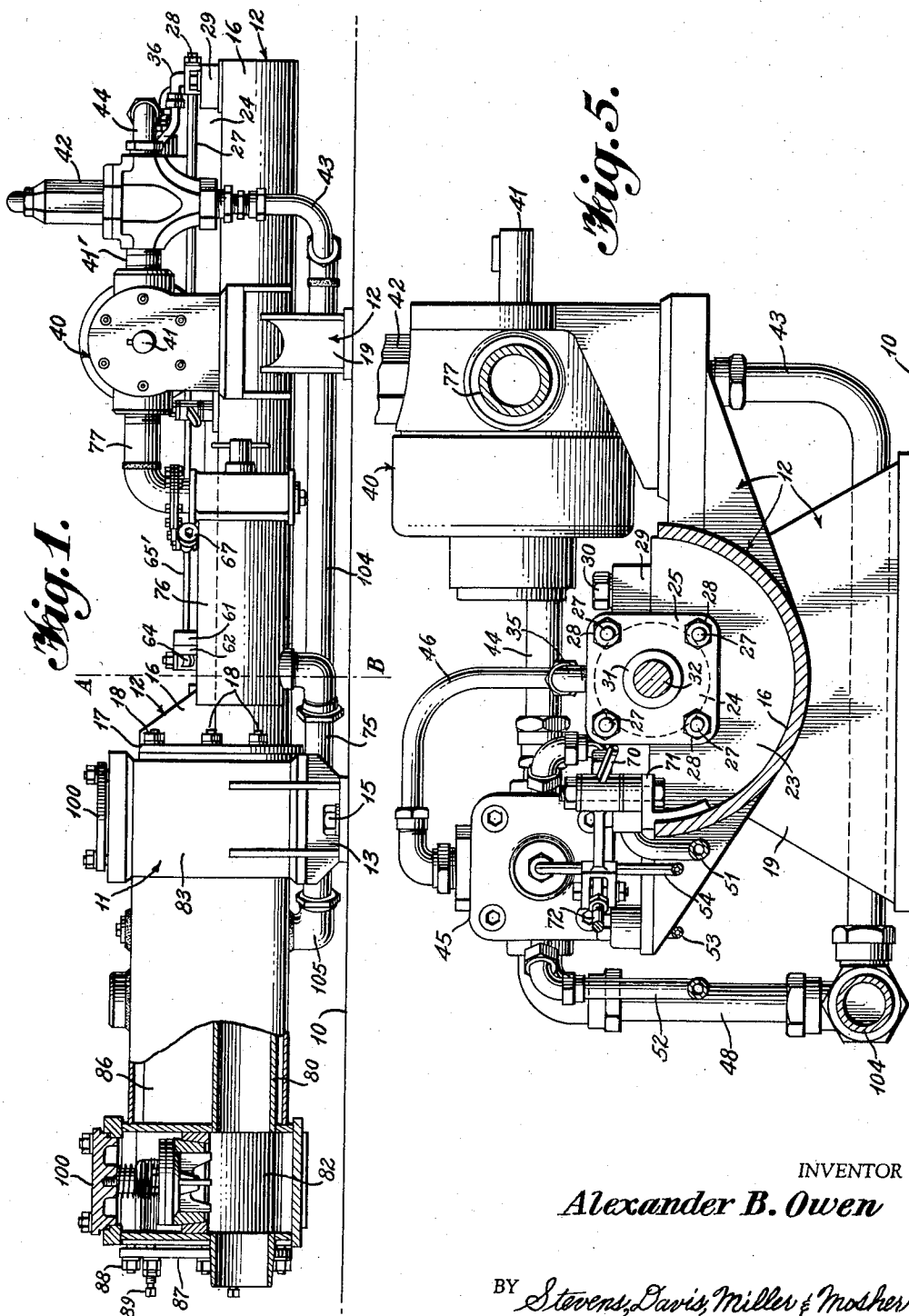


A. B. OWEN
SEISMIC MUD PUMP

6 Sheets-Sheet 1

Filed June 29, 1954



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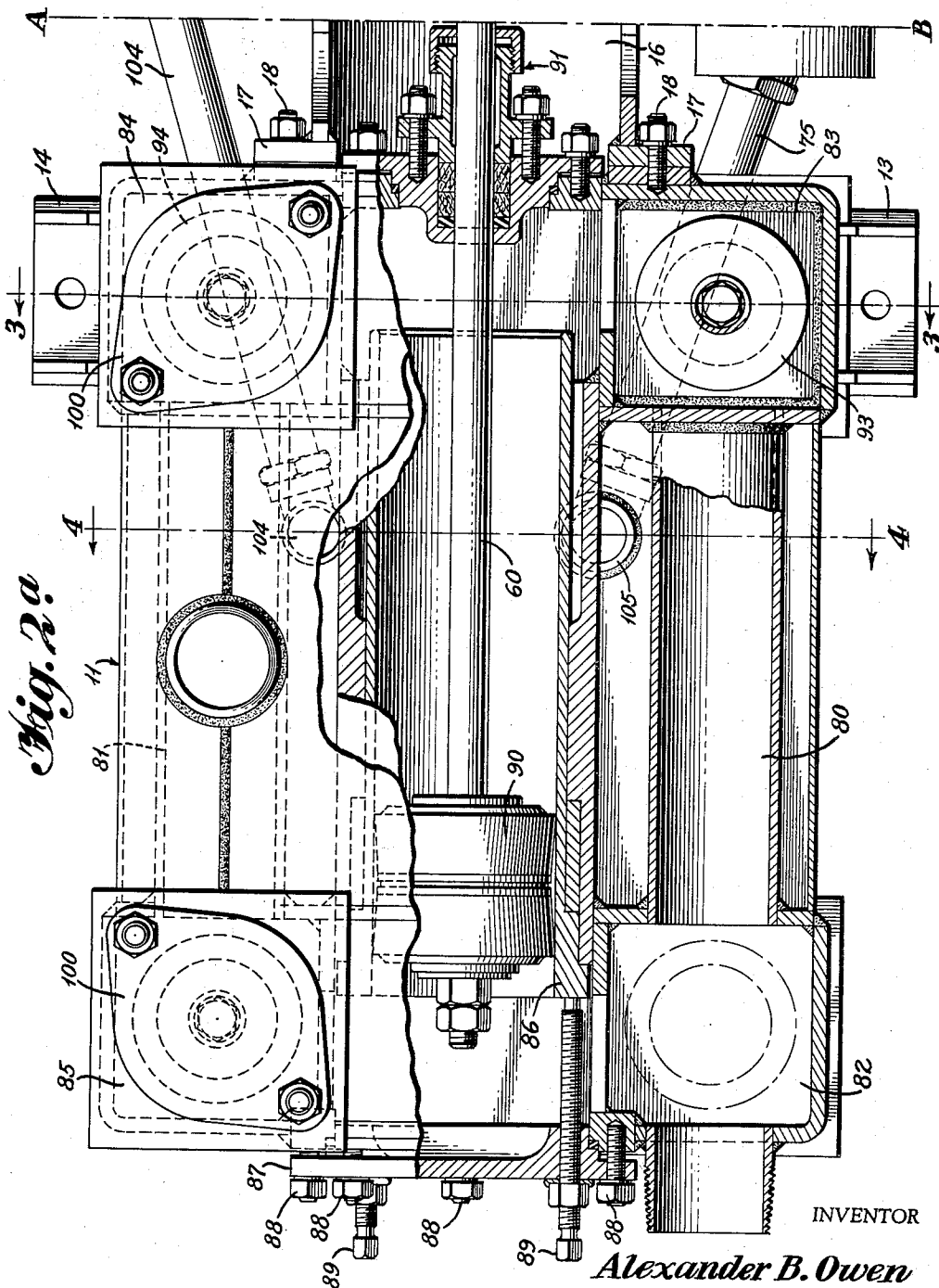
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SEISMIC MUD PUMP

