Jan. 13, 1942. B. F. SCHMIDT 2,269,789

FLUID PISTON PUMP

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FIG. 1.

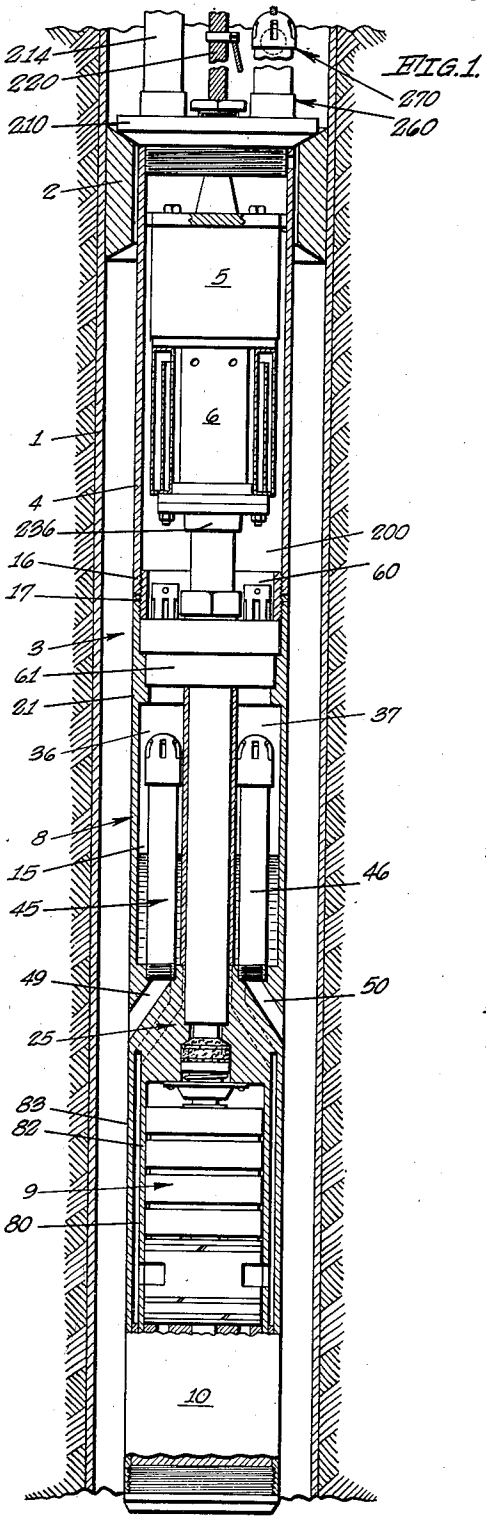
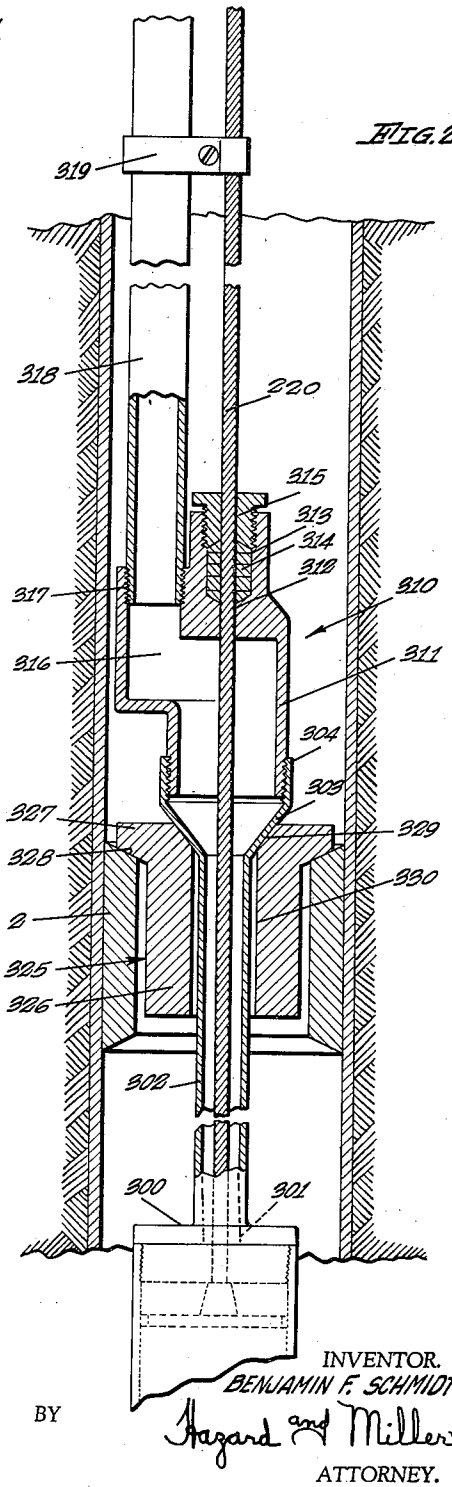


FIG. 2.



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FIG. 12.

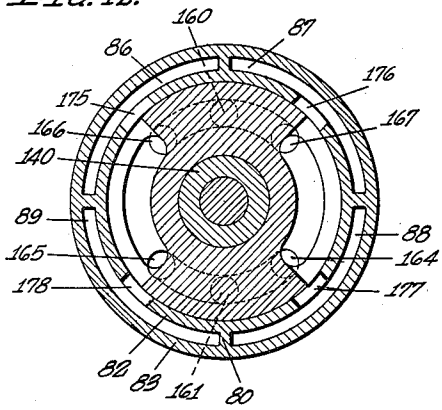


FIG. 14.

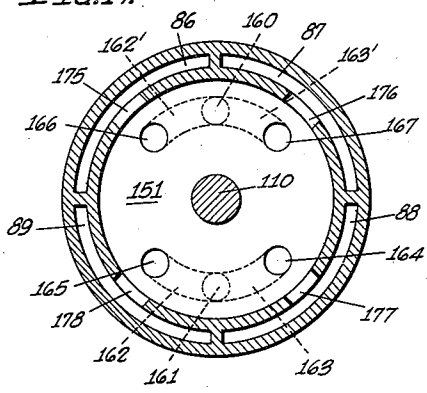


FIG. 13.

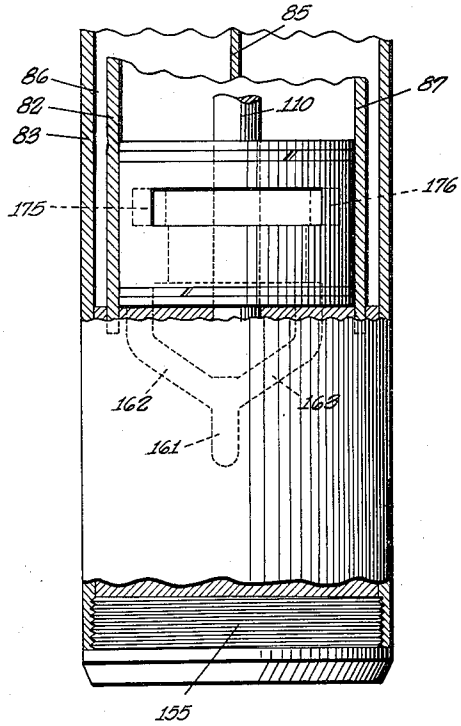
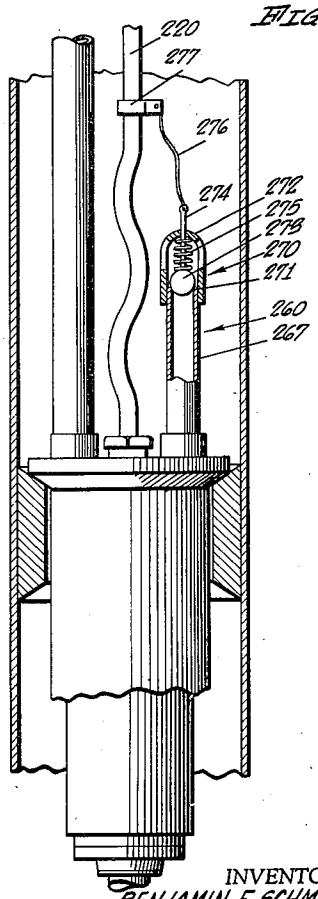


FIG. 3.



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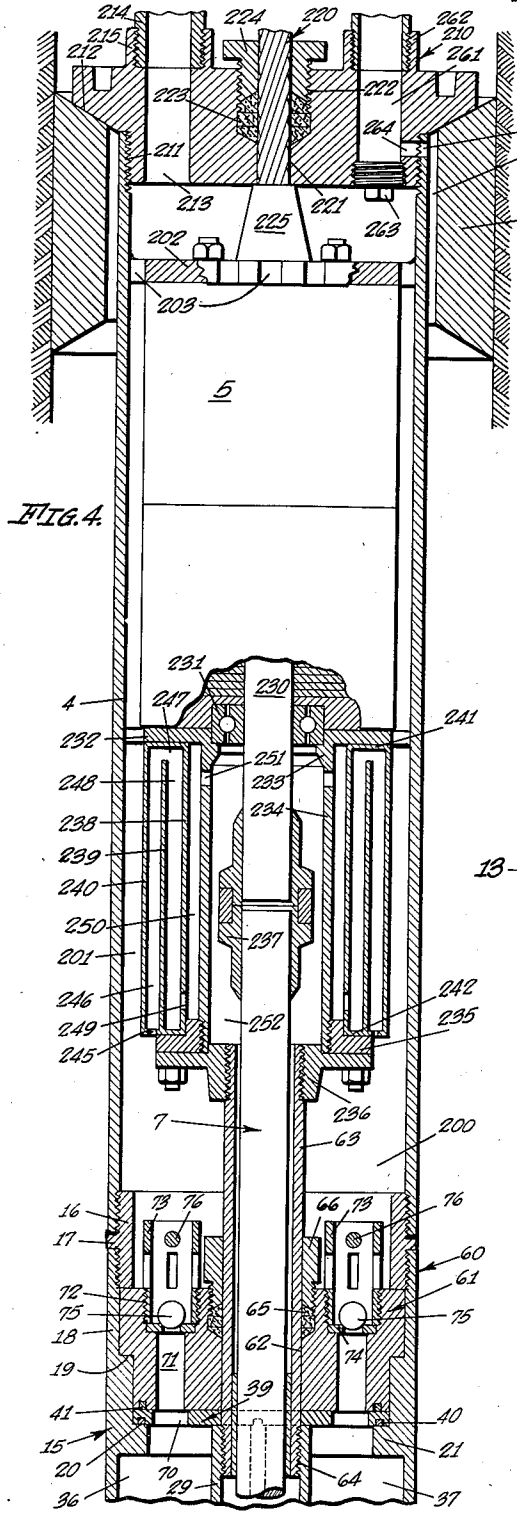


FIG. 4.

