry the functional components of the apparatus. Pivotally carried on the beams **42** in bifurcated support members **43** is a derrick **44** having at its upper end a rotatably mounted sheave **45**. The derrick **44** may shift from right to left about the pivotal axis thereof, and its precise position is established by the setting of a turn buckle **46** that connects the rod **47** affixed to the derrick and a rod **48** that is rigidly secured to the standards **49** that are spaced apart and at their lower ends have an enlarged space therebetween.

The lower ends of the standards are rigidly secured to a support **50**, that in turn is rigidly secured to an upright **51** rigidly affixed through a support **52**, to the beams **42**. Additional support is provided for the standards **49** by an angular support member **53** that is welded or otherwise permanently joined to an L-shaped channel **54** at its lower end that extends between the support beams **42** and are secured thereto. Adjacent the upper ends of the standards is a reinforcing strap **55** which is secured thereto, and the strap extends downwardly and angularly therefrom, and at its lower end is rigidly secured (not shown) to the support beams **42**.

The casing for a well with which the pump apparatus is used is designated with the numeral **56**, and is provided with a reciprocatory pump rod **57** that through a coupling **58** is attached to a cable or chain **59** that is entrained over the sheave **45**. This cable is also drawn over a rotatable pulley wheel or sheave **60** positioned at the upper end of a vertical support **61** which is rigidly secured at its lower end to a mounting member **62** affixed to the beams **42**. The cable then passes over a pair of pulley wheels **63** and **64**, rotatably mounted, respectively, at opposite ends of a movable beam **65** that extends horizontally and in generally parallel relation with the beams **42**.

From the pulley wheel 64, the cable extends downwardly and passes under pulley wheels 66 and 67 that are rotatably mounted on the support member 50. Thereafter, the cable is drawn upwardly and over a rotatable sheave 68 carried by a mounting bar 69 secured to the standards 49. Then the cable is drawn downwardly, and at its lower end is affixed to a coupling member 70 that is rigidly secured by a nut 71 or by other suitable means to the beams 42.

It will be apparent from the structural description so far set forth that the pump rod 57 is reciprocated when the horizontal beam 65 is moved up and down, since by such movement the cable 59 is effectively lengthened or shortened at the pump rod and therefore causes its reciprocatory movement. The apparatus for reciprocating the horizontal beam 65 will now be described.

The lift or upstroke cylinders which cause the beam 65 to move upwardly, are supported upon a plate 72 that extends between and is affixed to the spaced apart beams 42, as are the members 43, 62, 52 and 54. These cylinders are in line with each other, and though not clearly illustrated in FIGURE 1, are designated with the numerals 73, 74 and 75 and are more clearly seen in FIGURE 2. Each is equipped with a reciprocatory piston having rods 73*a*, 74*a* and 75*a* that at their upper ends are rigidly secured to the horizontal beam 65. Therefore, as the pistons within these cylinders are moved upwardly, the beam 65 moves upwardly, as does the well rod 57.

The downstroke cylinders are designated with the numerals 77 and 78, and these cylinders at their upper ends are rigidly affixed to a horizontal support beam 79 that in turn is welded or otherwise secured to the standards 49. Each of these downstroke cylinders is provided with a reciprocatory piston having, respectively, rods 80 and 81—the first being secured to a strap 82 and the second to a similar strap 83. The straps in turn are carried by the horizontal beam 65. In operation of the apparatus, the downstroke cylinders 77 and 78 have the fluid pressure therein released when the upstroke cylinders are actuated to permit the beam 65 to move upwardly; and when the beam is to be moved downwardly, the cylinders 77 and 78 are energized while fluid pressure is released from the upstroke cylinders 73 through 75.

The complete hydraulic circuit is illustrated in FIGURE 2. It is there seen that in addition to the upstroke and downstroke cylinders and pistons heretofore described, it includes a main valve operative through a rod 87 which provides a control and a means for changing the condition of and between a plurality of flow ports within the main valve 88 to alter the flow path of hydraulic fluid in the system. The rod 87 is moved upwardly when the lift pistons approach the uppermost point of travel in their upward movement; and conversely, the rod is moved downwardly when the lift pistons approach the lowermost point of travel in their downward travel. The structural interconnection with the rod 87 is disclosed in detail in my copending application referred to hereinbefore. The main valve 88 is also described in detail in my patent, No. 2,422,895.

