

Jan. 16, 1968

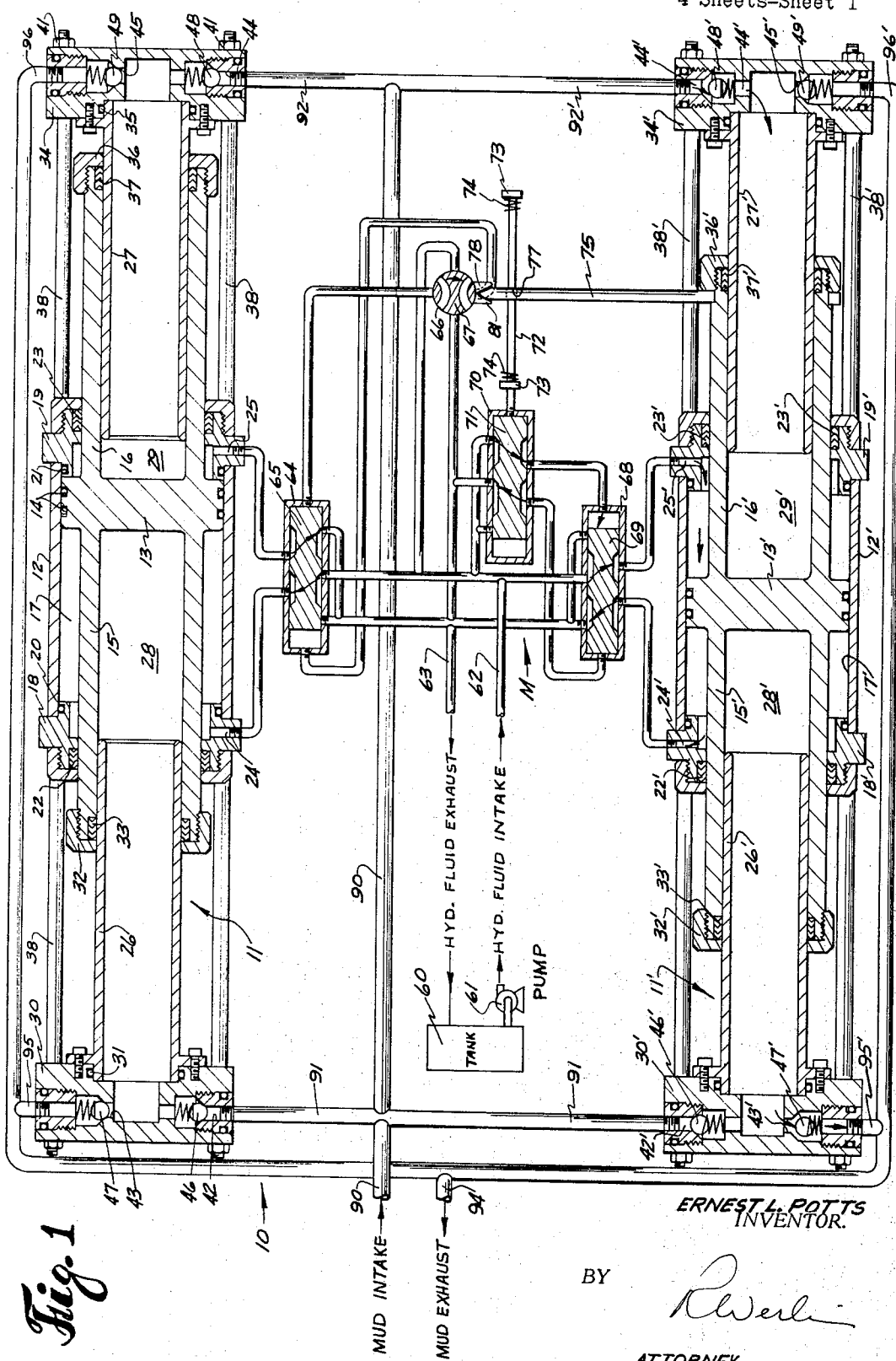
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FLUID PRESSURE-DRIVEN MULTIPLEX PUMP