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Filed June 29, 1954

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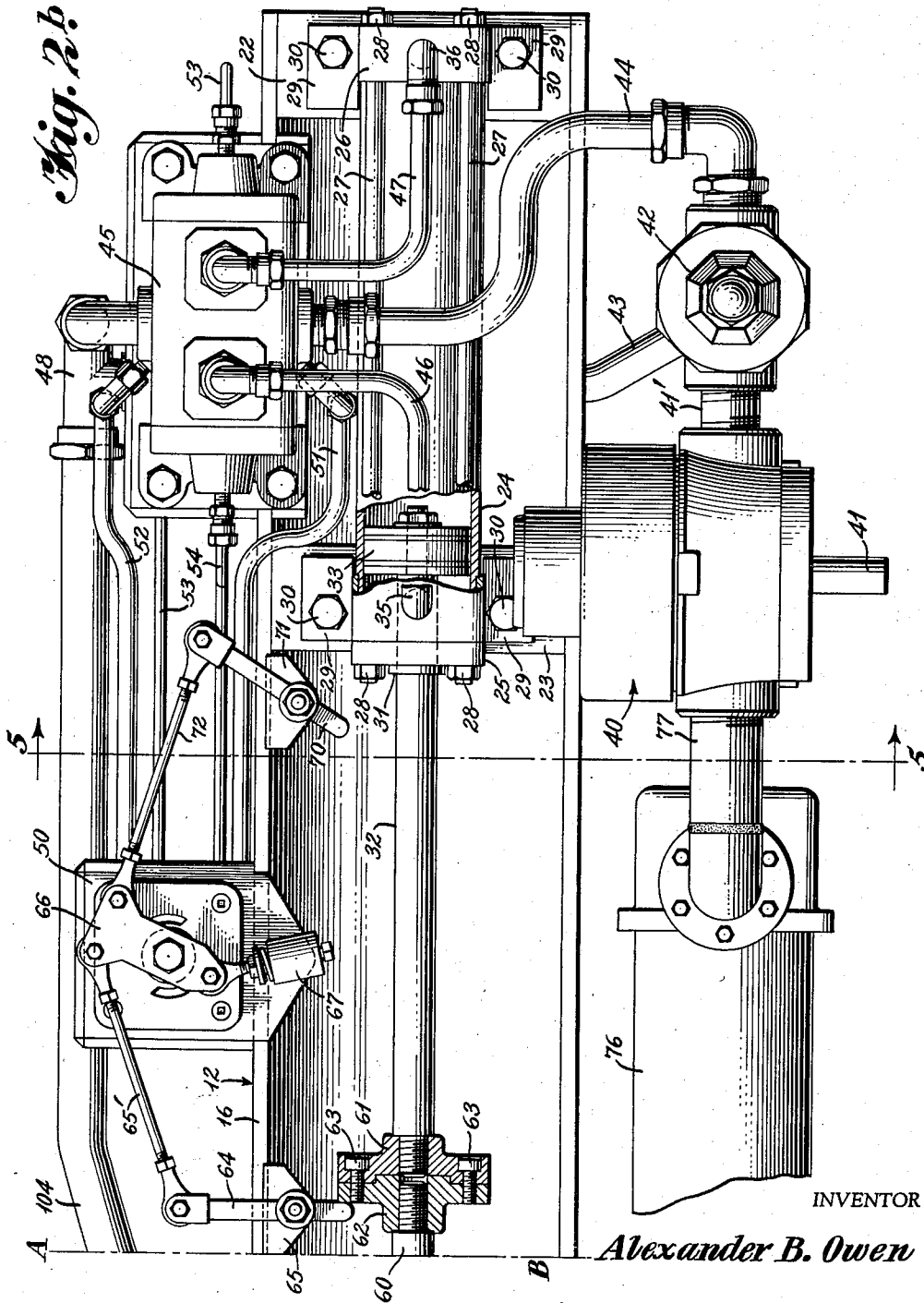
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SEISMIC MUD PUMP