Also included in the system are piston and cylinder structures which may be designated as a cushion, and are indicated generally by the numeral 89. The cushion 89 comprises a plurality of cylinders designated with the numerals 90, 91, 92 and 93. Each of the cylinders is provided with a piston mounted for reciprocatory movement therein, and each of the pistons has a rod extending downwardly through the cylinder casing, and these are designated, respectively, wth the numerals 94 through 97. All of the rods are rigidly secured at their lower ends to a tie bar 98, and that member in turn is rigidly secured to the rod 99 of a piston mounted for reciprocatory movement in the cylinder 101. It will be appreciated that when hydraulic fluid exerts an upward force against the piston within the cylinder 101, the tie member 98 will be forced upwardly, as will all of the pistons within the cylinders 90 through 93.

The cylinders 90 through 93 are all interconnected at their upper ends through manifold sections 102 and 103, that in turn are connected to a flow conduit 104 communicating with a tank 105 that, through a flow circuit 106, communicates with an air storage tank or reservoir 107. At its lower end the tank 107 is adapted to be connected to an air compressor (not shown) through a conduit 108 which is preferably provided with a manually operable on/off valve. At its upper end the tank 107 may be equipped with a safety release valve 110.

The hydraulic system is a closed system and fluid is fed to the valve 88 by a pump through a line 111, and fluid is returned from the valve through a line 112 to a storage tank and then recirculated by the pump. Neither the pump nor the storage tank are illustrated. It is seen from FIGURE 2 that additional components are also included in the system, and these comprise a retard valve 113 and a back flow control or cushion valve 114 characterized by defining a uni-directional flow of fluid through the line 119. The valve 113 is connected to the two lift cylinders 74 and 75 through a line 115, and through a conduit 116 with the cylinder 101 (through a branch conduit 117) and through a branch conduit 118 with the valve 114. The valve 114 also has a conduit 119 connecting it with the main control valve 88, and it has two additional conduits 120 and 121 also connecting it with the main control valve 88 adjacent the reduced upper end thereof.

The operation of the structure and hydraulic circuitry so far described is set forth in copending application, Serial No. 560,179, of which this is a continuation-in-part, and reference may be made thereto for such a complete description. As an aid, however, in facilitating the reading of this specification, the following generalized summary may be considered.

Fluid flows through the conduit 111 to the main control valve 88, and from there through the valves 114 and 113 to the lift cylinders 73 through 75, with the result that the pistons thereof are forced upwardly whereby the beam 65 is elevated and the pump rod 57 elevated through the cable 59. At such time, pressure in the downstroke cylinders 77 and 78 is relieved through the control valve 88. When the lift cylinders reach their uppermost limit, the condition of the main control valve 88 is altered by shifting of the control rod 87 thereof, whereby the downstroke cylinders 77 and 78 are energized to drive the beam 65 downwardly as pressure is relieved in the upstroke cylinders.

When the pump rod is at the bottom of its stroke, and at the moment pressure fluid is applied to the lift cylinders to elevate the rod 57, the rod at such time because of its inertia (and also because of the weight of the liquid, frictional resistance, etc.) offers a substantial resistance to movement. Therefore, the force applied thereagainst is a force that increases progressively in magnitude because a portion of the hydraulic fluid being fed to the lift cylinders is also simultaneously being fed to the cylinder 101, and thereby to the cushion cylinders 90 through 93. As a result, the initiation of the upward motion of the pump rod is smooth and gradual. This upward movement is one of continuous acceleration, however, over a substantial portion of the stroke, for once upward movement commences the air cushion feeds energy back into the system, with the result that a greater pressure is developed in each of the lift cylinders than would otherwise be developed.

Incorporated in this system are a pair of counterbalancing cylinders 122 and 123 having reciprocable pistons therein each equipped with a pump rod 124 and 125, respectively. As is apparent from FIGURE 2, these rods are rigidly connected with the horizontal beam 65. The cylinders 122 and 123 are connected together through conduits 126 and 127, respectively, and through a common conduit 128 equipped with a manually operated on-off valve 131 to a tank or vessel 129 adapted to receive a

liquid such as oil. The valve 131 is open when the system is in operation, and is closed when it is desired to hold the pump rod in an elevated position.

