

May 3, 1966

G. A. HILL

3,249,054

PUMP

Original Filed April 20, 1962

6 Sheets-Sheet 1

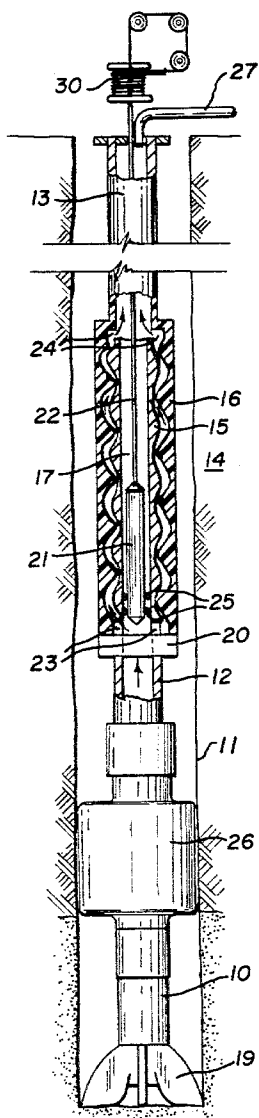


Fig. 1

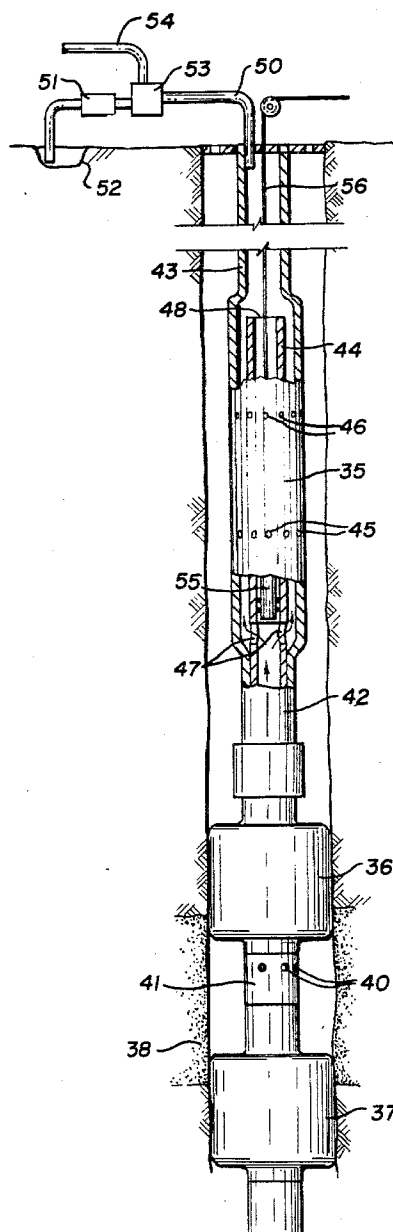


Fig. 2

INVENTOR

Gilman A. Hill

BY

McGraw-Hill

ATTORNEYS

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G. A. HILL

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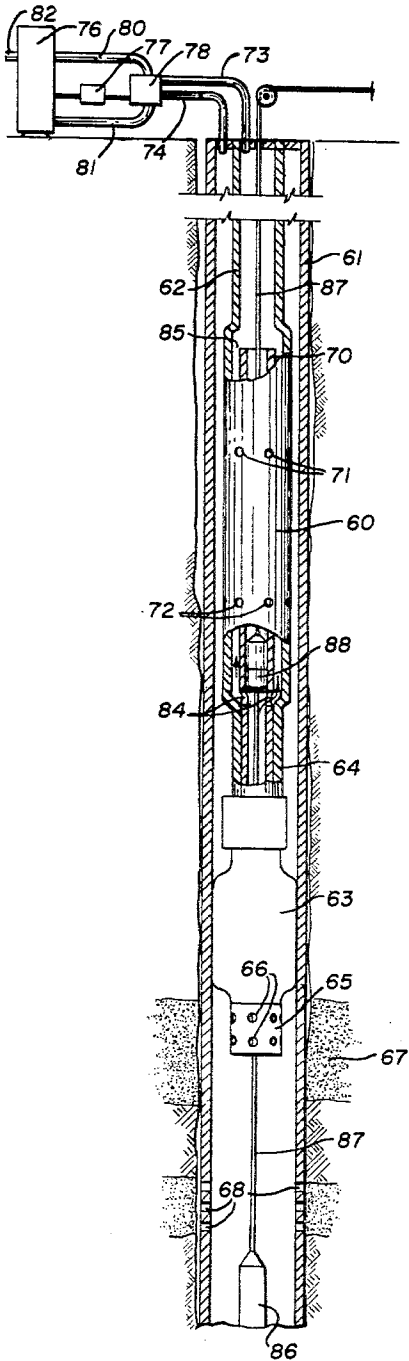