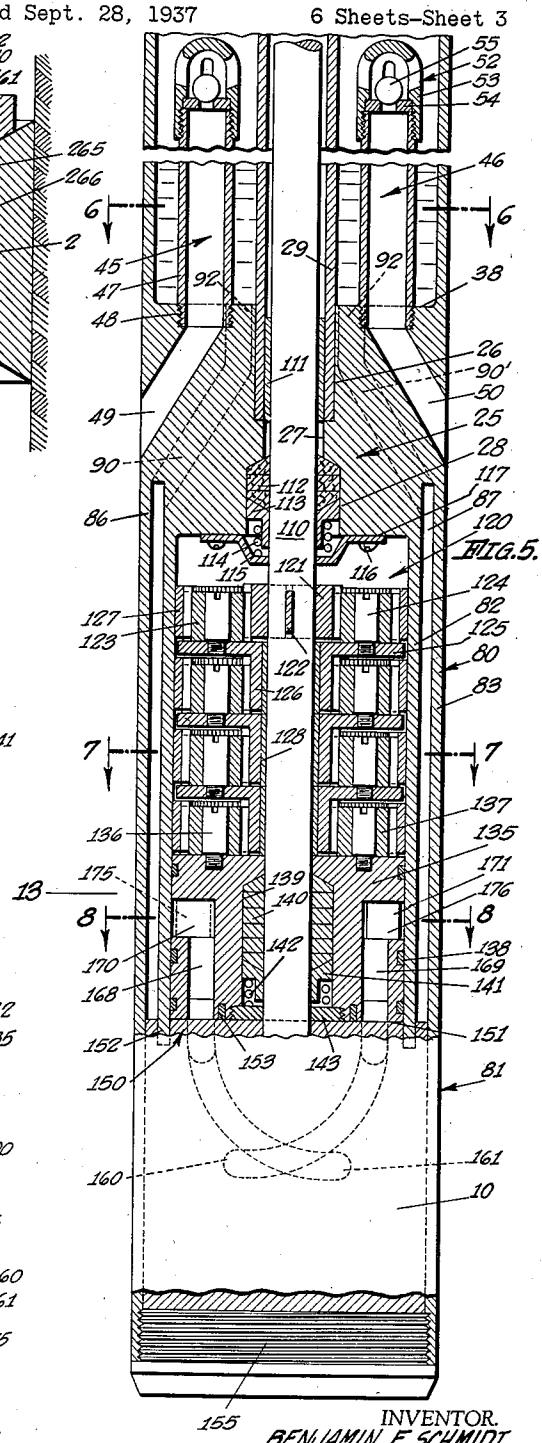


FIG. 5.

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FLUID PISTON PUMP

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FIG. 6.

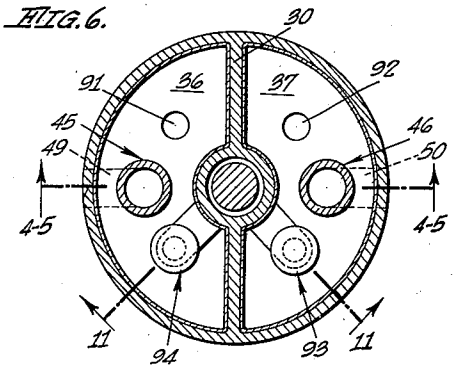


FIG. 7.

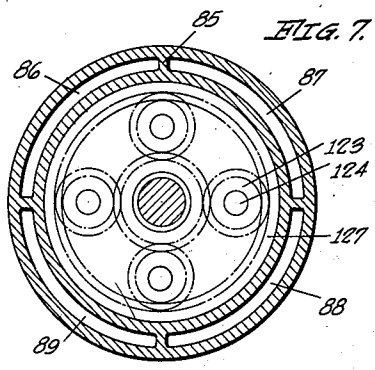


FIG. 8.

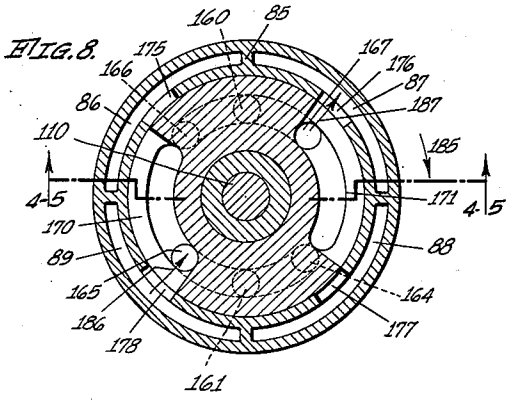


FIG. 9.

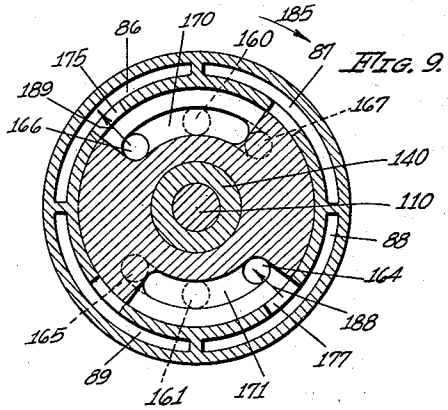


FIG. 11.

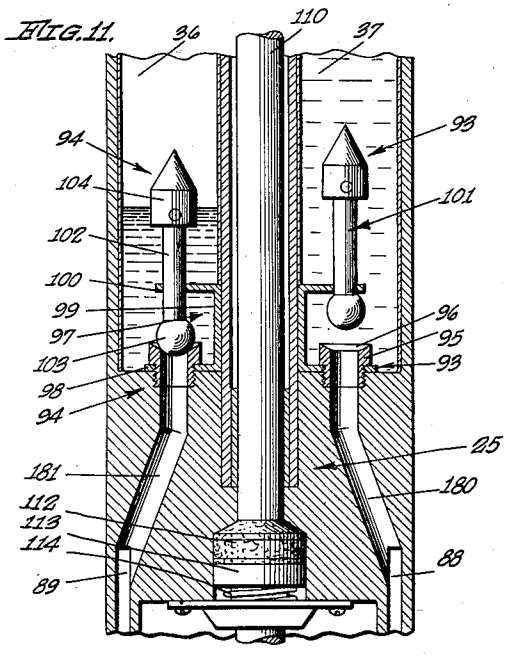
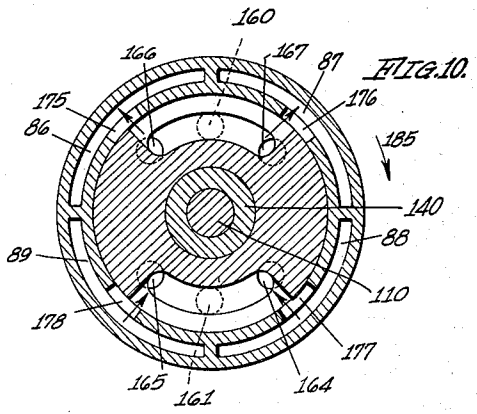


FIG. 10.



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Jan. 13, 1942. B. F. SCHMIDT 2,269,789

FLUID PISTON PUMP

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FIG. 16.

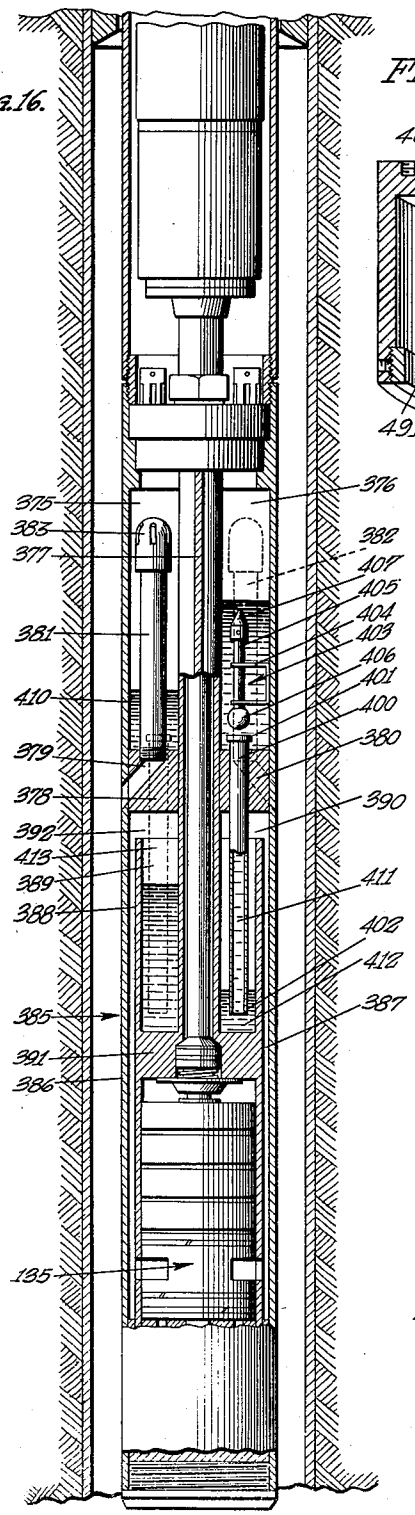
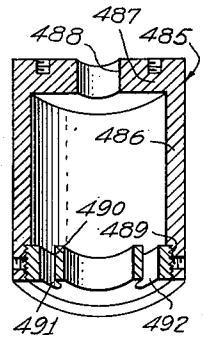


FIG. 21



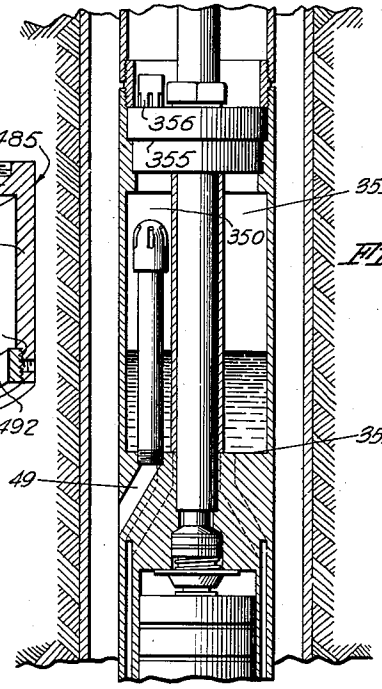


FIG. 15.

FIG. 19.

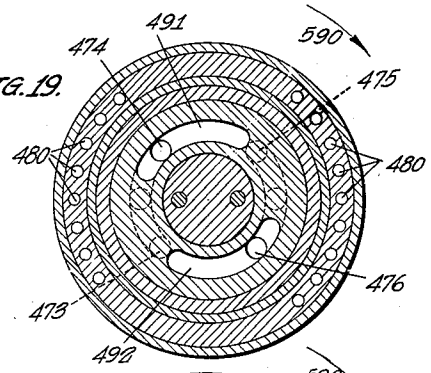
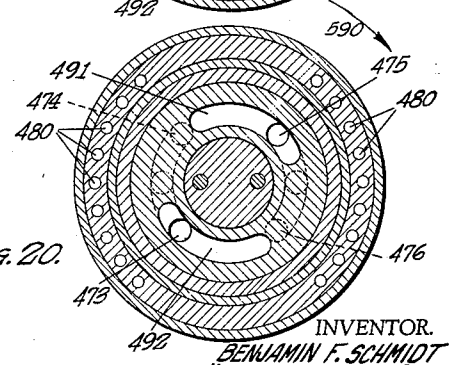


FIG. 20.



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FLUID PISTON PUMP

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FIG. 17.