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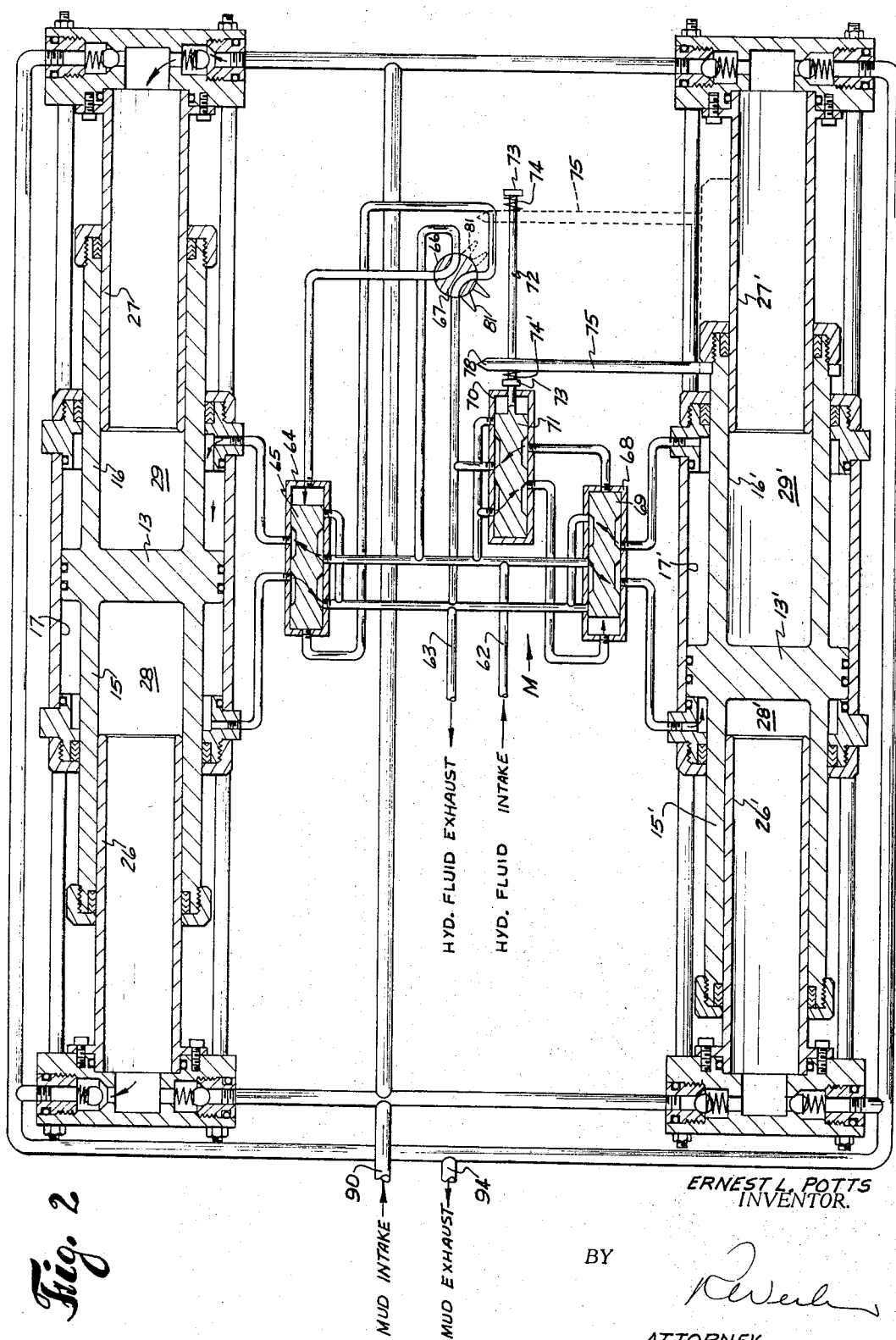