It is desired to support the pump rod at an elevated position when the pump is shut down because the fluid, when the pump is used in an oil well for example, delivered by the pump contains a considerable amount of sand and other particulate matter. When the pump is shut down for any length of time, this sand and other particulate matter settles downwardly in the pump casing 56 to leather packings, etc. that lift the fluid when the pump is in operation. After a time, such particulate matter packs tightly against the leathers, and the force of the liquid thereabove tends to maintain it in packed condition. Thereafter, if the pump is put in operation and the movement of the pump rod is upwardly, the packed particulate matter resists such movement of the pump rod, often with such a force as to prevent movement thereof. Under such conditions, it is necessary to vibrate or otherwise jar the rod so as to loosen the sand, and even then the sand and other particles scour and abrade the pump casing and cut the leather packings. This, of course, decreases the life of the casing and pump parts, etc.

In conventional pumps, the first movement of the pump rod is ordinarily in an upward direction after the pump has been shut off for any period of time because no matter what the position of the pump rod when the apparatus is shut down, the heavy weight of the rod causes it to settle to the bottom of the well (consider that in a deep well, the pump rod may exceed several thousand pounds in weight).

In the apparatus of this invention, the manually operated valve 131 when shut off will hold the pump rod in any position that it is in when the valve is turned to the off position, and preferably the pump apparatus will be shut down when the pump is in an intermediate position and moving in a downward direction. Shutting off the valve 131 will prevent any further movement of the rod, and when the pump apparatus is thereafter turned on the rod will first be moved downwardly, forcing a jet of liquid upwardly through the packed particulate matter whereby it again is returned to suspension in the liquid. Thus, the rod is free to move and there will be no scouring of the pump casing and leather packings, etc. Preferably, the system includes a safety valve 131*a* extending between the conduit 128 and the tank 129. This valve functions to by-pass hydraulic fluid to the tank 129 in the event that the pump apparatus is actuated without first opening the manually operable valve 131, thereby preventing damage to the system.

The tank 129 at its upper end is connected through a conduit 130 with a constant pressure air tank 132 which may be equipped with a pressure gauge 133 and safety release valve 134. The air tank is connected at its lower end, through a conduit 135 equipped with a valve 136, with a pump 137 which supplies air thereto under pressure.

The counter-balancing means then employed in the system described comprises a substantially constant force urging the horizontal beam 65 upwardly, which then is a counter-balance for the pump rod and its assembly 57 that, through the cable 59 of the various pulley wheels over which it is entrained, urges the beam 65 downwardly. It will be appreciated that downward movement of the beam 65 reciprocates the pistons inwardly into the counter-balancing cylinders 122 and 123, whereby the fluid therein (a liquid such as oil) flows freely outwardly therefrom through the relatively large conduits 126 and 127 and into the large common conduit 128, and from there into the large tank 129 (which contains the oil or other liquid) and larger constant pressure space in the tank 132 (which contains air). As has been brought out before, the volume in the tank 132 is sufficiently large when compared with the displacement of the pistons within the cylinders 122 and 123 that there is in proportion substantially no change in the total volume in the counter-balancing system and, of course then, no appreciable change in pressure.

It will be clear that the force applied by the counter-balancing cylinder assemblies provides an effective means for counter-balancing the weight of the pump rod assembly, etc., and it is a relatively easy matter to increase or decrease the magnitude of the counter-balancing force as required simply by altering the pressure within the tank 132 by means of the pump 137 and valves 136 and 134. Thus, the pump may be tailored with facility to meet any given well installation. However, the system does not have the tremendous inertia that is found in mechanical counter-balancing systems wherein heavy weights are employed in opposition to the weight of the pump rod assembly. The only intrinsic inertia is that of the pistons and the rods 124 and 125 provided thereby. The inertia of the system does not change by displacement of these pistons and their rods because of the constant pressure arrangement described.

It will be noted that the fluid pressure system comprising the counter-balancing cylinder assemblies 122 and 123 is a separate system from that of the other piston and cylinder arrangements, etc. in the pump operating apparatus. This serves as a safety device in that power or control of the main hydraulic system is independent thereof, so that in the event of a power failure in the main system the counter-balancing cylinder assemblies are operative to substantially support the pump rod, and if the force in the counter-balancing system is not sufficient to completely immobilize the pump rod in the event of such contingency it will at least cause the rod to settle slowly and not drop suddenly. As has been brought out, a smaller motor or power system may be used in a pump operating apparatus equipped with the pneumatic counter-balancing means for the motor need not lift the complete weight of the pump rod since the pump rod is counter-balanced, and also, the motor need not overcome the inertia of a mechanical counter-balancing system employing large weights.