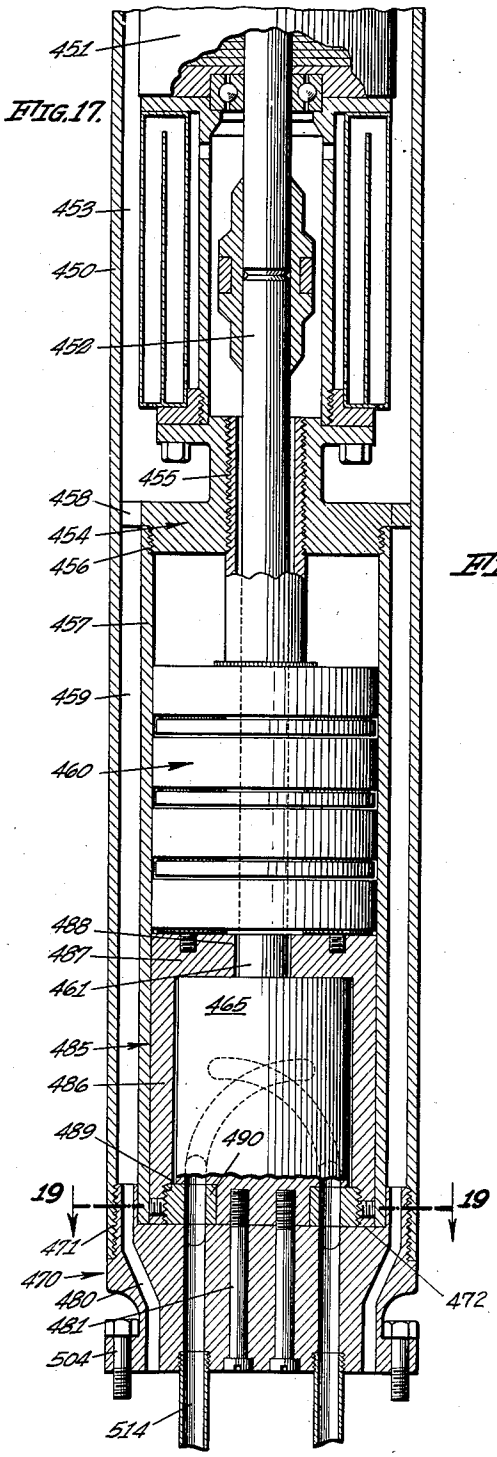
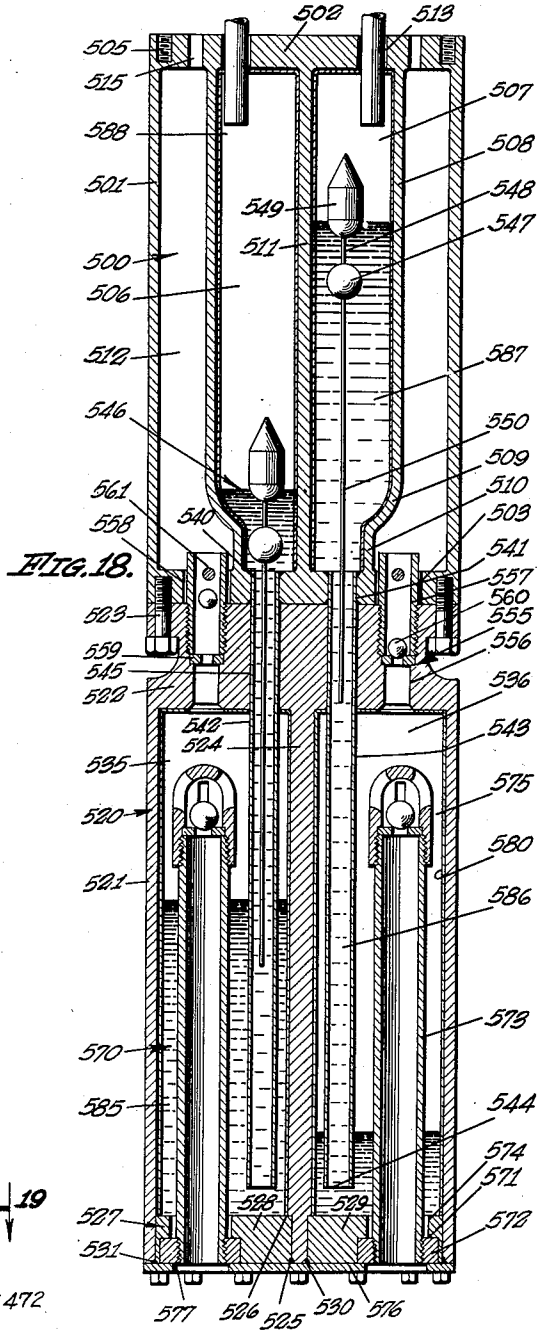


FIG. 18.



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Patented Jan. 13, 1942 2,269,789

UNITED STATES PATENT OFFICE

2,269,789

FLUID PISTON PUMP

Benjamin F. Schmidt, Los Angeles, Calif.

Application September 28, 1937, Serial No. 166,097

28 Claims. (Cl. 103—165)

My invention relates to a type of pump particularly adapted for deep well pumping in which a mobile liquid is utilized as the active pumping medium, that is, it provides a fluid piston which in the rise and fall causes the upward pumping of the liquid from the well. In this type of pump the liquid piston must be of such a character that it does not deteriorate when brought into contact with the liquid in the well or with abrasive or gritty material or other foreign matter which is carried as a mixture in the well liquid. As my invention is particularly adapted for pumping deep oil wells, I prefer to use mercury as the pumping liquid to form the fluid piston. The mercury is not contaminated by the oil or by sand, the gases or other foreign materials in the oil. I find it also advisable in my pumps to have the surfaces which are alternately in contact with the well oil and the mercury silver plated as this facilitates the mercury cutting or removing any adherent oil or materials from the metal parts of the pump with which the mercury may contact.

One of the main objects and features of my invention in this type of a fluid operated pump is in providing a plurality of pump chambers to contain the mercury acting as the pistons and the oil to be pumped. The mercury is pumped from one chamber to another and as the volume of mercury in one chamber is depleted, oil is drawn in to such chamber by suction or the pressure in the well. The mercury pumped out of one chamber is forced into another, thereby expelling the oil from such latter chamber which oil is conveyed upwardly by any suitable type of piping.

A further object and feature of my invention in this type of pump is having a continuous pumping action on the mercury as by means of a continuously acting mechanical pump of a construction which may develop a high pressure, and in conjunction with the mechanical pump I employ a rotary valve which develops a reverse flow of mercury from one pumping chamber to the other and then back again as a column of oil is forced upwardly through the assembly. However in a fluid piston pump employing a plurality of chambers operating in the manner described, it is sometimes difficult to prevent one chamber being completely exhausted of the mercury. This may be due to irregularities in the conduits or such like for transferring the mercury from one chamber to another or by more or less accumulation of gas in one or both of the chambers. As such gas is compressible it may cause one chamber to be depleted of mercury, that is, the fluid piston, while the other chamber has an excess of mercury.

Therefore another feature of my invention relates to a float stop valve construction operated by the column of mercury in each chamber so that when the mercury is depleted to a predetermined amount, the outflow valve of the mercury from such chamber is closed. At substantially the same time the rotary valve occupies a position so that the mercury in the chamber having a surplus quantity is transferred to the chamber having the depleted volume of mercury and thus again equalizes the amount of mercury requisite for the proper pumping in both chambers. The shut-off valve for each mercury chamber is preferably of a float type in which normally the valve is floated in the body of mercury but on depletion the valve drops to a seat, thus making a closure against the outflow of mercury from the particular chamber. For sake of simplicity of construction, for deep well pumping I preferably provide two elongated chambers each substantially semi-cylindrical and constructed in a cylindrical housing accommodated in the bore of the well, or the well casing.

Another object and feature of my invention in a submerged pump includes the feature of lowering the whole assembly, preferably by a cable or the like and having the power unit or motor positioned deep in the well and contiguous to the pump proper. In this connection I preferably use an electric motor and illustrate this in the drawings, but it is to be understood that other types of motors such as liquid operated or air motors might be utilized. However, with the electric motor the suspension cable for lowering the equipment into the well is constructed to house the conducting cables for the electric motor.

A further object and feature of my invention therefore is in employing a motor in a deep well pump and having this operate a vertical shaft which drives the mechanical pump. Such mechanical pump is at the bottom of the pump assembly and may be of any suitable type, however I prefer to include a system of reduction gears to reduce the high speed necessary for an electric motor to a low speed suitable for a rotary valve operated with said pump. Therefore as the electric motor and the gear reduction equipment must be under high hydraulic pressure due to the pressure of the oil in the well, another feature of my invention includes liquid baffle connections from, for instance, the interior of the motor to the oil of the well so that the motor as to the inside and outside pressure is equalized with the hydraulic head in the well. Likewise in the reduction gear train, by providing that this operate in an oil bath and the shaft also be surrounded by oil with pressure connections to the oil of the well, it is not necessary to have expensive or pressure tight packings to prevent entrance of the well oil.

My pump may be mounted in a well in various

suitable ways such as by employing a packer type of shoulder in a well casing and providing the upper end of the pump assembly with a head block which may rest on a packing type of shoulder. This head block is provided with a passage for the upward flow of the well liquid such as oil. If desired the oil may be carried upwardly in the well casing in which instance it is desirable to have a relief valve in the head block with a check valve connected to the lifting and lowering cable which cable also encloses the electric conducting cable. Such check valve prevents the downflow of oil but when it is desired to lift the assembly the upward pull on the lifting cable opens the check valve to release part of the oil in the upper part of the casing to equalize the pressure immediately above and below the packing shoulder. By another form of construction I may run a small bore string of oil tubing from the head block to the top of the well, this being useful in conditions in which the casing does not run to the well surface. In another form of construction I may employ a well tubing connected directly to the head block of the pump assembly with the hoisting and lowering cable passing centrally through this oil tubing, then by means of an offset fitting, a string of oil tubing is carried up parallel to the cable. With this arrangement it is desirable to employ a sleeve-like head having a loose fit on the lower part of the oil tubing and provided with a head engaging the packing shoulder. This sleeve by means of a flare supports the flared upper end of the lower part of the oil tubing, thus suspending the pump assembly in the well and allowing for readily lowering and lifting this whole assembly. Where the pump assembly is supported on a packer type of shoulder my invention comprehends not only the release of any oil accumulating above the head block or sleeve-like head, but the release of any sand which may so accumulate on the initial movement to lift the pumping assembly in the well. In case of a shut down it is often desirable to release any sand or oil which accumulates above the packer and this may be done by slightly lifting the pumping assembly which allows all of the sand with the oil to flow downwardly to the bottom of the well and thus prevents "freezing" the pump in the well.

My invention also includes a construction and mode of operaton in which the so-called fluid piston includes a clean liquid such as oil which may be operated through the pump and this acts on the piston liquid which is insoluble in the liquid being pumped. Such insoluble liquid is preferably mercury and when the pump chambers are plated in a suitable manner, the mercury operates to clean any sticky or gritty material in the well liquid from such finished surface. In this case of pumping a clean and relatively light weight liquid, such clean liquid forms with the mechanical pump an actuating means for the insoluble fluid. My invention also comprehends a construction by which the motor, the pump and reduced speed gear, together with the main valve operating with the pump may be located above the intake for the well fluid through the well liquid and above the chambers for the insoluble fluid piston. However if desired the electrical and mechanical equipment may be separated by the location of the chambers for the fluid piston and for the flow of the well liquid. My invention also comprehends a construction and operation in which the well liquid is drawn in and pumped upwardly from a single chamber in which case it is necessary to use a chamber or reservoir for the storing and flowing of the pumping fluid on the suction or discharge strokes.

My invention is illustrated in connection with the accompanying drawings, in which:

Fig. 1 is a vertical section of the lower part of a well illustrating the pump assembly housing in a partial section and interior parts of the pump assembly mainly in elevation.

Fig. 2 is a vertical section through the lower part of a well showing an alternative construction for supporting the pump assembly.