Fig. 2

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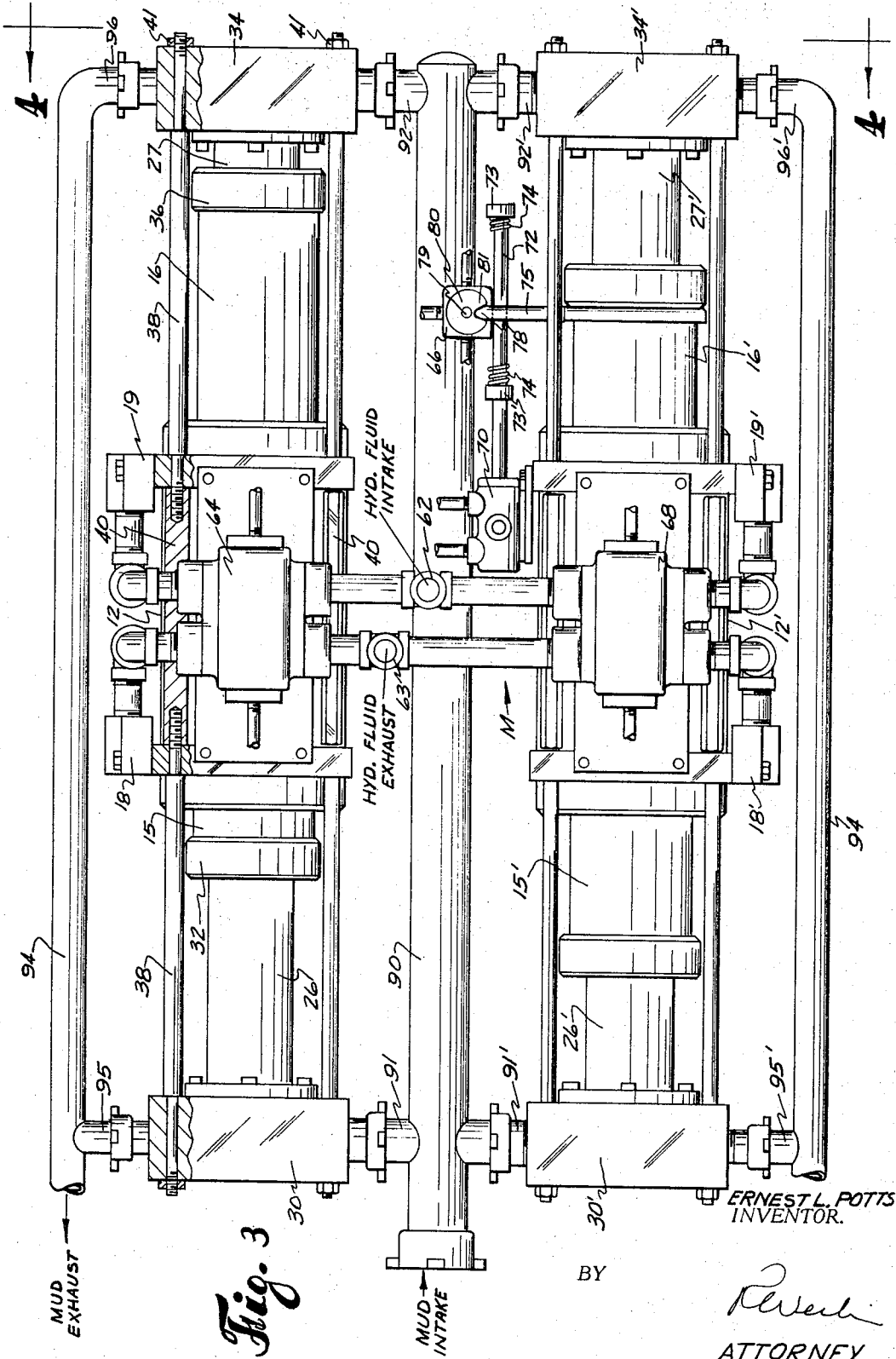
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Fig. 4