The number of strokes that the pump operates in a given time period may be varied by changing the downstroke cylinders 77 and 78. Such a change in the system to alter the number of strokes that the pump puts out will not change the speed of the upstroke, which in this pump may always be maintained at maximum. That is, the rate of the downstroke movements may be changed whereby the total number of strokes in a given time interval will be altered. However, such will not change the speed of the upstrokes which for greatest efficiency should always be at maximum. This, of course, is advantageous in that leakage being proportionate to the rate of upstrokes whereby greater quantities of liquid are brought up by the pump for each upstroke. All of the packings in the pump apparatus are at atmospheric pressure whereby there is no danger of high pressure fluid escaping therethrough, and all of the cylinders are single-acting.

While in the foregoing specification an embodiment of the invention has been set forth in considerable detail for purposes of making a complete disclosure thereof, it will be apparent to those skilled in the art that numerous changes may be made in those details without departing from the spirit and principles of the invention.

I claim:

1. In a hydraulic system, a first lift cylinder, a second lift cylinder and a return cylinder each equipped with a piston reciprocable therein for connection with a work element to reciprocate the same through a cycle of operation, a hydraulic circuit for said cylinders and having a pressure side and a return side, a control valve for selectively connecting the return cylinder to the pressure side of said circuit and the first lift cylinder and second lift cylinder to the return side of said circuit or for connecting the return cylinder to the return side of

said circuit and the first and second lift cylinders to the pressure side of said circuit, an energy storage and release cushion connected to said circuit intermediate the connections of said first and second lift cylinders thereto, a uni-directional flow valve interposed in said circuit intermediate such connection of said cushion and first lift cylinder thereto, said uni-directional valve being a positively operated valve operative in one condition thereof to permit the flow of fluid from the pressure side of said circuit to said second lift cylinder but operative in other condtion thereof to prevent the return flow of fluid therethrough and to direct it into said cushion, a counter-balance cylinder having a piston reciprocable therein for connection with such work element to bias the same in the direction of movement enforced thereon by actuation of said lift cylinders, and means for maintaining a relatively constant force upon said counter-balance piston to effect such biasing force thereof.

2. The system of claim 1 in which said means comprises a tank defining a pressurizable space of relatively large volume compared to the volumetric displacement of said counter-balance piston during the reciprocatory cycle thereof, said pressurizable space being in open communication with said counter-balance cylinder.

3. In a hydraulic system, a work element adapted to be reciprocated in the performance of a useful function, a first lift cylinder and a second lift cylinder each equipped with a reciprocable piston connected with said work element for moving the same in one direction, a return cylinder equipped with a reciprocable piston connected with said work element for moving the same in the opposite direction, a hydraulic circuit for said cylinders including a pump for supplying fluid under pressure thereto, control valve means in said circuit for selectively connecting either said return cylinder or said first and second lift cylinders to the pressure side of said pump and at the same time connecting the other thereof to the return side of said pump, uni-directional valve means interposed in said circuit between the connections of said

first and second lift cylinders thereto, an energy storage and release cushion connected in said circuit intermediate said uni-directional valve means and said second lift cylinder, said uni-directional valve means being a positively operated valve effective in one condition thereof to prevent the flow of fluid from said second lift cylinder to the return side of said pump and to direct such fluid into said cushion when said first lift cylinder is connected to the return side of said pump and in the other condition thereof to define a flow path for fluid to said second lift cylinder to permit energy excesses to be stored by said cushion when said first and second lift cylinders are connected to the pressure side of said pump, a counter-balance cylinder equipped with a reciprocable piston also connected with said work element for applying a biasing force thereto tending to move the same in the aforesaid one direction enforced thereon by said first and second lift cylinders, and means for maintaining a substantially constant force upon the piston of said counter-balance cylinder to effect such biasing forces whereby the value thereof is substantially independent of the position of said counter-balance piston.

4. The system of claim 3 in which said means for maintaining a substantially constant force comprises a gas-containing tank connected with said counter-balance cylinder and defining a relatively large volume therein compared to the volume displaced by said counter-balance piston during each stroke thereof so that no appreciable change occurs in the pressure within said tank as a result of such displacement.

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