Fig. 3 is a detail elevation of the upper part of Fig. 1 to illustrate the operation of a relief valve used when withdrawing the pump from the well.

Figs. 4 and 5 are connected vertical sections through the pmp of Fig. 1 shown on a larger scale and may be considered as taken on the section line 4—5 of Figs. 6 and 8 in the direction of the arrows.

Fig. 6 is a transverse section on the line 6—6 of Fig. 5 in the direction of the arrows.

Fig. 7 is a transverse section on the line 7—7 of Fig. 5 in the direction of the arrows.

Fig. 8 is a transverse section on the line 8—8 of Fig. 5 in the direction of the arrows.

Fig. 9 is a section similar to Fig. 8 with the rotary valve in a second position.

Fig. 10 is a section similar to Figs. 8 and 9 with the rotary valve in a third position.

Fig. 11 is an enlarged vertical section on the irregular line 11—11 of Fig. 6 taken in the direction of the arrows.

Fig. 12 is a section similar to Figs. 8 and 9 showing the valve in another position.

Fig. 13 is an elevation broken away of the lower portion of the well showing the passages connecting the pump and the valve.

Fig. 14 is a section similar to Figs. 8 through 12 with the valve removed illustrating the ports connecting to the pump.

Fig. 15 is a vertical section of part of the pump illustrating a single chamber piston pump, such figure may be considered a modification of a portion of the section shown in Fig. 1.

Fig. 16 is a vertical section of a modification of the construction of Fig. 1 in which additional chambers are used for the liquid piston and in which a clean oil or the like is actuated by the mechanical pump instead of the mercury and this clean oil develops a rise and fall of the mercury in the piston chambers. This may be considered as a section somewhat similar to Fig. 1.

Figs. 17 and 18 are upper and lower sections of a further modification of the pump in which the motor, the gear reduction train and the pump are located in an upper position of the assembly, the piston pump chambers being located adjacent the bottom and reservoirs for the fluid piston and a clean liquid positioned thereabove. In this case the clean liquid is actuated by the mechanical pump and operates on the fluid piston or mercury.

Fig. 19 is a horizontal section on the line 19—19 of Fig. 17 in the direction of the arrows showing the ports of the valve block in one position.

Fig. 20 is a similar section showing the valve block ports in another position.

Fig. 21 is a perspective view of one-half of the value of Figs. 17, 19 and 20.

Referring first to the construction of Fig. 1, in this a well casing or well bore is indicated by

the numeral 1 having a packing or other supporting shoulder 2. The submerged pump assembly 3 has a cylindrical casing or housing 4 in which a motor 5 is located at the top. Below the motor there is an oil pressure equalizing assembly 6. The shaft assembly 7 extends through the fluid pump chamber assembly 8 and drives a speed reduction gear assembly 9, this latter being operative to actuate a rotary valve hereunder described. The pump 10 is illustrated as having a direct drive for shaft 7 but a gear reduction may be used.

Dealing first with the main characteristics of the fluid or liquid pumping and its chamber designated by the assembly numeral 8, the housing assembly 3 having the casing 4 employs as part of this casing a lower or preferably cast fabricated pump structure 15 which at its upper end has an internal threaded coupling 16 provided with an annular rim 17 having a threaded connection to the upper part of a cast or fabricated pump housing 18. This housing is cylindrical on its outside and is provided with an upper internal shoulder 19, a lower internal shoulder 20, these being formed in a thickened internal valve support 21. At the lower part there is a solid block or base 25 with a recess 26 therein and a cylindrical bore 27, this also terminating at its lower end in a packing recess 28. A shaft casing tube 29 is seated in the recess 26 and is preferably either cast therein or fabricated. A diametrical partition or web 30 connects the outside wall 18 and the shaft casing tube 29 (note Fig. 6). This structure may be fabricated or cast. The shaft casing tube 29 and the webs 30 terminate at the level of the lower shoulder 20, note Fig. 4. There are thus defined two liquid chambers 36 and 37 on opposite sides of the partition 30 having a bottom surface 38 forming the upper part of the block section 25. A closure plate 39 seated on the shoulder 20 and on the upper end of the casing tube 29 and the webs 30 form the upper limit of the liquid or fluid space. This plate 39 is properly seated and provided with suitable packing 40 forming a liquid tight joint at the shoulder 20, the upper edges of the partition 30, and the circular upper edge of the casing tube 29. This plate 39 has studs or pins 41 extending upwardly to engage in complementary sockets in a valve block assembly hereunder detailed.

Dealing next with the portions of the pump functioning directly with the flow of the well oil, at the bottom of each of the pump chambers 36 and 37, there are two oil intake valve assemblies designated respectively 45 and 46. These are of the same type and each has a tube or pipe 47 having a threaded connection to the block 25 as indicated at 48 and, below this, sloping oil inlet ducts 49 and 50 communicate with the exterior of the block 25. It will be noted that there is an annular space for the upflow of oil between the submerged pump assembly and the well casing 1. Check valves 52 are secured to the upper ends of the pipes 47, these being illustrated as having a cage 53 threaded on the upper ends of the pipe and retaining a valve seat ring 54 in place upon which seats the ball 55. The cages are illustrated as slotted. These check valves therefore allow upward flow of the well oil but prevent the downward flow.

The upper oil valve assembly 60 (note particularly Fig. 4) employs a valve block 61 which has its lower end bearing directly on the plate 39, there being sockets to accommodate the studs or pins 41 and thus permit accurate centering of this block. Such block has a bore 62 through which extends an upper shaft casing tube 63, this having a threaded connection 64 to the lower casing tube 29. A packing 65 and packing gland 66 form a leak-tight joint.

The port and outlet valves consist of a pair of ports 70 in the closure plate 39 which register with two ports 71 in the block 61. This block has two threaded recesses 72 in which is threaded the outlet valve cage tube 73, this seating on a seating ring 74 upon which rests a ball 75. A transverse pin 76 limits the upward movement of the ball and the edge of the cage tubes is slotted, thus giving adequate area for outflow of the oil. The coupling 16 is operative to retain the valve block 61 and its assembled parts in position.

The lower portion of the liquid chambers 36 and 37 forms a space for the liquid piston and, as above described, for pumping oil I find that mercury is the most satisfactory liquid for this purpose. The pump 10 therefore is a mercury pump receiving its supply from one of the chambers 36 and discharging into the other, the action being in an alternate manner controlled by a valve. Such construction is detailed hereunder. Extending downwardly from the block 25 is a combination gear housing assembly 80 with the pump housing 81 therebelow. The gear housing includes an internal cylinder 82 connected to the outer cylinder housing 83, there being illustrated four radial connecting webs 85, note Figs. 7 through 10. These define therefore four segmental spaces 86, 87, 88 and 89. The upper ends of these spaces lead to diagonal passages 90 and 90', note Fig. 5, which converge inwardly to two ports in the bottom of the chambers 36 and 37, thus from the space 86 there is an inlet port 91 (note Fig. 6) and from the space 87 there is an inlet port, 92, from the space 88 there is an outlet port valve assembly 93 and from the space 89, an outlet port valve assembly 94.

The valve assemblies 93 and 94 each have a float valve assembly including a valve seat ring 95 (note Fig. 11) threaded into the bottom surface 38 of the block 25 and each communicating with a diagonal passage. These are each provided with a cone type of valve seat 96. A guide bracket 97 has a base 98 held in place by the seating ring 95, and is provided with an upstanding post 99 and a horizontal arm 100, having a guide opening for the float valve 101. Each of these valves has a rod 102 slidable through the opening at the bottom with a ball type valve plug 103 to engage the seat 96. A float head 104 is secured to the top of each rod. These float valves may be made of metal of such a specific gravity that they will float in mercury.

The shaft assembly 7 leading from the motor 5 has a lower or driving end 110 which passes through the block 25, there being a sealing packing 111 located inside the lower portion of the shaft casing 29. The packing recess 28 is provided with packing 112 (note Fig. 5), this being held in place by a slip gland 113. A compression spring 114 bears against this gland and thrusts against a bridging plate 115 secured at 116 to the lower surface 117 of the block 25. In the space defined by the internal cylinder 82 and this bottom surface 117, there is located a reduction gear train 120 consisting of a series of planetary gears of which the main driving gear 121 (note Fig. 5) is secured by a key 122 or the

like to the shaft 110. This drives the first set of planetary gears 123 mounted on studs 124 on a flange 125 of the second hub gear 126, there being the stationary ring gear 127 meshing with the planetary or pinion gears. The sequence of gears is built up in the same manner, the shaft having a bushing 128 on which the hub gears rotate. In this manner a speed reduction is communicated to a slow speed valve block designated by the numeral 135, the last set of studs 136 of the gear train carrying the last set of pinions 137 being secured to this valve block. Such block has a series of sealing rings 138 engaging the inside cylinder 82 and is provided with a packing recess 139 in which there is compressible packing 140 held in place by a slip gland 141 by a compression spring 142. This spring engages threaded clamping rings 143 (note Fig. 5) which are held in place by the pump block 150, this being defined as having an upper surface 151, the lower ends 152 of the inner cylinder 82 being seated therein with suitable packing or connections to be proof against the leak of mercury. There is also a packing 153 between the lower part of the valve block 135 and the upper surface 151 of the pump block 150. This pump block is held in place by a threaded plug 155 threaded in the lower end of the pump housing 81. I do not illustrate the details of the mercury pump as there are a number of types of rotary pumps which may be used for this purpose and if one pump cannot develop sufficient pressure, two pumps, one above the other may be interconnected to develop sufficient pressure in the mercury pumped to and fro in the chambers 36 and 37.

The mercury pump has two passages indicated at 160 and 161 which lead upwardly and each is divided having two branch arms 162 and 163 which lead to ports 164 and 165 which in the present drawings may be considered as inlet ports to the mercury pump conducting the mercury downwardly from the oil chamber having the mercury piston to such mercury pump. At the mercury pump the branches 162' and 163' lead to ports 166 and 167 which may be considered as providing for the forced upward flow of mercury from the mercury pump to the oil chamber to raise the level of the mercury in the fluid pump for upward discharge of the oil. All of these ports 164, 165, 166 and 167 are concentric with the valve block 135 and hence with the drive shaft 110 and are spaced inwardly and aligned with the vertical mercury flow slots 168 and 169 in the valve block 135. These latter are connected at the top with radial slots 170 and 171 of the valve block 135, these slots leading to the internal cylinder 82.

This cylinder is provided with a series of ports, the port 175 communicating with the segmental space 86, the port 176 with the space 87, the port 177 with the space 88 and the port 178 with the space 89. At the upper end of the segmental spaces 88 and 89, there are upwardly extending passages 180 and 181 communicating respectively with the outlet float valve ports 93 and 94 from the fluid piston chamber (note Fig. 11). From the segmental spaces 86 and 87, there are also the upwardly inclined passages 90 and 90', note Fig. 5, leading respectively to the inlet ports 91 and 92 of the fluid pump.

As above mentioned the valve block 135 rotates at a relatively slow speed and this is indicated as being in the direction of the arrow 185 (note Figs. 8, 9 and 10). Presuming the valve block 135 is in the position shown in Fig. 8, then mercury is being drawn out of the chamber 36 through the outlet valve 94, crossed downwardly through the passage 181 to the space 89, inwardly through the port 178 through the aligned radial slot 170 of the valve block 135, downwardly through the passage 168 and thence through the port 165 which forms an inlet to the mercury pump in the lower part of the assembly. From this pump the mercury is forced upwardly through the port 167, the passage 169, the slot 171, the port 176 to the lower part of the space 87 and thence upwardly through this space, the inclined passage 90' and by the inlet 92 flows into the chamber 37. It will thus be seen that the pump at this stage has its inlet or supply from the chamber 36, thus lowering the mercury piston in such chamber and forcing the mercury into the chamber 37. The direction of flow of the mercury through the ports 176 and 178 is indicated respectively by the arrows 186 and arrows 187.