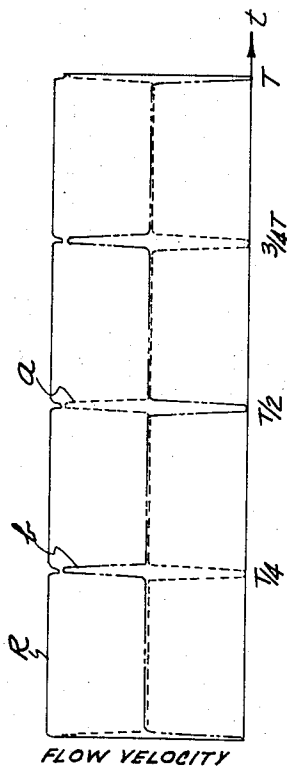
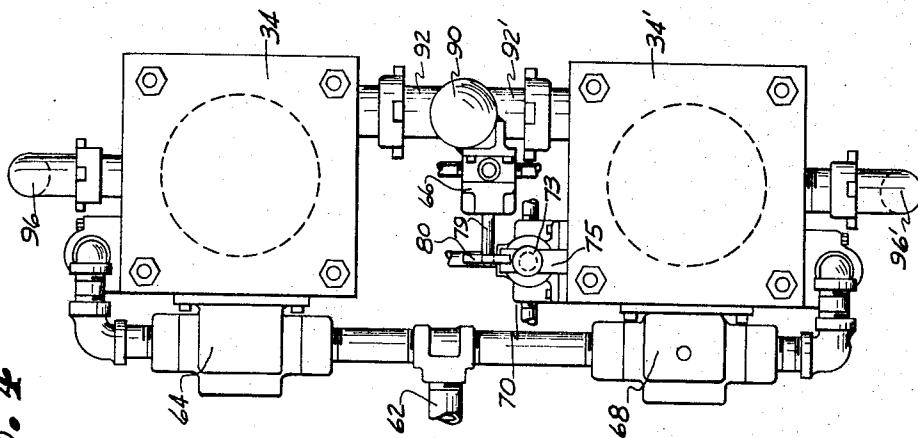


Fig. 5

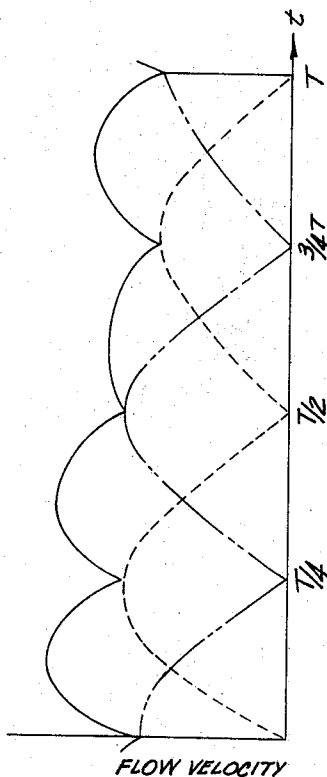


Fig. 6

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FLUID PRESSURE-DRIVEN MULTIPLEX PUMP

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5 Claims. (Cl. 103-49)

ABSTRACT OF THE DISCLOSURE

A duplex, double-acting pump system employing a hydraulic fluid pressure drive and a control system arranged to establish a pre-determined phase angle relation between the pistons in the respective units whereby to substantially eliminate pressure surges in the discharging fluid.

This invention relates to multiplex, double-acting, piston-type pumps, and more particularly to such pumps which are hydraulically driven and which are especially suitable for pumping mud and for other services in the drilling of oil and gas wells.

Prior art mud pumps are generally crank-driven. Such pumps, even though extensively employed, are undesirable because they are relatively heavy, bulky and inefficient. Moreover, the flow velocity in such pumps periodically pulsates substantially, causing undesirable periodic pressure surges. To prevent failures in the hydraulic lines and associated equipments, which may be caused by these surges, heavier gage materials and hose are required. Also, the variations induced by the surges and pulsations are damaging to the pumps and the connected equipment.

Consequently, it is a principal object of this invention to provide new and improved pumps which overcome the above and other disadvantages and limitations of prior art mud pumps.