2,887,955

Filed June 29, 1954

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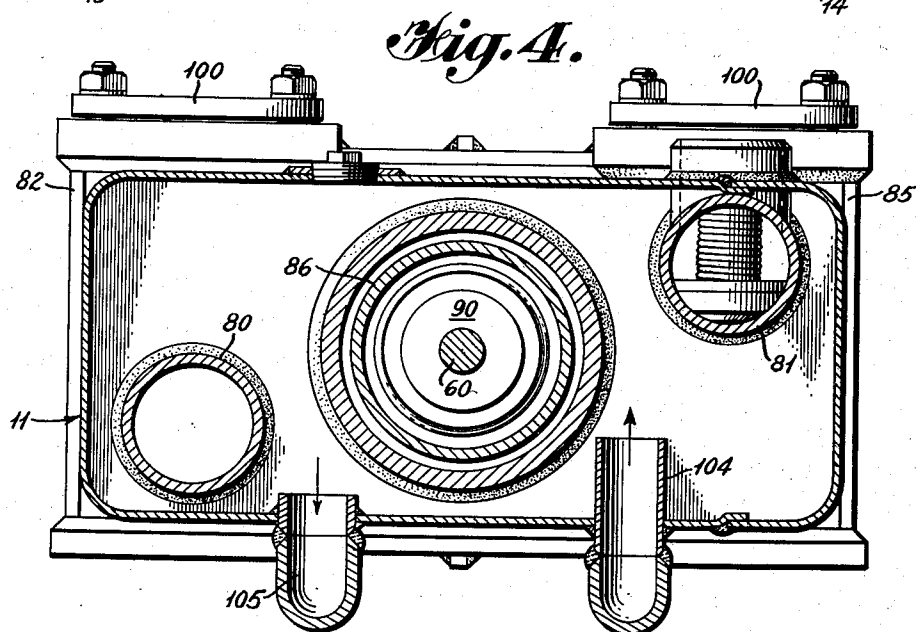
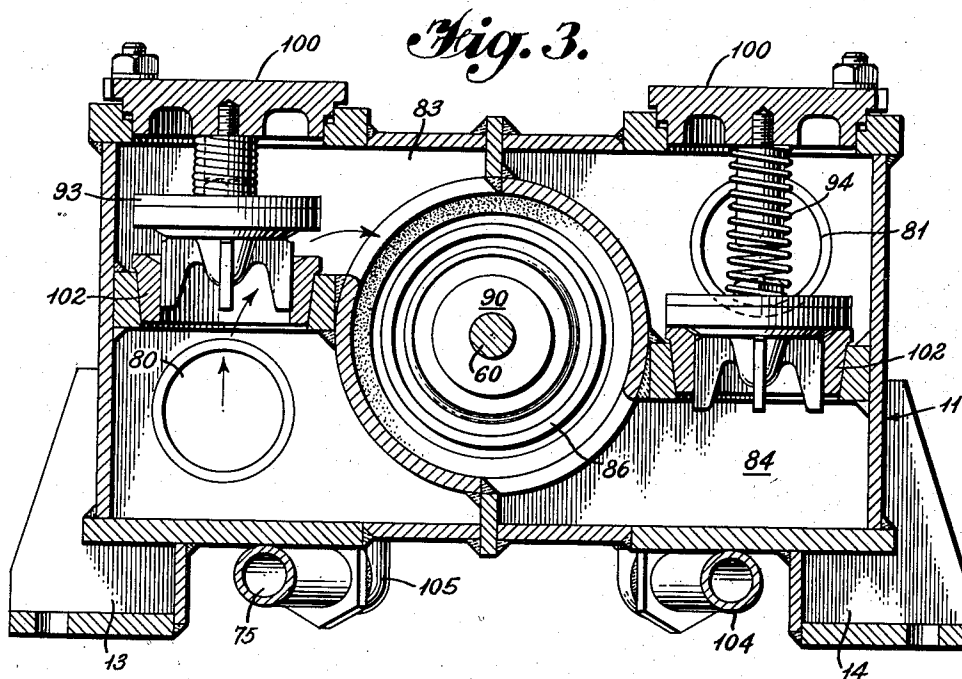
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2,887,955

Filed June 29, 1954

6 Sheets-Sheet 4



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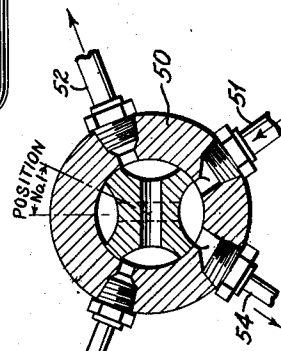
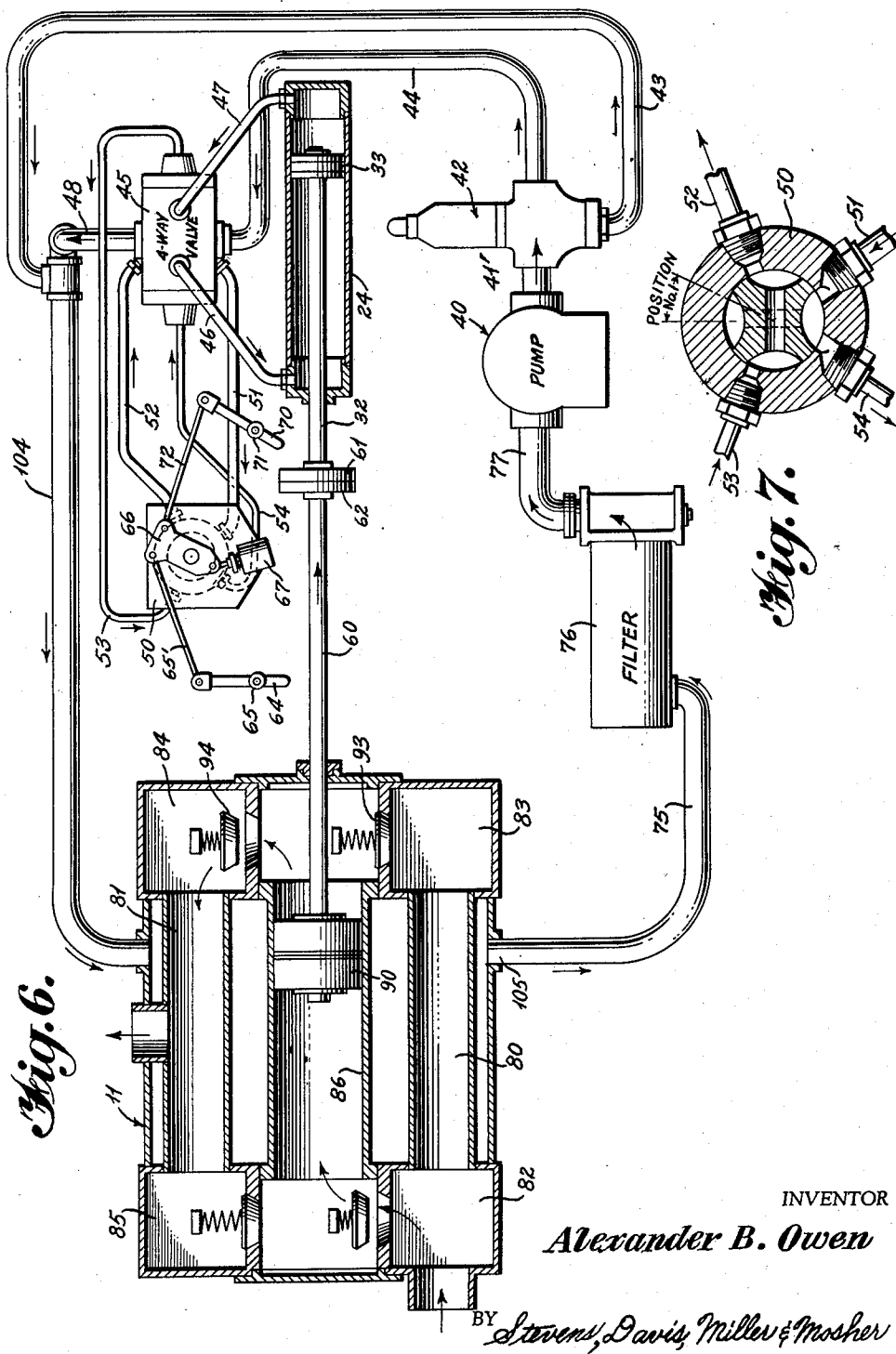
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Filed June 29, 1954