In the stage of rotation of the valve block 135 illustrated in Fig. 9, the outlet valve 93 of the mercury chamber 37 forms the downflow inlet to the mercury pump. The flow is thus downwardly through the inclined passage 180 (note Fig. 11), the segmental space 88, the port 177, the valve slot 171 communicating by the vertical passage 168 with the port 164, thus supplying mercury to the pump, the direction of flow through the port 177 being indicated by the arrow 188. The mercury forced upward by the mercury pump has its outlet through the pump port 166 and flows upwardly through the passage 168 of the valve block 135, the slot 170, the port 175, to the segment 68, the direction of flow through the port 175 being indicated by the arrow 189. The flow is then upwardly through this segment 86, the inclined passage 90 to the inlet port 91 of the fluid piston chamber 36, thus replenishing the mercury in such chamber and raising its level while it flows downwardly and outwardly from the chamber 37. Therefore it will be seen that by the flow of mercury into and out of the fluid piston portion of the pump that this only flows in a downward direction in the segmental spaces 88 and 89 from the outlet valves 93 and 94. Also the flow is only in an upward direction in the segmental spaces 86 and 87 discharging through the ports 91 and 92 into the chambers 36 and 37. Therefore there is only an inward flow through the ports 177 and 178 from the spaces 88 and 89 and only an out flow through the ports 175 and 176 to the spaces 86 and 87.

As above mentioned, it may happen sometimes that the mercury in one of the chambers either 36 or 37 will be exhausted to too low a level and in which case one or other of the float valves 101 will seat. This action is illustrated in Fig. 11 in which the float valve communicating with the chamber 36 is shown in the seated position, that is, the ball plug 103 is seated on the seating ring 95. During the relative slow rotation of the valve block 135 this condition becomes rectified. For instance when the valve block is in the position shown in Fig. 10, both of the parts 164 and 165 communicating from the oil chamber, that is, the fluid piston chambers to the power pump are open and the two ports 166 and 167 through which the mercury is forced from the power pump upwardly are also open and, as above mentioned, as the mercury can only flow downwardly in the spaces 88 and 89 and the float valve 94 leading

to the space 89 is closed as shown in Fig. 11, all of the mercury to provide for the operation of the power pump is drawn from the over-full chamber 37 through the float port outlet 93. On account of the ports 166 and 167 also being both open at the same time, the mercury is forced upwardly by the power pump through the spaces 86 and 87, the ports 91 and 92, to the chambers 36 and 37. Therefore these chambers receive a supply of mercury and as it cannot float out of the chamber 36, the valve 94 being closed, the mercury level is raised. In addition due to the differential hydraulic head in the chambers 36 and 37, there is a greater back pressure in the chamber 37 to the replenishing flow of the mercury, hence most of the mercury pumped from the chamber 37 through the space 88 and the port 164 is replenished to the chamber 36, thus equalizing the mercury in the two chambers so that in the normal operation the valves 93 and 94 do not close unless of course there is some irregularity to the flow of mercury downwardly to the mechanical pump and upwardly from such pump in one of the lines of communication. An irregularity in the flow of mercury may be gas accumulating in the pumping chambers, such gas separating from the well oil and hence as such gas would be compressible, it might cause an irregular flow of the mercury and too great a depletion of one chamber.

In view of the fact that the mechanical pump is always operating, it is necessary to provide for a continued flow of mercury from one or other of the spaces 36 and 37 or both and back to one or both of these chambers. When the valve block 135 is in the position shown in Fig. 12, it will be seen that there is a communication between the ports 165 and 166 of the mechanical pump from and to the chamber 36 through the medium of the spaces 89 and 86. Likewise there is a communication through the ports 164 and 167 through the spaces 88 and 87. Thus mercury is simultaneously pumped out of chamber 36 and back into such chamber and also to chamber 37 and back into the same chamber. On account of the movement of the valve block 135 being comparatively slow, there does not develop a quick and decided shut off or opening of any particular channel of flow of the mercury and hence there is no effect developed similar to a water hammer or the like.

The flow of oil from the well is developed and controlled by the action of the fluid mercury pump. Hence for instance as the mercury drops in the chamber 36 oil is forced into this chamber by the hydraulic pressure in the well, the outlet valve connecting with such chamber being closed by the oil thereabove. This inlet of oil to the chamber 36 is through the inlet duct 49 and the valve 45. The upwardly moving fluid piston developed by the rise in the level of mercury in the chamber 37 forces the oil in this chamber above the mercury upwardly and out of its outlet valve. The back pressure against the valve 46 in seating the ball valve prevents a back flow of oil to the well. There is thus a repeated cycle of the inlet of oil to, say, chamber 36, the elevation of such oil, then the forcing of the oil upwardly from the chamber 36 while it is being replenished in the chamber 37, such cycle repeating.

The flow of oil in the construction shown in Figs. 1, 3 and 4 from the fluid piston, that is, the mercury pump, includes as an oil float space, the chamber 200 inside of the upper part of the casing 4. This is an annular space surrounding the upper shaft casing tube 63, the space 201 surrounding a baffle balance 6 described hereunder in detail and also surrounding the motor 5. This motor is attached to the housing 4 by a motor support plate 202, this having a series of channels or perforations 203 for the upward flow of the oil.

The suspension of the pump in the well by the equipment of Figs. 1, 3 and 4 includes the packer or supporting shoulder 2, a head block 210 which has a threaded connection 211 to the upper part of the housing 4 and is provided with annular shoulders 212 seating on the conical upper end of the packer or supporting shoulder 2. There is an oil outlet passage 213 through the head 211 and through an oil pipe 214 made up in stands and leading to the top of the well. This is shown as having a screw threaded connection to the rim 215.

The combined electrical conducting and lifting and lowering cable 220 by which the whole of the pump is lowered into the well and lifted passes through an opening 221 in the head 210, the head being provided with a recess 222 having a packing 223 and a packing gland 224, thus making an oil tight connection. There is a clamp or other attaching device 225 connecting the lower end of the cable to the plate 202 with the conducting leads to the motor.

The oil pressure equalizing assembly 6 which may be considered as a baffle oil balance, equalizes the internal pressure in the motor by bringing oil inside the motor under the same hydraulic head as the oil being pumped upwardly through the spaces and chambers 200 and 201 and thence to the top of the well. The shaft assembly designated by the numeral 7 has a motor shaft 230 (note Fig. 4) which extends downwardly through an anti-friction bearing 231 mounted in the motor and engaging a lower motor head 232, this head having a shoulder 233. An internal sleeve 234 is shown as formed integral with the head 232 and extends downwardly to a screw threaded coupling ring 235, the connection being screw threaded. This ring is bolted to an internally threaded disk 236 which has a threaded connection with the upper shaft casing tube 63. Inside of the sleeve 234 is located the shaft coupling 237 which may be of any suitable type connecting the motor shaft to the downwardly extending drive shaft. In constructing the baffle balance a second sleeve 238 surrounds the inner sleeve 234, a third sleeve 239 is spaced further outwardly and there is the outermost or confining shell 240, the sleeves 238 and 239 having an upper end closure 241 and a lower similar closure 242 engaging between the heads 232 and the ring 235 and being secured by a packing to be oil tight. A series of openings or perforations 245 shown in the closure 242 communicate with the outer annular space 246. Passages 247 at the top of the sleeve 238 communicate with the annular space 248. A series of perforations 249 at the lower part of the sleeve 238 communicate with the space 250 and a series of upper perforations or ports 251 communicate through the sleeve 234 to the inner chamber 252. When all of these spaces and chambers are filled with clean oil and clean oil is filled in the space 200 and 201 before the pump assembly is lowered into the well, it will thus be seen that the balance baffle due to the intricate channels which would be required for the inflow or outflow of oil, maintain this clean oil developing an internal pres-

sure in the electric motor and the clean oil is not washed out by the upward flow of well oil and there is practically no intermingling. This clean oil also fills the annular space between the various sections of the pump 8 extending downwardly in the various sections of the shaft housing.

In the construction shown in Figs. 1, 4, and 5, I illustrate the oil pipe 214 as extending upwardly in the well. If the well casing is tight it is not necessary to continue this pipe to the top of the well. In fact, it may be omitted entirely and the oil flowed upwardly in the casing from the oil outlet passage 213 in the head block 210. It is usual to have a liquid-tight seal by means of the packing at the joint formed by the annular shoulders 212 and the supporting shoulder 2. If the oil is pumped upwardly in the well casing, omitting the oil pipe 214 or even when this pipe is used on account of the possibility of there being a head of oil or other liquid on the head block 210, it is desirable to have an equalizing valve construction which may be opened to drain liquid from above the head 210 to a portion of the well below the supporting shoulder 2. Such a relief valve assembly is illustrated in Figs. 1 and 3, certain details being shown in Fig. 4, this being designated by the assembly numeral 260. This includes the head block 210 having a vertical bore 261 leading downwardly from a threaded rim 262. A closure plug 263 blocks the bottom of this bore and from the bore there is a lateral passage 264 in the head block leading through an opening 265 in the upper end of the cylindrical casing 4. This communicates with an annular space 266 inside of the shoulder 2. A valve tube 267 leads upwardly from the rim 262 to which it is connected and has a check valve 270 at its upper end. This check valve includes a seat 271. On the upper end of the tube 267 a perforated cage 272, a ball 273 mounted in the cage and having a stem 274 connected with the ball and operating through a bearing in the top of the cage. A compression-seating spring 275 normally maintains the ball seated. A pull cable 276 is connected to the upper end of the stem 274 and attached to a clamp 277 which is secured to the main cable 220.

When the pump assembly is being lowered into the well, this main cable is taut and hence the pull cable lifts the ball off its seat. However, when the head 210 rests and is supported on the shoulder 2, the spring 275 seats the ball and thus closes the valve 270 and this remains closed in the normal operation of the pump, and thus, if the well oil is pumped upwardly in the casing or if the oil pipes 214 are disconnected so that the oil or other well liquid develops a considerable hydraulic pressure on the head 210, then this valve may be opened when it is desired to lift the pump assembly from the well. In this action the upward pull on the main cable 220 through the medium of the clamp 277 exerts a pull on the short cable 276, thus lifting the ball from its seat and allowing any liquid above the head 210 to flow downwardly through the bore 261 to the passages 264, 265, and 266 to the section below the well to the shoulder 2 and thus equalizes the pressure above and below the head 210, allowing ready removal of the whole pump assembly. It will be noted there is sufficient clearance inside of the shoulder 2 for lowering and setting the pump for again lifting it to the surface of the well.