Other objects of this invention are to provide new and improved hydraulically-driven, duplex, double-acting pumps which are compact in design, which require a minimum of moving parts, which have a long operating life, which have a substantially constant flow velocity, which are relatively free of pressure surges, which are light weight, which can be driven and controlled from remote locations, and which are especially suitable for use in performing well drilling operations.

The above and other objects of this invention are accomplished by providing, in one embodiment, a new and improved duplex pump having two double acting pump units. The piston in each pump unit is driven by a fluid, preferably a hydraulic fluid, alternately applied to the opposite faces of the piston. Pressure or velocity surges are minimized by establishing a suitable phase shift between the positions of the pistons on their stroke trajectories.

An important object of this invention is the provision of a reciprocating pump employing a novel expansible and contractible pump chamber construction providing a high degree of pumping efficiency.

A more specific object is the provision of a hydraulic pressure-driven, duplex, double-acting, reciprocating pump wherein each pump unit employs a single main piston having tubular extensions projecting coaxially from the opposite ends of the piston and slidably reciprocable over tubular cylinder sleeves closed at their outer ends to define with said extensions pump chambers which are expansible and contractible in response to the reciprocation of the main pistons, the outer ends of the cylinder sleeves being closed by cylinder heads carrying the intake and exhaust valves for the respective pump chambers.

Further objects and advantages of the present invention will become apparent from the following description when

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read in conjunction with the accompanying drawing which illustrates one useful embodiment in accordance with this invention.

FIG. 1 is a longitudinal cross-sectional view, partially diagrammatic, of a pump in accordance with this invention;

FIG. 2 is a view similar to that of FIG. 1 except that the pistons are shown in positions 90° displaced from their positions in FIG. 1;

FIG. 3 is a top plan view of the pump shown in FIGS. 1 and 2;

FIG. 4 is an end view taken along line 4-4 of FIG. 3;

FIG. 5 shows plots of the flow velocity from each pump unit and the resultant action thereof as a function of time; and

FIG. 6 shows for comparison with FIG. 5, similar plots for a conventional duplex crank-operated pump.

While this invention is susceptible of embodiment in many different forms, there are shown in the drawing and will herein be described in detail, a preferred embodiment of the invention with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention and is not intended to limit the invention to the embodiment illustrated.

Referring to the drawing and especially to FIG. 1, there is shown a duplex pump, designated generally by the numeral 10, which includes two identical double-acting pump units 11 and 11'. To better emphasize the similarity between the pump units, identical parts in both units bear the same reference characters, but those in pump unit 11' are followed by a prime marking, therefore, the detailed description need only be given of pump unit 11, it being understood that this description will apply to the other unit as well. Pump unit 11 comprises a main or power cylinder 12 in which is reciprocably disposed a solid cylindrical piston 13 having mounted about its periphery a pair of seal rings 14 for slidable sealing engagement with the wall of cylinder 12. Integral with and extending from the opposite end faces of piston 13 are two tubular extensions 15 and 16 which are concentric with but sufficiently spaced from the inner wall of cylinder 12 to define therewith a pressure chamber 17. Two annular end caps 18 and 19, respectively, provided with O-rings 20, 21 and with seals 22, 23 make the chamber 17 fluid-tight about extensions 15 and 16. Two passages or ports 24, 25 are provided in caps 18, 19, respectively communicating with the portions of chamber 17 on opposite sides of piston 13. Snugly fitted inside piston extensions 15, 16 are cylinder sleeves 26, 27, respectively, over which extensions 15 and 16 are slidably reciprocable in response to the reciprocations of piston 13. The space inside extension 15 and cylinder sleeve 26 defines a pump chamber 28. Similarly, the space inside extension 16 and cylinder sleeve 27 defines a pump chamber 29. Chamber 28 is made fluid-tight at its outer end by a cylinder head 30 having a seal 31 and bolted to the outer end of sleeve 26. A stuffing box 32, fitted with packings 33, provided in the outer end of piston extension 15 forms a slidable seal between the piston extension and sleeve 26. Chamber 29 is sealed off at its outer end in a similar manner by means of a cylinder head 34 having a seal 35 bolted to the outer end of sleeve 27. A stuffing box 36, fitted with packing 37, provided in the outer end of piston extension 16 forms a slidable seal between this piston extension and sleeve 27. Two pairs of bolts are fixedly maintained, in spaced-apart relation, in cap 18 and cylinder head 30 and end cap 19 and cylinder head 34. These bolts shoulder on caps 18 and 19 and are screwed into spacers 40 (see FIG. 3) which firmly hold the caps 18, 19 against cylinder 12. The cylinder heads 30, 34 rest on shoulders provided on bolts 38 and are securely held in place by nuts 41.