6 Sheets-Sheet 5



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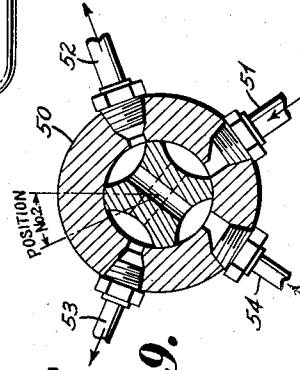
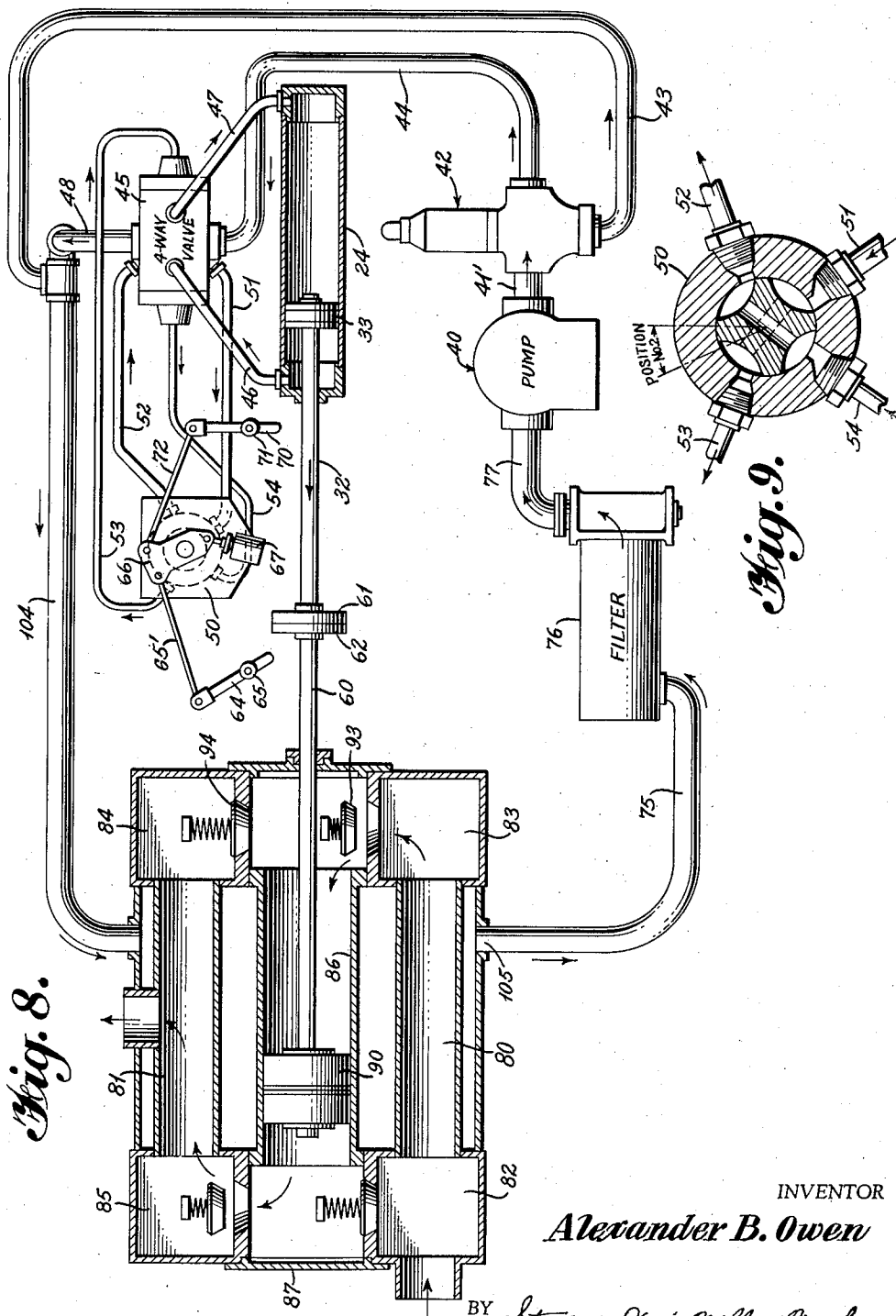
May 26, 1959

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2,887,955

Filed June 29, 1954

6 Sheets-Sheet 6



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2,887,955

SEISMIC MUD PUMP

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Application June 29, 1954, Serial No. 439,971

9 Claims. (Cl. 103—48)

This invention relates to earth-boring equipment, and more particularly to well-drilling apparatus. Even more specifically, it relates to pumping equipment for circulating the mud or slurry used in the rotary drilling of oil wells and the like. This particular pumping equipment is especially well adapted for use in the drilling of relatively shallow holes in the earth for seismic prospecting purposes.

It is common practice in the drilling of holes in the earth for the purpose of tapping the earth's reservoir of oil, or for the purpose of detonating charges of explosive below the surface of the earth for seismic prospecting purposes, to utilize a rotating drill bit at the bottom end of a string of drill pipe and to circulate down through this drill string and bit and up around the outside thereof a stream of drilling fluid. This liquid is commonly referred to in the industry as drilling mud. In order that the drilling mud may bring the dislodged particles of earth or rock to the surface, it is necessary that this drilling mud be forced through the drill pipe and upwardly around the outside of the drill pipe at a rate sufficient to bring the cuttings to the surface. As a result, it is common practice to use a pump capable of delivering the drilling mud under a fairly high pressure and at a fairly high rate.