In Fig. 2 I show an alternative construction for mounting the pump in a well necessitating a slight change in the upper part of the pump assembly. For instance, instead of the head block 210 I substitute a head block 300 connected to the upper part of the housing 4 by a screw threaded connection and this head has a central opening 301 for the upward flow of oil and to form a passage for the lifting and conducting cable. Where this cable passes through the head block I employ packing and a packing gland somewhat in accordance with the construction of Fig. 4. An oil tube or pipe 302 is attached to the head block 300 preferably by welding, the inside aligning with the opening 301. This tube has a flared upper end 303 with a threaded rim 304 extending thereabove. A tubular oil fitting 310 has a cylindrical lower part 311 having a threaded connection to the rim 304 and is provided with a perforation 312 for the cable 220, there being a recess 313 in which is fitted a compressible packing 314 held in place by a gland 315 forming an oil tight connection with the cable. An offset tube 316 is threaded at its upper end 317 and to this is connected a string of oil tubing 318 which may lead to the top of the well. This tubing has clamps 319 connected to the cables at various stands to prevent the cable and the pipe becoming tangled. In order to support the pump assembly on the supporting shoulder 2 I employ a substantial sleeve head 325. This has a cylindrical section 326 and an enlarged head 327, such head having a bevel 328 engaging the upper surface of the shoulder 2. The head has a beveled surface 329 engaging the flared upper end 303 of the oil tube 302. The central bore 330 is of sufficient diameter to give a clearance for the tube 302. With this construction as the assembly is being lowered in the well the head sleeve 325 rests on the head block 300 until there is an engagement with the shoulder 2. The pump assembly is then lowered until the pump is supported by the flared upper end 303. The oil or other well liquid is pumped upwardly past the motor through the oil tube 302, the fitting 310 and the string of oil tubing 318. In this case it is not necessary to have any relief valve as the weight of oil or other well liquid on the sleeve block 325 is insufficient to prevent the upward lift of the pump assembly breaking the joint with the shoulder 2. In both the construction of Figs. 1, 4 and 2 it is preferable to have a compressible packing at the contact upper surface of the shoulder 2 as is common practice in oil well and similar constructions.

In Fig. 15 I show a modification of the construction of Fig. 1 in which I employ one pumping chamber 350 and one reservoir chamber 351. These may be the same shape and contour as shown in connection with Fig. 1 except that there is only one intake passage 49. Thus the reservoir chamber 351 has a closed bottom 352 except for the ports for the in and out flow of mercury. The valve block 355 is also modified by having only one outlet valve assembly 356. Otherwise the construction is substantially the same as illustrated and used in connection with Fig. 1 and associated figures.

In the operation of the single chamber fluid piston on the suction stroke in which the well oil flows in through the inlet duct 49, the mercury is withdrawn from the pumping chamber 350 and is charged into the reservoir chamber 351. When assembling the pump before lowering in the well, it is desirable to fill the reservoir chamber 351 with mercury or else to have only a small volume

of an inert gas at the top of this chamber, such gas therefore being compressible and allowing an adequate volume of mercury to be filled into the reservoir **351**. On the lifting stroke the mercury is pumped from the reservoir **351** into the piston chamber **350** and forces the oil trapped therein upwardly through the outlet valve **356**. By using this construction of a single fluid piston chamber, such chamber may be made of considerable length and in fact the reservoir **351** and the pump chamber **350** are not necessarily on the same level but may be positioned in different parts of the pump assembly.

The construction of Fig. 16 illustrates in vertical section the equipment for using a clean oil or similar liquid actuated by the mechanical pump and this clean oil develops the mercury flow. By such construction the mercury never contacts the mechanical pump and the clean oil entering and being discharged from the mechanical pump never comes in contact with the well oil. In this arrangement I employ piston pump chambers **375** and **376** of the same type as shown in connection with Fig. 1, these being divided by a vertical partition **377**. The bottom of each chamber is formed by a base block **378** having substantially the same structure and function as the base block **25** of Fig. 1. Through this block there are two inlet oil passages **379** and **380** leading to oil inlet tubes **381** and **382**, each having a standing valve assembly **383** to allow the inflow but check the back flow of oil.

Below the block **378** I employ the double shell structure **385** having the outer casing **386** and the inner cylinder **387** spaced therefrom and forming a series of vertical segmental passages **388** the equivalent of the segmental passages **86**, **87**, **88** and **89**. These lead downwardly to the rotary valve **135**. There are two reservoir chambers **389** and **390** separated by a continuation of the partition **377** and terminating at the bottom block **391**. There are ports indicated as **392** leading from each of these reservoir chambers to the segmental passages **388**. The outlet connection for the mercury from each of the chambers **375** and **376** includes an outlet tube **400** which extends through the block **378** and has a valve seat **401** thereon. The lower end **402** of each of these pipes is open and positioned spaced slightly above the bottom block **391**. A float valve assembly **403** consists of a guide **404** through which operates the valve rod **405**, this having a ball **406** to engage the seat **401** and a float **407**, the operating function being the same described in connection with the float valve **94**. By this construction there is therefore the active fluid piston indicated by the mercury **410** in the chambers **375** and **376** and the mercury column **411** in each of the flow tubes **400**. In this case there is only the single tube connection from the upper pumping chambers to the reservoir chambers providing for the up and down flow of the mercury by means of the column **411**. There is always a body of mercury **412** in the reservoir chambers **389** and **390**. The clean oil or other liquid occupies the space **413** above the mercury level in the reservoirs **389** and **390**, and the passages **388** to the valve block **135** and hence to the pump.

The operation of the construction of Fig. 16 is substantially as follows: In this case the mechanical pump plus the clean oil which flows through such pump through the valve **135** may be considered as the activating means for the mercury piston. On the intake stroke for the well oil, for instance into the chamber **375**, the clean oil is pumped out of the reservoir **389** through the reservoir **390**. This increases the level of the mercury in the reservoir **389**, lowering its level in the pump chamber **375**, such mercury flowing downwardly through the connecting pipe **400**. In this same procedure the clean oil is forced by the mechanical pump into the reservoir **390** causing a displacement upwardly of the mercury as a column indicated at **411**, thus raising the mercury level in the pump chamber **376** and forcing the well oil upwardly from said chamber. The action is substantially the same as described in connection with Fig. 1 and associated drawings except that in this case the mechanical pump and the valve **135** operate on the clean oil or similar liquid and this liquid directly actuates the mercury of the fluid piston. By such construction the mercury does not enter the mechanical pump and the clean oil is kept spaced and distinct from the well oil.

The construction of Figs. 17 through 20 employs a clean liquid such as oil actuated by the mechanical pump and operative to displace the mercury. As such latter forms a fluid which is insoluble both in the pumping oil and the well oil, the mercury forms the active element of a fluid piston. This construction changes the position of certain of the mechanical elements from that of the prior described illustrations. In such arrangement I employ a cylindrical casing or housing **450** which is similar in character to the element **4** of Fig. 1 and may be connected to a head block or the like. The electric motor **451** is supported in an upper part of the housing and operates the drive shaft **452**. The equalizer baffle assembly **453** is located below the motor and bolted directly to the lower end of this assembly I employ an upper suspension block **454** which has a casing tube **455** secured thereto and surrounding the shaft. This upper suspension block has a threaded section **456** from which depends an internal cylinder **457**. There are slots or openings **458** adjacent the casing **450** for the upflow of well liquid from the circular or segmental spaces **459** between the casing **450** and the internal cylinder **457**. The gear reduction train designated **460** is mounted in the cylinder **457** and driven by the shaft **452**. The lower end **461** of such shaft is connected to and operates the pump designated by the assembly **465**. The internal cylinder **457** terminates at an upper bolting block **470**, this block having a threaded connection **471** to the casing **450**. The upper surface **472** forms a ported valve seat, note particularly Figs. 19 and 20. This is provided with four ports, **473**, **474**, **475** and **476**, each port extending through the block. In addition such block is provided with a series of passages **480** communicating at the top with the space for passage for well liquid designated **459**. Bolts **481** extend through the block **470** and secure the pump in place preventing its rotation.

In this construction the rotary valve **485** has a cylinder or cage construction **486** surrounding the sides of the pump **465** and having an upper head **487** connected to the last slow speed drive of the reduction gear train, there being a central opening **488** for the passage of the lower end **461** of the shaft **452**. The sleeve **486** is preferably internally threaded as indicated at **489** in which is fitted a bolted valve ring **490**. Such ring has two segmental ports **491** and **492**. These are formed of slots extending through the valve ring from the top to the bottom and concentric with the axis of the valve and positioned to cover

and uncover the ports 473, 474, 475 and 476. This ring thus engages the upper seating surface 472 of the block 470. The pump may be the same as described in connection with Fig. 1 except that the passages and ports of the pump are reversed and extend downwardly instead of upwardly.

A reservoir section 500, note Fig. 18, has an outside cylindrical wall 501 preferably the same size as the cylinder casing 450. It is provided with an upper closure head 502 and a lower closure head 503. The upper head is secured to the block 470 by bolts 504, these engaging in threaded recesses 505. In this construction I illustrate two reservoir chambers 506 and 507 defined by preferably an internal cylinder 508 extending downwardly from the head 502. This converges inwardly as indicated at 509 and is connected at the bottom 510 to the lower head 503. A transverse vertical partition 511 connects both the heads and thus forms two reservoirs substantially semi-circular in cross section. This construction provides a longitudinal space or passage 512 between the lower and upper heads outside of the internal cylinder 508. This may have strengthening ribs connecting with the outside cylindrical wall 501 if desired, however it provides a large passage for the upflow of the well liquid. The upper head is provided with four perforations 513 through each of which extends a connecting pipe 514 secured to the block 470 and each connected to a port 473, 474, 475 and 476. The upper portion of each of the reservoirs 506 and 507 is for a clean liquid such as a clean oil which is pumped through the mechanical pump 465 and transferred from one reservoir to another. The head 502 is provided with a series of passage perforations 515 which register with the passages 480 for the upward flow of well liquid.

The chamber structure for the liquid piston designated by the assembly numeral 520 employs a cylinder 521 preferably of the same diameter as the cylinders 450 and 501. This has an outlet valve block 522 at the top and is secured to the lower head 503 by bolts 523.

A diametrical wall or partition 524 is preferably formed integral with the block 522 and extends downwardly, being connected to diametrically opposite sides of the cylinder 521. This partition has a lower section 525 reduced in thickness, thus providing two transverse shoulders 526. A lower or closure head 527 is formed of two substantially semi-circular plates 528 and 529 fitted inside of the lower end of the cylinder 521 and engaging the narrow section 525 of the partition 524 and abutting the shoulders 525 and is secured in place by welding indicated at 530 and 531. This structure thus forms two pumping chambers designated 535 and 536.

The bottom head 503 of the reservoir assembly 500 has two outlet openings 540 and 541, each having a pipe indicated at 542 and 543 extending downwardly, the lower ends terminating as indicated at 544 spaced above the lower head 527. These pipes are shown as secured by wells to the lower head 503 and pass through long perforations 545 in the outlet valve block 522.

A float valve assembly 546 is provided by a ball plug 547, a rod 548 and float 549. The rod has a lower extension 550 extending downwardly in each of the tubes 542 and 543. The balls thus form a plug at the valve seat formed by the perforations 540 and 541 or the upper ends of the tubes.

An outlet valve assembly 555 includes a recessed passageway 556. For a two chamber construction there is an outlet valve from each chamber having a cage 557 threaded in the upper part of the recess, such cage passing through a perforation 558 in the lower head 503 and at the bottom has a check valve seat 559 engaged by a ball plug 560. A pin 561 retains the ball in the cage. This provides a check valve for the upflow of the well liquid but prevents a reverse or downward flow.