Cylinder head 30 has an inlet port 42 and an outlet port 43 communicating with chamber 28, and cylinder head 34 has an inlet port 44 and an outlet port 45 in communication with chamber 29. Inlet ports 42, 44 are provided with back-check valves 46, 48, respectively. Similarly, outlet ports 43, 45 are provided with back-check valves 47, 49, respectively.

An intake conduit 90 for fluid to be pumped, such as drilling mud, is provided with lateral branches 91, 92 connected to inlet ports 42, 44, respectively, and with other lateral branches 91', 92' which connect to inlet ports 42', 44' of the pump unit 11'. Similarly, a common discharge conduit 94 has lateral branches 95, 96 communicating, respectively, with discharge ports 43, 45 and branches 95' and 96, communicating with discharge ports 43' and 45'. Thus, all inlet ports for the several chambers communicate with a common intake or fluid supply conduit and all discharge ports for the several pump chambers likewise communicate with a common discharge conduit. It will be evident that the pumping action is effected by the alternate expansions and contractions of chambers 28, 29 and 28', 29' in response to the reciprocations of pistons 13 and 13', respectively. For example, as piston 13 moves to the left from the position shown in FIG. 1, the volume of chamber 28 contracts and the fluid therein is compressed and expelled through discharge port 43 into the discharge conduit. At the same time, the volume of chamber 29 expands, creating suction therein sufficient to draw fluid into chamber 29 through intake port 44. The same action, of course, occurs in pump unit 11'.

To hydraulically drive the pistons 13, 13', there is provided a tank of hydraulic fluid 60. A pump 61 feeds, at a constant pressure, the fluid from tank 60 into a main supply line 62. The fluid is returned to the tank by a main return line 63. Main supply line 62 and return line 63 communicate, through appropriately manifolded connections, indicated by the letter M, with ports 24, 25 and 24', 25', which are in communication, respectively, with cylinders 12 and 12' of the respective pump units.

Pump 61 can be said to provide a uni-directional of "direct pressure" (by analogy to direct current). Before this direct pressure can be employed to drive pistons 13, 13', it must be converted into a bi-directional or "alternating pressure." This conversion is accomplished by the use of four 4-way valves, namely, two master valves and two control valves appropriately installed in manifold M to permit selectively directing the flow of power fluid to and from the opposite end portions of cylinders 12 and 12', as will appear hereinafter. These valves are well-known in the art and can be obtained from several manufacturers.

Piston 13 is driven through a spool-type master valve 64 having a slidable spool 65, the position of which is hydraulically controlled by a plug-type control valve 66 having a rotatable spool 67. Piston 13' is driven through a spool-type master valve 68 having a slidable spool 69, the position of which is hydraulically controlled by a spool-type control valve 70 having a slidable spool 71. Extending from spool 71 is a rod 72 having two spaced stops 73, 73' protected by two springs 74, 74', respectively. Fixedly attached to piston extension 16' and movable therewith is a tripping arm 75 provided with a cylindrical opening 77 for allowing arm 75 to slide over rod 72. The free end of arm 75 is bevelled to form a tripping finger 78. The spool 71 can assume only two stable positions, as is well-known. It assumes its right-hand position when arm 75 hits spring 74 on stop 73 and its left-hand position when arm 75 hits spring 74' on stop 73', as shown in FIG. 2. The shaft 79 of the plug-type valve 66 is terminated with a circular operator 80 having a V-shaped notch 81 cut therein (see FIG. 3). When spool 71 is at its left-hand position, spool 67 assumes its stable position as shown in FIG. 2. Just before arm 75 reaches its mid-position moving from left to right,