For many years there has been only one type of pump available for this purpose. This type of pump is a horizontal, two-cylinder, double-acting, reciprocating pump driven through gears, a crankshaft, connecting rods, reciprocating cross-heads and piston rods connecting these cross-heads to the pistons of the pump. The crankshaft is fixed to and turns with a very large gear and is connected to the cross-heads by the connecting rods. The cross-heads are mounted for reciprocation axially of the cylinder which they serve and thus convert the motion of the connecting rod into a reciprocating motion to operate a piston rod and piston. This type of drive results in at least three major interrelated limitations on the pump. The first limitation is that a relatively long connecting rod must be used with a comparatively short pumping stroke. As the crankshaft rotates with the gear, it is obvious that the connecting rod exerts a force directly in line with the reciprocating motion of the piston and piston rod at only two points during each complete revolution of the gear and crankshaft. At all other points during the pumping cycle, the connecting rod is out of line with the direction of effective pumping force and therefore produces a resultant force of which only the horizontal component is available to produce the required fluid pressure. It follows that as the angle of the connecting rod increases from the horizontal, the resultant force increases at the expense of the horizontal component, and so the force transmitted by the crankshaft through the connecting rod must be increased in order to deliver the required pumping force. It has been found that a long stroke with a short connecting rod results in excessive cross-head bearing pressures, while a long stroke with a long connecting rod increases the length of the pump out of all proportion and thereby adds considerable weight to a pump the weight of

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which is already excessive. Therefore, the available pump has been designed as a compromise between these two alternatives and has a short stroke and a long connecting rod.

The second major limitation concerns the size of gears used to transmit the driving force to the fluid end. Since a certain fluid pressure is required to remove the drill bit cuttings from the hole, and since all components of the drive between the piston and the gears are directly connected, the gears must be designed to transmit the required pressure. Any factor which increases the power required to deliver the necessary pressure to the pump increases the size of the gears needed to transmit this power. The angle of the connecting rod with the horizontal is the main factor in increasing the power requirements and furnishes another reason why the crankshaft drive is limited to a short stroke and a long connecting rod.

The two factors above cause a third limitation of this type of pump, that of limited volume displacement per cylinder. The volume of fluid delivered per stroke is defined as the effective area of the pump times the length of the stroke times the volumetric efficiency of the pump. To compensate for the loss of capacity due to the short stroke, it was necessary to add another fluid cylinder and consequently the attendant suction and discharge valves and driving linkage.

In addition to the effect of the short stroke on the pump capacity, another factor must be considered, which is the piston speed. Due to the fact that the reciprocating motion is produced by the rotation of the crankshaft, it follows that the piston speed is directly dependent upon the angle of the crankshaft with the horizontal and the angular velocity of the crankshaft. Therefore, when the crankshaft is in line with the piston rod, the piston is at the end of the stroke and has no velocity. As the crankshaft rotates through 180° the piston speed increases from zero to a maximum when the angle between the crankshaft and the connecting rod is 90° and decreases again to zero as the remainder of the half revolution is completed. A curve of the piston velocity plotted against time approximates the form of a sine wave and since the pumping stroke is a related function of time also, a curve of the pump discharge per cylinder plotted against time is the same as the piston velocity curve. The variable piston speed inherent in the crankshaft drive produces a variable discharge and consequently, a surge action in the pump. A second fluid cylinder is needed not only to provide additional capacity but to minimize the surge action caused by the variable piston speed. The surge action is minimized, but not eliminated, by delivering power to the second cylinder out of phase with respect to the power delivered to the first cylinder. With the conditions of equal piston areas and lengths of stroke, a constant speed piston having a speed equal to the maximum speed of a variable speed piston such as is had in the pump above described, will deliver approximately 50 percent more fluid.

A crank-driven type pump of the size most commonly used has a 4.5-inch diameter piston, a 6-inch stroke, and a one-inch piston rod. This pump weighs approximately 2,300 pounds. Attempts to reduce the weight of such a pump by casting it from aluminum instead of steel tend to increase the cost of the pump and decrease its design working pressure. Attempts to increase the capacity of the pump by driving it beyond rated speed have tended to produce rapid wearing and boring out of the cylinder liner and generally produce failures of one part or another of the mechanism due to the overload. Without exception, the previous attempts to overcome the limitations of this type of pump have been directed either toward the fluid end, which in most cases is overdesigned, or toward the housing of the power end, and not toward a change in the

driving principle which is the limiting factor of this pump. Consequently, none of these attempts to improve the efficiency and overcome the limitations of this type of pump have proved satisfactory.

The purpose of this invention is to provide a completely different kind of pump and one that has not heretofore been used for this purpose. The pump of this invention differs from the previous mud pump in that it operates with far higher volumetric efficiency, and in that the weight of the pump is far lower in comparison with its output than the previous mud pump. The new pump is also arranged so that the parts that are subject to wear are easily accessible and easily replaceable and thus, in addition to being light in weight and efficient, the pump is easily serviced in the field and has an unusually long life under circumstances that are particularly destructive.

The pump itself is a double-acting pump in which the piston has a constant velocity throughout its stroke rather than a variable velocity. This is made possible by driving the pump by means of a reciprocating fluid motor which also has a double-acting piston, and by connecting the piston of the driving motor directly to the piston of the pump. The driving motor is driven, in turn, by fluid under pressure supplied by a positive displacement, relatively high pressure, liquid pump which is driven by the prime mover.

The usual driving fluid supplied by the constant displacement pump to the driving motor is oil and this oil is circulated from the output of the driving motor through a heat transfer jacket around the pump cylinder and the pump manifolds. From this point it is returned through a filter to the constant displacement pump and the constant displacement pump then passes the oil through a relief valve and back to the driving motor. If the oil pressure exceeds a set amount, it is by-passed around the driving motor. The reciprocating driving motor is controlled as to its operation by a main oil control valve and this valve in turn is controlled by a pilot valve which is tripped as a flange on the shaft connecting the driving motor piston and the pump piston reciprocates.

Drilling mud comes in contact with only the mud pump end of the mechanism and this part of the mechanism is specially constructed so as to minimize wear and so that wear or erosion by reason of gritty particles in the mud can be repaired by simply replacing the affected parts in a very simple manner. Thus each valve and each valve seat is easily accessible and the cylinder and cylinder liner of the mud pump are also easily removable and replaceable. Likewise, the piston of the mud pump can easily be removed and replaced without disassembling the whole device.