Into each chamber 553 and 556 there is an inlet valve assembly 570. This is made up by providing a circular recess 571 in each of the semi-circular plates 528 and 529 fitting an internally threaded ring 572 in each recess. An inlet pipe 573 threaded to each ring extends upwardly through an opening 574 in each segmental plate. A check valve assembly 575 is provided at the top of each pipe. This may be of any suitable character such as by having a cage, a seat and a ball confined within the cage. To secure the rings 572 in place and retain the pipes 573 in proper position and also make a tight seal, I preferably employ a bottom cover plate 576 bolted to the lower head 527 having openings 577 for the inflow of the well liquid. In the chamber 535 and 536 I preferably insert before assembly a thin metal shell designated 580. This shell has openings at the top for the pipes and for the outlet ports or passages. Such shell is plated preferably with silver especially over the area contacted by mercury and the well liquid. It is also desirable to have a thin shell or the plating on the surface of the reservoirs 506 and 507 especially on the area where there is a contact between the mercury and the clean oil.

The manner of operation and functioning of the pumping assembly of Figs. 17 through 20 is substantially as follows: the piston liquid is indicated at 585 in the lower part of the chambers 535 and 536. This fills upwardly in the tubes 543 forming two vertical columns 586. The mercury also occupies the lower portion of reservoirs 506 and 507, being indicated at 587. The clean oil or other similar liquid activated by the mechanical pump is indicated at 588 in the upper part of the reservoirs 506 and 507 and communicates through the pipes 514 to the rotary valve 485 flowing through the fixed ports 473, 474, 475 and 476 and the segmental slot ports 491 and 492 in the rotary ring part of the valve.

Presuming the valve to be rotating in the direction of the arrow 590, Figs. 19 and 20, in one position of the valve the clean oil is being pumped upwardly from one of the reservoirs, presuming this to be the reservoir 507 and discharged downwardly in the reservoir 506. This displaces downwardly the mercury body 587 in the reservoirs giving a downward flow to the column 586 and raising the mercury level in the chamber 535. Thus this action depletes the mercury in the reservoir 506 and also depletes the volume in the chamber 536 and increases this in the reservoir 507. Such action therefore causes an inflow of the well liquid into the chambers 535 and 536. As depicted in Fig. 18, it is presumed that such liquid is flowing inwardly in the chamber 536 and being forced out from the chamber 535. The alternate action therefore causes a transfer of the clean oil between the reservoirs 506 and 507, the transfer of mercury between, for instance, the reservoir 506 and the chamber 535 and the reservoir 507 and the chamber 536, thus giving alternate upward displace-

ment to the well liquid, such as well oil, which after passing the check valve assembly **555** flows up in the space **512** through the perforations and passages **515** and **480**, the space **559** and upwardly past the motor assembly and thence to the top of the well in any suitable manner. It will be seen by this construction that there is no opportunity for the mercury to come into contact with the pump but the clean oil is always undergoing a pumping flow. Should the mercury in either reservoir **506** or **507** become depleted below a desired amount, the float valve of such chamber will close. This prevents outflow of mercury from such chamber but the clean oil may be transferred from one chamber to another, thus allowing a release of pressure on the mercury in the depleted chamber and a raising of its elevation. The action however of the float valve and the flow of clean oil is somewhat different than from the construction of Figs. 1 and 2 for in the construction of Fig. 16 and Figs. 17 and 18, the liquid piston, that is, the mercury, flows between a reservoir and an associated pumping chamber by means of a column including a pipe. This mercury has an up and down flow, there being a pair of reservoirs thus connected to a pair of pumping chambers. The clean liquid acting on the mercury in the reservoir flows through the rotary valve, and through the pump from one reservoir to another. Therefore as the mercury becomes depleted in one reservoir to such an extent that the float valve in such reservoir closes, it shuts off the mercury in such reservoir. In this case the clean liquid in the reservoir is considered to be in excess of that required for the proper operation of the pump so that such clean liquid is pumped from a reservoir having the excess to the other reservoir which is depleted of the clean liquid by having a surplus of mercury. This action relieves the pressure of the clean liquid in the reservoir depleted of mercury by its transference to the other reservoir and thus allows mercury to be forced upwardly from the pumping chamber connected to the reservoir depleted of mercury, raising the level and at the same time lifting the float valve.

In the structures using both a chamber and reservoir for the mercury, with a connecting tube, it will be understood that my invention comprehends utilizing a long tube functioning as the reservoir. This makes a satisfactory construction where the pump assembly is quite long. The clean liquid may then occupy part of the tube and flow through the control valve and pump to and from one tube. In cases in which the pump is above the tubes and the clean oil, the mercury float valve may be installed in the long tube by providing a proper seat.

Various changes may be made in the details of the construction without departing from the spirit or scope of the invention as defined by the appended claims.

I claim:

1. In a deep well pumping unit, the combination of a deep well pump assembly having means for lowering same into the well, and means for suspension of the assembly in a deep well, said assembly including a mechanical pump for a fluid piston, a shaft for operating the mechanical pump, means to rotate said shaft, said pump assembly having two fluid chambers with fluid therein, operating as a fluid piston, a rotatable valve having ports driven in synchronism with the mechanical pump by a connection to the shaft, flow ports and passages from each of the chambers to the valve, ports and passages connecting the valve to the mechanical pump whereby on operation of the pump and the valve the fluid is pumped from one chamber to another chamber, inlet means for well liquid to the fluid piston chambers including passages and a valved inlet to each chamber, a valved outlet from each chamber for the well liquid and means to conduct the flow of well liquid to the top of the well whereby, on operation of the pump and the valve, the fluid piston flows from one chamber causing an intake of well liquid therein and flows into another chamber causing upward displacement of well liquid from such a latter chamber.

2. In a deep well pumping unit, the combination of a deep well pump structure having two chambers for the liquid to be pumped in the well with a valved inlet and outlet means to and from said chambers for the flow of the well liquid, a reservoir connected to each chamber, a fluid in each chamber and reservoir insoluble in the liquid to be pumped, a pumping means, a clean liquid in each reservoir in contact with the said fluid and means to operate the pump with a control means for causing a flow of the clean liquid to and from each reservoir and thereby causing a flow of the fluid to and from each reservoir and its associated chamber, such fluid being operative as a fluid piston to develop a flow of the well liquid through the said chambers.

3. In a device as described, the combination of a deep well pump structure having two chambers with inlet and outlet control means for the well liquid to be pumped, a reservoir for each chamber and connected by a conduit, a fluid in each reservoir and connecting through a conduit to its associated chamber, such fluid being insoluble in the liquid to be pumped, a control valve, means to operate said valve, a clean liquid in each reservoir, passages connecting each reservoir and the valve, a pump, means to operate the pump in synchronism with the valve, connections between the pump and the valve for the flow of the clean liquid from one reservoir to another to thereby displace the said fluid from each reservoir to a chamber and to develop a reverse flow of the fluid from each chamber to its reservoir whereby a flow of the well liquid is developed through each chamber, the said fluid being operative as a liquid piston in each chamber.

4. In a deep well pumping unit as claimed in claim 3, an outflowing float valve in each reservoir and operative on depletion of the said fluid in a particular reservoir to prevent the flow thereof, the said valve and passages forming a connection whereby the clean liquid may be transferred from a reservoir depleted of the fluid to another reservoir and thus relieve the pressure on the fluid for replenishing the fluid in such reservoir from its connected chamber.

5. In a deep well pumping unit, the combination of a structure constructed and adapted to be lowered in a well and including a reservoir for a fluid piston and an inert gas, a pumping chamber with valved inlet and outlet for well liquid to be pumped, a mechanical pump and mechanical valve to pump at least part of the fluid piston in each cycle of operation from the reservoir to the pumping chamber for displacement of well liquid, said pump and valve having passage for transfer of at least part of the fluid piston in each cycle of operation from the pump-

ing chamber to the reservoir for inflow of well liquid to said pumping chamber.

6. In a deep well pumping unit, the combination of a deep well pump structure having two chambers with a valved inlet and outlet for each chamber for the well liquid to be pumped, each chamber being adapted to contain in its lower portion a fluid piston, a fluid piston reservoir for each chamber with an up and down flow connection between a first reservoir and a first chamber and a second chamber and a second reservoir, the chambers and reservoirs being located at different elevations, means to positively force the liquid piston out of a first chamber to a first reservoir and from a second reservoir to a second chamber and thereby develop an intake of well liquid into the first chamber and a displacement of the well liquid from the second chamber, the fluid piston comprising a first fluid of a heavy specific gravity and a second fluid of a lesser specific gravity, the flow means including a pump and valve operating on the second fluid and having connections for transferring the second fluid between the two reservoirs.

7. In a deep well pumping unit the combination of a deep well pump structure having a first and a second chamber with a valved inlet and outlet for well liquid to be pumped, each chamber being adapted to receive and contain a fluid piston, a first and a second reservoir positioned above the chambers with a flow connection from the first reservoir to the first chamber and from the second reservoir to the second chamber each having its discharge adjacent the bottom of the respective chambers, the reservoirs being adapted to contain a portion of the fluid piston, means to vary the hydraulic head of the fluid piston in each of the reservoirs and hence change the height of the fluid piston in the said chambers in an alternating manner and thereby develop an intake of well liquid into one chamber while the well liquid is being displaced from the other chamber.

8. In a deep well pumping unit the combination of a deep well pump structure having a first and a second chamber with a valved inlet and outlet for well liquid to be pumped, each chamber being adapted to receive and contain a fluid piston, a first and a second reservoir positioned above the chambers with a flow connection from the first reservoir to the first chamber and from the second reservoir to the second chamber each having its discharge adjacent the bottom of the respective chambers, the reservoirs being adapted to contain a portion of the fluid piston, means to vary the hydraulic head of the fluid piston in each of the reservoirs and hence change the height of the fluid piston in the said chambers in an alternating manner and thereby develop an intake of well liquid into one chamber while the well liquid is being displaced from the other chamber, the fluid piston including a first fluid of a heavy specific gravity and a second fluid of a lesser specific gravity in the reservoirs, the means to change the head of the fluid piston in the reservoir including a pumping means to positively transfer the second fluid between the two reservoirs.

9. In a deep well pumping unit, the combination of a deep well pump structure having a pair of upper compartments and a pair of lower compartments, a heavy specific gravity fluid piston in each of the compartments and one pair of the compartments having a light specific gravity fluid piston, up and down flow connections between each of the upper to its corresponding lower compartment, a float valve in each of the upper compartments controlling the depletion of the heavy fluid piston from the upper compartments, one pair of the compartments having means for controlling the flow of well liquid therethrough, a pump with connections to transfer the light liquid piston between the two compartments of one of the pairs of compartments whereby the heavy fluid piston flows between upper and lower compartments thereby taking in and discharging the well liquid, the float valve on closing being adapted to check the flow of the heavy fluid piston between an upper and a lower compartment, the pump being adapted to transfer the lighter fluid piston and thereby decrease the pressure on the heavy fluid in one of the compartments to thereby open the float valve of the depleted compartment for flow of the heavy fluid piston therein.

10. In a deep well pumping unit having two pumping chambers each with a valved inlet and outlet for well oil to be pumped, each chamber being adapted to contain a liquid piston, each chamber having an inlet port and an outlet float valve for the liquid piston, a positively driven pump with a valve and flow connections for the liquid piston to transfer the liquid piston between the said chambers, such liquid piston passing out through the float valve in one chamber and into the other chamber through its inlet port, the said valve having connections whereby if the liquid piston is depleted below a working level in one chamber by the outlet float valve of such chamber being closed, the liquid piston is pumped from the chamber having the excess of the liquid piston to the depleted chamber through the inlet port of the depleted chamber.