its finger 78 engages in notch 81 and rotates shaft 79 and hence spool 67 to its position as shown in FIG. 1 which corresponds to the mid-position for arm 75. As arm 75 continues on its right-hand trajectory, the finger 78 leaves the notch 81 after rotating the spool 67 into the broken line position opposite to that shown in FIG. 2. Having explained the function of the control valves 66 and 70, it will now be explained how the fluid mud being pumped, which arrives via supply conduit 90, exits through exhaust conduit 94.

In operation, a pump 61 delivers at a constant velocity a power fluid, preferably a hydraulic fluid, from a tank 60 to a supply line 62. The fluid in line 62 is at a substantially constant pressure. At $t=0$ (see FIG. 5), assume that pistons 13, 13' and the spools 65, 67, 69 and 71 are in their positions as shown in FIG. 2. The power fluid then flows in the directions indicated by the arrows. Piston 13' starts moving to the right and piston 13 continues moving to the left from the mid-position. When piston 13' reaches its mid-position, the finger 78 engages notch 81 in plate 89 and shifts the spool 67 into its alternate position, i.e., the broken line position shown in FIG. 2. The rotation of spool 67, when piston 13' reaches its mid-stroke position, causes pressure to become applied against the left-hand face of spool 65 thereby moving spool 65 into its right-hand position. Thus, at $t=T/4$, where T is the period, piston 13' reaches its mid-position, piston 13 reaches its left-hand position, spool 65 switches to its right-hand position thereby causing pressure to exert on the left-hand face of piston 13. At $t=T/2$, piston 13' reaches its right-hand position, arm 75 hits spring 74 thereby causing spool 71 to assume its right-hand position, the driving fluid then flows into cylinder 12', in the direction shown in FIG. 1, causing piston 13' to move to the left. At $t=3/4T$, piston 13' again reaches its mid-position, piston 13 reaches its right-hand position, spool 67 rotates into the position as shown in FIG. 2, fluid flows into cylinder 12, in the direction as shown in FIG. 2, causing piston 13 to move to the left. At $t=T$, piston 13' reaches its left-hand position and piston 13 reaches its mid-position, thereby completing one full cycle. The second cycle will be completed at $t=2T$, etc.

Now, when piston 13 moves to the left from its right-hand position, as shown in FIG. 1, chamber 29 expands allowing mud from branch 92 to enter chamber 29 through the inlet valve 48. During this suction action, valve 49 remains closed. Also, when piston 13 moves to the left, piston extension 15 slides over cylinder sleeve 26 thereby compressing the fluid in chamber 28 and causing it to exit through the exhaust valve 47. Valve 46 remains closed during this compression action. When piston 13' reaches its mid-position, moving from right-to-left, piston 13' will have reached its left-hand position, as shown in FIG. 2.

By means of the pump construction and operation heretofore described, a sequence of movements of the pistons in the two pump units is established by means of which the flow of fluid through the pump from intake to discharge will be substantially free of any sharp pulsations, but will instead provide a continuous, smooth, full volume flow of fluid being pumped.

FIG. 5 is a chart plotting flow velocity versus time during one complete cycle of the duplex pump in accordance with this invention as heretofore described, curve a displaying the parameter for pump unit 11 and curve b for pump unit 11'. Curve R is the resultant of the pumping actions of the two units, showing that the flow velocity is substantially constant and at a maximum throughout the entire pumping period and that such pulsations as occur are extremely short in time and of very small magnitude.

FIG. 6, which illustrates the corresponding pumping action, through one cycle of a conventional crank-driven, duplex, double-acting piston pump, clearly shows the large pulsations which occur in the resultant flow velocity

of this conventional type of pump as contrasted with the smooth flow obtained with the pump in accordance with this invention.

From the foregoing it will be evident that the pump herein described provides a structure which effectively accomplishes the various objects and advantages of this invention.