Several direct and immediate advantages have resulted from the use of an opposed hydraulic cylinder for the driving means. For example, it has been possible to reduce the over-all length of the pump and the weight from about 2,300 pounds to between 600 and 700 pounds with no sacrifice in pumping capacity. Transportation equipment does not have to be modified to accommodate the pump since the length and weight have been so materially reduced. The fluid end piston is driven by the hydraulic piston at a constant speed and can therefore pump equal quantities whether the pump stroke is long or short. The ability to use a long stroke, however, provides a further advantage in that fewer strokes are required for the same displacement and consequently fewer valve actions and a higher volumetric efficiency is possible. The fluid end is designed for the maximum expected fluid pressure and since it is protected from overload by a relief valve, it can be fabricated from relatively light-weight materials instead of being cast into a heavy, overdesigned mass. These and many other advantages have been made possible by the change in driving principle.

Many other details and advantages of this invention

will be apparent from the following detailed description of the preferred embodiment thereof.

In the drawings Figure 1 is a side elevation partly in section of the preferred form of the seismic mud pump of this invention;

Figures 2a and 2b taken together are a plan view partly in section of the same pump;

Figure 3 is a sectional view of the same pump taken on lines 3—3 of Figure 2a;

Figure 4 is a sectional view of the same pump taken on lines 4—4 of Figure 2a;

Figure 5 is a sectional view of the same pump taken on lines 5—5 of Figure 2b;

Figure 6 is a diagrammatic illustration of the same pump showing the path of fluid travel as the pistons move to the right as shown in this figure;

Figure 7 is a sectional illustration of the pilot valve as it is positioned in Figure 6;

Figure 8 is a diagrammatic illustration of the same pump showing the flow of liquid as the pistons travel to the left;

Figure 9 is a sectional illustration of the pilot valve as it is positioned in Figure 8.

The preferred embodiment of the seismic mud pump of this invention, as illustrated specifically in Figures 1 to 5, is arranged so that it can be mounted on a flat base 10, as shown in Figure 1. This base may be the bed of a truck or a special base or frame of any desired type. As shown in Figure 1, the left-hand end of the device is a pumping end and the right-hand end is the driving end. This is true also in Figures 2a and 2b taken together and in Figures 6 and 8, which show the operation of the pump.

The framework of the pump is rather complex in shape. It comprises two sections. One supports and forms part of the pump section and is generally designated as 11, and the other supports and forms part of the motor section and is generally designated as 12. The framework section 11 is formed with downwardly extending supporting members 13 and 14 which rest upon the base 10 and support frame 11 above the base and these supporting members are adapted to be bolted in place on the base 10 by bolts 15. The framework 12 includes an elongated semi-circular shell member 16 and this member has a flange 17 at the end of it adjacent to the frame member 11 and the two are bolted together by bolts and nuts 18. The frame member 12 is supported from the base 10 by downwardly extending leg 19 which is shown in Figures 1 and 5.

Within the semi-circular shell member 16 of the motor frame 12 there are fastened a pair of semi-circular supporting blocks 22 and 23, as can be seen in Figure 2b and in these supporting blocks a power cylinder 24 is mounted.

The power cylinder 24 is closed at its ends by end caps 25 and 26, which caps are generally square in shape as shown in Figure 5 and are shaped to surround the ends of the cylinder 24, which are somewhat reduced in diameter, as shown in Figure 2b. The end caps 25 and 26 are held tightly on the cylinder by means of four longitudinally extending rods 27 which pass through the end caps and are terminated by nuts 28 which bear against the end caps and hold them tightly in position. The caps are provided with wings 29 through which cap screws 30 extend to fasten them to the semi-circular supporting blocks 22 and 23. A packing gland 31 is provided in the cap 25 and a driving rod 32 extends from a piston 33 which is positioned within the cylinder, and connects to the pump portion of the machine. The end cap 25 has an opening that extends from the top to the inside of the cylinder and this is fitted with a fitting 35 so that liquid may enter and leave that end of the cylinder through this fitting. A similar opening and fitting 36 is provided in the cap 26 for the same purpose. It will at once be apparent as fluid enters one

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fitting and leaves the other, the motor piston will move from one end of the power cylinder to the other, thus moving the driving rod 32 which drives the pump portion of the machine.

Hydraulic fluid under high pressure is furnished for the operation of the motor piston by a positive displacement pump 40, which is mounted on a projecting part of the frame 12, and driven through a keyed shaft 41. In operation this positive displacement pump is driven constantly, usually by direct drive from a gasoline or diesel engine. From the pump 40 a hydraulic fluid under high pressure passes through a connection 41' to a pressure relief valve 42. If the pressure in the line becomes excessive, this pressure relief valve permits the hydraulic fluid to escape through a pressure relief pipe 43. Unless the pressure is excessive, the hydraulic fluid passes from the relief valve 42 through a pressure line 44 to a motor control valve 45 and from the motor control valve 45 either to one end or the other of the hydraulic power cylinder 24 through fluid connection 46 or fluid connection 47, depending upon the setting of the valve 45. The connection 46 connects to the fitting 35, thus delivering fluid to the left end of the power cylinder, and the connection 47 connects to the fitting 36, thus delivering fluid to the right end of the power cylinder. When one of these pressure pipes 46 or 47 is connected by the valve to deliver hydraulic fluid to one end of the power cylinder, the other pipe 47 is connected to conduct pressure fluid away from the other end of the power cylinder and to discharge that hydraulic fluid through the valve 45 into an exhaust line 48 connected to the control valve 45. Thus depending upon the setting of the control valve 45, the piston 33 is moved to one end or the other of the power cylinder 24.

The control valve 45 is a two-position, four-way valve mounted on the motor frame section 12 and hydraulically operated by means of a pilot valve 50 also mounted on the frame section 12. The control valve and pilot valve used herein are well known and commercially available and hence need not be described in great detail. The pilot valve 50 is mounted on the U-shaped part 16 of the motor frame 12 and is operated through a link and lever system from the driving rod 32.

The driving rod 32 connects to an aligned rod 60 that extends into and drives the pump. This connection is effected by a flange member 61 threadedly mounted on the end of the driving rod 32 and a corresponding flange member 62 mounted on the abutting end of the driving rod 60. These two flange members 61 and 62 are fastened together by cap screws 63 to form the driving connection. They serve both to connect the rods 32 and 60 and to actuate the pilot valve 50 at the proper times. As shown in Figure 2b, the driving rod 32 has just reached the extreme left end of its stroke and in this position the flange 62 has contacted a lever member 64 which is pivoted on a support 65 attached to the frame 12, and has rotated this lever member 64 in a clockwise direction. This rotation of the lever 64 moves a link 65' connected to the upper end of the lever (as seen in Figure 2b) and this movement of the link 65' rotates an arm 66 attached to the operating shaft of the pilot valve 50.