11. In a deep well pumping unit, the combination of a deep well pump structure having two chambers for a fluid piston and at least one of said chambers being for the well liquid to be pumped with valved inlet and outlets for the well liquid chamber, each chamber containing a fluid piston, a power driven means to positively flow the fluid piston with an up and down motion from one chamber to the other to thereby cause an intake of the well liquid into the well liquid chamber and a displacement therefrom, each of the chambers having an inlet port and a valve outlet for the fluid piston, the power driven means having associated therewith and with each of the valved outlets for the fluid piston means for directing the flow of such piston to prevent depletion of the liquid piston in either of the chambers below a working level.

12. In a deep well pumping unit, a structure arranged to be lowered into a well having a chamber provided to receive liquid to be pumped, valved inlet and outlet to said chamber for such liquid, a reservoir, a circulating fluid insoluble in the liquid to be pumped retained in said chamber and reservoir to act as a piston on said liquid, a circulating pump, a rotary flow control valve, passageways connecting the fluid in said chamber and reservoir to the circulating pump through the rotary flow control valve causing said fluid in said liquid chamber and reservoir to flow in and out of said chamber and reservoir thereby drawing in liquid to be pumped and/or discharging liquid from said chamber to produce a pumping action in the liquid to be pumped, and a motor associated with said unit connected to operate said circulating pump.

13. In a deep well pumping unit, a structure

provided to be lowered in a well having two chambers for a liquid to be pumped, valved inlet and outlet to said chambers for a flow of liquid to be pumped, a circulating fluid insoluble in the liquid to be pumped in said chambers acting as a piston on said liquid, an actuating means including a pump for said fluid, a flow control valve interposed between said chamber and the said pump, passageways connecting the fluid in said chambers to said valve and to said pump, the surface finish of said chambers and the characteristics of said fluid being such as to prevent sticky or gritty material adhering to said surface finish, a motor having a connection to operate the pump and the valve thereby causing such fluid to flow in or out of said chambers and hence cause an inflow and/or a discharge flow of liquid to be pumped to and/or from said chambers, means to stop the outflow of fluid from said chambers to thereby prevent depletion and a control through the valve and passages to replenish the fluid in a partially depleted chamber.

14. In a deep well pumping unit having two valved chambers with a liquid piston therein, a positively driven pump and flow means interconnecting the chambers for causing the liquid piston to rise or fall in said valved chambers, the said pump and flow means having connections at certain positions of their operations to supply part of a fluid piston from a chamber having an excess to a chamber having a depletion of fluid piston to maintain a working level of the fluid piston at all times in the chambers, said pumping unit including valved means to pump well liquid by the rise and fall of the fluid piston.

15. In a deep well submersible pumping unit, the combination of a deep well pump structure having two chambers with a valved inlet and outlet for each chamber for the well liquid to be pumped, each chamber being adapted to contain in its lower portion a fluid piston, a fluid piston reservoir for each chamber with an up and down flow connection between a first reservoir and a first chamber and a second chamber and a second reservoir, a flow connection between the two reservoirs, the chambers and reservoirs being located at different elevations, means to positively flow liquid between the reservoirs and force the liquid piston out of a first chamber to a first reservoir and from a second reservoir to a second chamber and thereby develop an intake of well liquid into the first chamber and a displacement of the well liquid from the second chamber.

16. In a deep well submersible pumping unit, a structure having a chamber provided to receive well liquid to be pumped, valved inlet and outlet to said chamber for such well liquid, a reservoir, a circulation fluid insoluble in the well liquid to be pumped in said chamber or reservoir acting as a piston on said well liquid, an actuating means for said fluid, a change of direction flow means for the fluid, passageways connecting to the fluid in said chamber and reservoir to the actuating means causing said fluid in said liquid chamber and reservoir to flow in and out of said chamber and reservoir thereby drawing in liquid to be pumped and/or discharging such liquid from said chamber, and a submerged motor directly associated with said unit connected to operate said actuating means.

17. In a deep well submersible pumping unit, a structure having a chamber provided to receive well liquid to be pumped, valved inlet and outlet to said chamber for such well liquid, a reservoir, a circulation fluid insoluble in the liquid to be pumped partially retained in said chamber and reservoir to act as a piston on said well liquid, a pressure and/or suction means for such fluid, passageways connecting the fluid in said chamber and reservoir to the pressure and/or suction creating means causing said fluid in said liquid chamber and reservoir to flow in and out of said chamber and reservoir thereby drawing in the well liquid and/or discharging the well liquid to be pumped from said chamber, and a valve opening and/or closing the passageways through which the fluid acted on by said pressure and/or suction is to move, and a submerged motor directly associated with said pumping unit connected to operate said pressure and/or suction means and the valve.

18. In a deep well submersible pumping unit, the combination of a deep well pump structure having means for lowering the same and supporting in a deep well, said structure having a mechanical pump, two chambers for a fluid piston, a control valve connecting said chambers and the mechanical pump to control the flow of fluid piston between the chambers and the pump, means to actuate the mechanical pump and means to actuate the valve in synchronism therewith, ports and passages for a fluid communicating between said chambers and the mechanical pump for pumping a fluid from a chamber through the mechanical pump to the other chamber and hence flow the fluid piston in and out of the two chambers, a well liquid connection from the well to the chambers containing the fluid piston, a valved inlet and outlet for the well liquid in its flow from and to said chambers, and a flow connection for the well liquid to the top of the well whereby on operation of the mechanical pump and the said valve, fluid piston fluid is withdrawn from one chamber for intake of well liquid therein and fluid piston fluid flows to another chamber for displacement of well liquid upwardly.

19. In a deep well submersible pumping unit, a pump structure arranged to be lowered into a well having a well liquid chamber with means for in and out flow of well liquid, a pump, a valve, a receptacle, ports and passages communicating between the chamber and the receptacle, the pump and the valve, the said chamber having mercury therein operating as a fluid piston in the well liquid, the pump and valve being adapted to flow the mercury in and out of said chamber and receptacle, the said chamber having a silver plated surface whereby the mercury cleans such surface of any oil or grit accumulating from the well oil on such surface.

20. In a deep well submersible pumping unit, a pump structure arranged to be lowered into a well having a well liquid chamber with means for in and out flow of well liquid, a pump, a valve, a receptacle, ports and passages communicating between the chamber and the receptacle, the pump and the valve, the said chamber having mercury therein operating as a fluid piston in the well liquid, the pump and valve being adapted to flow the mercury in and out of said chamber and receptacle, the said chamber having an inserted lining susceptible to amalgamation whereby the mercury cleans the lining of any oil or grit accumulating from the well oil on such lining.

21. In a deep well submersible pumping unit,

the combination of a deep well pump structure having two chambers for a fluid piston and at least one of said chambers being for the well liquid to be pumped with valved inlet and outlets for the well liquid chamber, each chamber containing a fluid piston, a fluid piston circulating means, a submerged motor directly connected to said fluid piston circulating means to positively flow the fluid piston from one chmber to the other to thereby cause an intake of the well liquid into the well liquid chamber and a displacement therefrom.

22. A pump comprising containing means, a liquid piston therein, means for moving the liquid piston to and fro therein, a gas between the piston and one end of the container means adapted to be compressed by the piston when the piston is forced toward said end and to assist in forcing the piston in the opposite direction, there being an inlet and outlet to and from the containing means for the fluid to be pumped on the opposite side of the piston from said gas and means for preventing reverse flow thru the inlet and outlet respectively.

23. A pump comprising means providing a containing means having an inlet and an outlet for the fluid to be pumped, means for preventing reverse flow thru the inlet and outlet respectively, a liquid piston in the containing means, a gas confined in the containing means against the piston and means for moving the liquid piston back and forth in the containing means whereby when the piston is moved in one direction, fluid to be pumped will be drawn into the containing means thru the inlet and the gas will be compressed by the piston and when the piston is moved in the opposite direction the fluid to be pumped will be expelled thru the outlet and the compressed gas will assist in forcing the piston in said opposite direction.

24. A pump comprising means containing a liquid piston and a gas confined against one side thereof, there being an inlet and an outlet for the fluid to be pumped arranged on the other side of said piston, means for preventing reverse flow thru the inlet and outlet and means for moving the liquid piston back and forth in the containing means whereby when the liquid piston is moved in one direction fluid to be pumped will be drawn into the containing means thru the inlet and the gas will be compressed, and when the piston is moved in the other direction the compressed gas will aid such movement and the fluid to be pumped will be expelled thru the outlet.

25. In a deep well submersible motor oil pumping unit the combination of a deep well pump structure having a first and second chamber with a valved inlet and outlet for well liquid to be pumped, each chamber being adapted to receive and contain a liquid piston, a first and a second reservoir, each having at least a portion positioned adjacent one of the chambers with a flow connection from the first reservoir to the first chamber and from the second reservoir to the second chamber, each flow connection having its discharge adjacent the bottom of the respective chambers and additional flow connections between the reservoirs, the reservoirs being adapted to contain a portion of the liquid piston and pump circulating liquid separate from the well liquid, means to pump such circulating liquid from one reservoir to another and to vary the hydraulic head of the fluid piston in each of the reservoirs and hence change the height of the fluid piston in the said chambers in an alternating manner and thereby develop an intake of well liquid into one chamber while the well liquid is being discharged from the other chamber.

26. In a deep well self contained submersible motor driven pumping unit, a pump structure having means for lowering and supporting such unit in a deep well and including a fluid piston chamber, a reservoir and a mechanical pump for circulating an entrapped fluid between the chamber, the mechanical pump and the reservoir, means to operate said mechanical pump, there being connections between the said chamber and reservoir and mechanical pump for the entrapped fluid to circulate a fluid piston from and to said chamber and reservoir, an inlet means for well liquid to said chamber and a valve controlled outlet means for the well liquid from such chamber for the flow of the well liquid to the top of the well whereby, on operation of the mechanical pump, the fluid piston displaces the well liquid forcing it upwardly in the well.

27. In a submersible motor driven oil well pumping unit, the combination of a pump structure having two pump chambers with a valved inlet and outlet for each chamber for the well liquid to be pumped, each chamber being adapted to contain a fluid piston, two reservoirs also for fluid piston independent of and separate from the well liquid, flow connections between the reservoirs, means to positively force fluid under pressure from one reservoir to the other and to flow the fluid piston alternately from a first chamber to a first reservoir to decrease the fluid piston in such first chamber and increase the fluid piston in the first reservoir, and from a second reservoir to a second chamber to increase the fluid piston in the second chamber and decrease the fluid piston in the second reservoir and thereby develop an intake of well liquid into the first chamber and a displacement of the well liquid from the second chamber.

28. In an oil well submersible motor pumping unit, the combination of a pump structure having two pump chambers with a valved inlet and outlet for each chamber for the well liquid to be pumped, each chamber being adapted to contain a fluid piston, two reservoirs also for fluid piston, flow connections between the reservoirs, and means independent and separate from the well liquid to positively force the fluid piston alternately from one reservoir to another to flow the fluid piston from a first chamber to a first reservoir to decrease the fluid piston in such first chamber and increase the fluid piston in the first reservoir and from a second reservoir to a second chamber to increase the fluid piston in the second chamber and decrease the fluid piston in the second reservoir and thereby develop an intake of well liquid into the first chamber and a displacement of the well liquid in the second chamber, the means to flow the fluid piston from each reservoir to its corresponding chamber including a flow connection to cause a flow of the fluid piston to and from the bottom portion of the pump chamber.

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