What I claim and desire to secure by Letters Patent is:

1. A duplex pump system having an inlet and an outlet comprising: at least two cylinders, a piston in each cylinder, a tubular extension projecting from each face of each piston, cap means defining a fluid-tight chamber between the inner wall of each cylinder and the outer walls of the related pair of extensions, fluid passages communicating with each chamber on opposite sides of each piston, a stationary tubular sleeve member for each piston extension, end means including valve means terminating one free end of each sleeve member, said piston extensions being arranged to reciprocate over their corresponding tubular sleeve members in response to pressure alternately applied through said passages and exerted on the annular portions of the opposite sides of said piston positioned in said chamber, said reciprocating piston extensions creating alternate compressions and suction in said tubular sleeve members for pumping through said valve means a fluid from said inlet to said outlet, conduit means for supplying hydraulic pressure fluid to said passages, and control means for said conduit means responsive to the piston movements and arranged to cause reciprocation of said pistons in said cylinders at a pre-determined phase angle therebetween, thereby substantially completely eliminating pressure surges from the pumped fluid and providing a substantially uniform flow velocity.

2. The system of claim 1 and further including a source of direct hydraulic power fluid, means converting said direct power fluid into an alternating power fluid, and means responsive to the attainment of a pre-determined intermediate position of the piston in one of said cylinders for timing the application of said alternating fluid to said passages.

3. The system of claim 2, wherein said converting means include four-way valve means having movable spools therein, and wherein said responsive means control the positioning of said spools relative to each other and to the position of said pistons in said cylinders.

4. A pump system having an inlet and an outlet comprising: a pump body, at least two pump units in said body, each unit including a cylinder, a solid cylindrical piston in said cylinder having two flat faces; each piston face having a tubular extension axially aligned with and spaced from the inner wall of said cylinder; first end cap means at each end of said cylinder and defining between the inner wall of said cylinder and the outer walls of said extensions a fluid-tight chamber; said first end cap means including sealing means and having a port for accepting fluid under pressure; a stationary sleeve member snugly fitting in each extension; second end cap means at one

end of each sleeve member and including an inlet port and an exhaust port; a source of hydraulic fluid under pressure, a driving four-way valve supplying an alternating flow of power fluid to said chamber on either side of said piston; a control four-way valve coupled to said source and to said driving valve for timing the operation of said driving valve in each of said pump units, each of said valves having a movable spool; and means fixedly coupled to one of said extensions and to the spools of said control valves for positioning the spools in said control valves relative to each other and for maintaining a fixed phase angle therebetween; said alternating fluid driving said pistons in alternate directions, thereby creating alternate compressions and suction in said sleeve members for pumping a fluid from said inlet to said outlet.

5. A fluid pressure-driven pump, comprising, two pump units, each unit including, a cylinder, an annular piston reciprocable in said cylinder, tubular extensions projecting from opposite end faces of said piston coaxially of said cylinder, means sealing between the inner wall of said cylinder and said extensions on opposite sides of said piston to define a pressure chamber therebetween, fluid passages communicating with the portions of said chamber on opposite sides of said piston, a stationary cylinder sleeve having a closed outer end and having its inner end extending coaxially into the bore of each of said extensions and cooperating therewith to define pump chambers which are expansible and contractible in response to reciprocation of said piston, valved intake and discharge passages communicating with each of said pump chambers, intake conduit means communicating the intake passages of all of said units to a common fluid inlet, discharge conduit means communicating the discharge passages of all of said units to a common discharge outlet, power fluid conduit means communicating the corresponding fluid passages of the cylinders of the several units with each other and with a source of hydraulic pressure fluid, multi-port valve means interposed in said power fluid conduit means between said source of pressure fluid and said fluid passages and operable to direct pressure fluid to and from selected ones of said portions of said cylinders, and control means operable in response to the reciprocating movement of the piston in one of said pump units to selectively actuate said valve means in a sequence arranged to cause reciprocation of the pistons in the several pump units in a predetermined phase angle relation to one another.

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