This rotation of the arm 66 moves the pilot valve to a position where it will actuate the control valve 45 to reverse the stroke of the piston 33 in the power cylinder 24. An over center spring toggle arrangement 67 is attached to the lever arm 66 and to the casing of the valve 50 and this mechanism operates in a known manner to move the pilot valve 50 fully into the operating position at one end or the other of its movement.

As the power piston moves in the other direction, that is, toward the right as seen in Figure 2b, the flange member 61 will eventually, as the end of the stroke is reached, strike against a lever 70 which is pivoted on

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a supporting member 71 attached to the frame 12, and will rotate this lever 70 in a counter-clockwise direction. This movement of the lever 70 will move a link 72 attached to its upper end, as seen in Figure 2b, in such a direction as to rotate the pilot valve arm 66, to which it is attached, in a counter-clockwise direction. This will cause the pilot valve to move the control valve 45 in the opposite direction and again reverse the cycle.

The control valve 45 and the pilot valve 50 are interconnected for operation by four hydraulic lines 51, 52, 53 and 54. One of these hydraulic lines 51 is connected to the pressure side of the control valve 45 and receives fluid under pressure from supply line 44 and delivers this fluid to the pilot valve 50. Another of these hydraulic lines 52 is connected to the exhaust side of the control valve 45 and withdraws fluid from the pilot valve 50. Depending upon the position of the pilot valve 50, pressure fluid is delivered through one or the other of the two remaining hydraulic lines 53 and 54, to one end or the other of the control valve 45. The remaining line 53 or 54 exhausts fluid from the opposite end of the control valve. The control valve contains a conventional valve body (not shown) that is reciprocated by this fluid pressure to control the main fluid flow.

This completes the description of the driving mechanism, except for pointing out that the spent hydraulic fluid in the exhaust line 48 or in the pressure relief line 43 flows through suitable connections to heat transfer sleeves that surround the pump cylinder and pump manifolds in the other end of the device. From there the hydraulic fluid returns through a connection 75, a filter 76, and a connection 77 to the positive displacement hydraulic pump that powers the device.

The details of the pumping end of the apparatus are shown in Figures 1, 2a, 3 and 4. The frame section 11 of this end of the apparatus is shaped to provide an inlet header 80, an outlet header 81, valve boxes 82, 83, 84 and 85, one at each end of each header, and a central area adapted to support a pump cylinder 86 and provide fluid passageways from the ends of the pump cylinder to the adjacent valve boxes. The pump cylinder 86 fits snugly into this center section of the frame section 11 and an enlarged ring at the left-hand end, as seen in Figure 2a, prevents its movement to the right. A cover plate 87 closes an opening in the left-hand end of the frame through which this cylinder compartment would otherwise be exposed and this cover plate is held in place by cap screws 88. Longer screws 89 extend through this cover plate and press against the left-hand end of the pump cylinder, thus holding it tightly in position. The arrangement is such that the pump cylinder, which may be considered to be a cylinder liner, can be removed and replaced when it becomes worn. This is important in a mud pump since drilling mud is quite abrasive and pump cylinders wear quite rapidly.

Within the pump cylinder is located a pump piston 90 and this piston is connected to the driving rod 60 which is in turn connected to the driving rod 32 as shown in Figure 2b. A packing gland 91 is provided where the driving rod 60 passes out of the frame section 11. Thus the frame section 11 is completely closed and fluid passages are formed at each end of the pump cylinder, which fluid passages lead to the valve boxes on either side.

As shown in Figures 3 and 4, the intake header 80 is located near the bottom of the frame section 11 and connects with the bottom ends of the two valve boxes 82 and 83, the top ends of these valve boxes being connected to the end of the pumping cylinder. A spring-pressed check valve 93 is positioned in the valve box 83 and this valve allows liquid to flow upwardly from the header 80 and into the end of the pumping cylinder 86 when the pumping piston 90 is moving to the left. When the pump piston moves to the right the check valve closes and this forces liquid in the pumping cylinder to

pass into the lower part of valve box 84. The outlet header 81 is positioned near the upper part of the housing 11 and a spring-pressed check valve 94 permits liquid to flow upwardly and into this header when the piston 90 is moving toward the right in Figure 2a. The arrangement is exactly the same at the other end of the pumping section. As the pump piston 90 moves to the right liquid moves from the header 80 upwardly through the valve box 82 past a spring-pressed check valve and into the left end of the cylinder 86. When the piston 90 moves back toward the left, this liquid is forced into the bottom of valve box 85 and passes upwardly past a spring-pressed check valve and into the outlet header 81.

Each of the spring-pressed check valves is made accessible by mounting it on a removable valve port 100 held in place by stud bolts and nuts. Each spring-pressed check valve also has a removable valve seat 102 that can be removed through the valve port once the cover plate and valve have been removed. As a result all of the parts subject to major wear can easily be removed and replaced when that becomes necessary.

As can be seen in Figures 2a and 3, power fluid that has become somewhat heated by passage through the motor section enters the pump section through pipe 104, circulates around the headers 80 and 81 and the pumping cylinder 86, as can be seen in Figure 4, and leaves the pumping section through pipe fitting 105. Fitting 105 connects to pipe 75, which carries this fluid to the filter 76 and eventually back to the constant displacement pump 40.

Figures 6 to 9, inclusive, are presented as an aid to an understanding of the operation of the apparatus of this invention, and particularly as an aid to an understanding of the operation of the valve in this device.

In Figures 6 and 7 the pistons are moving to the right. Hydraulic fluid from the pump 40 is passing through the relief valve 42 and the pressure line 44 to the four-way control valve 45. The valve body in this valve (not shown) is moved to the right so that hydraulic fluid entering from line 44 is directed into line 46 which connects to the left end of the power cylinder 24, thus moving the piston 33 to the right. Hydraulic fluid then leaves the power cylinder 24 through the line 47 and the valve body in the valve 45 is so positioned that it allows this fluid to pass through the valve 45 and into the discharge line 48. Any excess of hydraulic fluid that is released by the relief valve 42 passes through the relief line 43 and joins this exhaust hydraulic fluid in the pipe 104 which leads to the heat transfer jacket of the housing 11 of the pump portion of the machine. After being cooled in this heat transfer jacket, and imparting some warmth to the mud being pumped, the hydraulic fluid passes through fitting 105 into line 75 leading to the filter 76. From here the hydraulic fluid goes through a line 77 to the constant displacement pump 40 and passes on around the cycle.

The position of the control valve 45 is governed by the pilot valve 50, as already explained. This valve 50 is supplied with hydraulic fluid under high pressure by hydraulic line 51, which connects directly to the high pressure side of the main control valve 45 and an exhaust for spent pressure fluid is provided by a line 52 which connects directly to the exhaust side of the control valve 45. With the pilot valve 50 in the position shown in Figures 6 and 7, high pressure from the line 51 is connected through the valve as shown in Figure 7 to a control line 54 which connects to the left end of the control valve 45 and there acts to push the control element to the right so as to make the fluid connections already mentioned. A line 53 connects to the right end of a control valve 45 and fluid exhausted therefrom passes through the line 53 into the pilot valve 50 and through the valve 50 as shown in Figure 7 and out through the exhaust line 52.

During the movement of the pistons to the right, as shown in Figure 6, the pump piston 90 must also move to the right. As a result incoming mud passes from the header 80 through the valve box 82 and past the spring-pressed check valve and into the cylinder 86. At the same time mud is forced out of the other end of the cylinder 86 and past the check valve in valve box 84 and into the outlet header 81 from which it passes out to the well.

The exact reverse of these operations is shown in Figures 8 and 9. In these figures the pilot valve is in the reversed position so that pressure entering the pilot valve from the line 51 passes through the opening shown in dotted lines in Figure 9, and into the line 53 which carries it to the right-hand end of the control valve 45, thus moving the valve body to the left-hand end of this control valve. Exhaust operating fluid passes out of the line 54 through the full line opening in the valve member of the pilot valve, as shown in Figure 9, and out through the exhaust line 52. The connections in the control valve 45 are thus reversed and the pistons moved to the left, thus drawing mud into the right end of the pumping cylinder 86 through valve box 83, and sending mud under pressure out through the valve box 85 and into the outlet header 81.

Numerous minor modifications in the construction of the preferred device of this invention will immediately be apparent to those skilled in the art and such modifications are considered to be within the scope of this invention.

I claim:

1. Mud pumping apparatus for use in earth boring operations that comprises a double acting, reciprocating piston, mud pump, a double acting, reciprocating piston, liquid operated, driving motor, a direct driving connection between the pump piston and the motor piston, a constant displacement liquid pump connected to supply liquid under pressure to drive said driving motor, means providing indirect heat exchange between the mud which is pumped by said mud pump and the spent driving liquid from said driving motor and means to return said spent driving liquid to said constant displacement pump.

2. Mud-pumping apparatus for use in earth-boring operations that comprises a double-acting, reciprocating piston, mud pump, including a heat transfer jacket surrounding the working parts of said pump, a double-acting, reciprocating piston, liquid-operated, driving motor, a direct driving connection between the pump piston and the motor piston, a constant displacement liquid pump connected to supply liquid under pressure to drive said driving motor, connections from said driving motor to said heat transfer jacket to conduct spent driving liquid to said heat transfer jacket, and further connections from said heat transfer jacket to said constant displacement liquid pump to return said liquid to said constant displacement pump.

3. Mud pumping apparatus for use in earth boring operations that comprises a double acting, reciprocating piston, mud pump, said pump including a removable cover plate at one end and a removable cylinder mounted in the pump and removable through an opening provided by the removal of said cover plate, a double acting, reciprocating piston, liquid operated, driving motor, a direct driving connection between the pump piston and the motor piston, a constant displacement liquid pump connected to supply liquid under pressure to drive said driving motor, means providing indirect heat exchange between the mud which is pumped by said mud pump and the spent driving liquid from said driving motor, and means to return said spent driving liquid to said constant displacement pump.

4. Mud pumping apparatus for use in earth boring operations that comprises a double acting, reciprocating piston, mud pump, said pump being provided with a plurality of spring pressed poppet valves for controlling

its action, and a plurality of valve ports, each closed by a removable cover carrying one of said poppet valves and each cover being removably bolted into position over a valve port so as to be removable and to remove said poppet valve therewith, a double acting, reciprocating piston, liquid operated, driving motor, a direct driving connection between the pump piston and the motor piston, means for supplying liquid to said driving motor under substantially constant pressure, means providing indirect heat exchange between the mud which is pumped by said mud pump and the spent driving liquid from said driving motor, and means to return said spent driving liquid to said means for supplying liquid to said driving motor.

5. Mud-pumping apparatus as defined in claim 4 which further includes a removable valve seat positioned under each poppet valve and removable through the corresponding valve port.

6. Mud pumping apparatus for use in earth boring operations that comprises a double acting, reciprocating piston, mud pump, a double acting, reciprocating piston, liquid operated, driving motor, said driving motor having a piston of substantially smaller diameter than the piston of said mud pump, a direct driving connection between the pump piston and the motor piston, means for supplying liquid to said driving motor under substantially constant pressure, means for providing heat exchange between the mud which is pumped by said mud pump and the spent driving liquid from said driving motor, and means returning said spent driving liquid to said means for supplying liquid to said driving motor.

7. In a mud pumping apparatus for use in earth boring operations, an elongated and reciprocable piston rod having first and second pistons at its opposite ends, first and second cylinders associated with said first and second pistons, respectively, said first piston and said first cylinder constituting a double-acting and reciprocating mud

pump, said second piston and said second cylinder constituting a double-acting, reciprocating and liquid-operated driving motor for driving said mud pump, means for supplying liquid under substantially constant pressure to drive said driving motor, and means for providing indirect heat exchange between said liquid and the mud which is pumped by said mud pump, said means comprising a heat transfer jacket surrounding the working part of said mud pump, connections from said driving motor to said heat transfer jacket to conduct spent driving liquid to said heat transfer jacket, and further connections from said heat transfer jacket to said means for supplying liquid under substantially constant pressure to return said spent driving liquid to said means for supplying liquid under substantially constant pressure.

8. Mud-pumping apparatus as defined in claim 7, which further includes a by-pass valve for by-passing liquid under pressure around said driving motor so as to maintain a constant pressure upon said driving motor.

9. Mud-pumping apparatus as defined in claim 7, which further includes a filter connected into the driving liquid circuit for removing foreign materials from the driving liquid.

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