Fig. 3

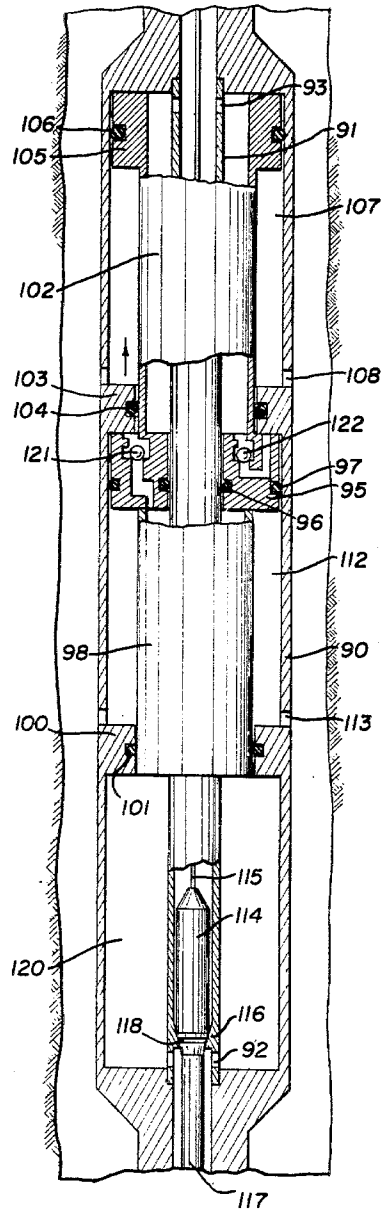


Fig. 4

INVENTOR

Gilman A. Hill

BY

McGraw-Hill

ATTORNEYS

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G. A. HILL

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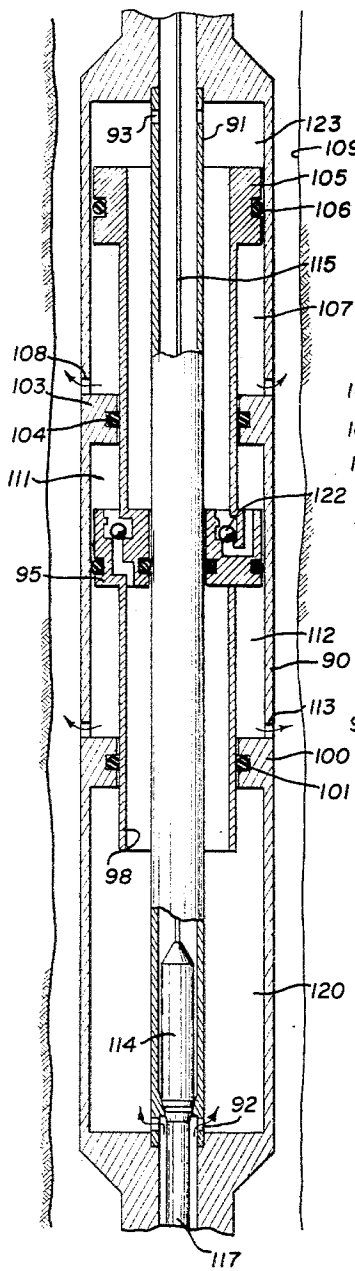


Fig. 5

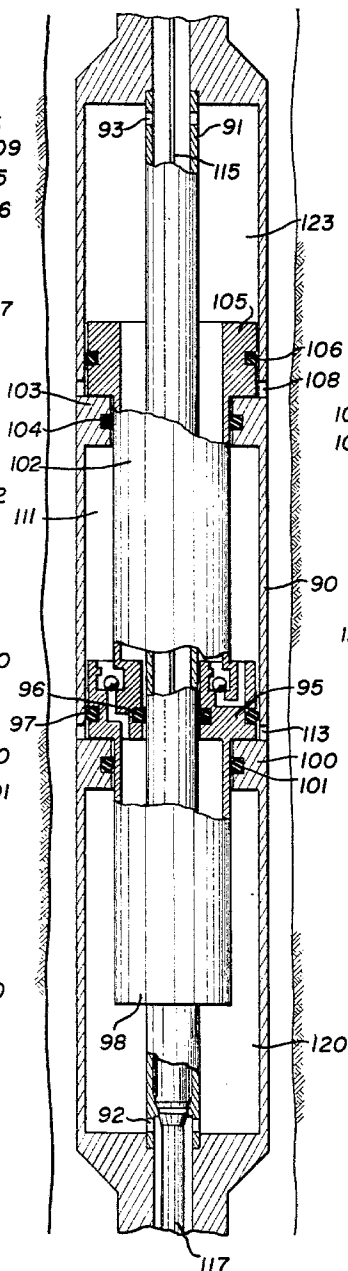


Fig. 6

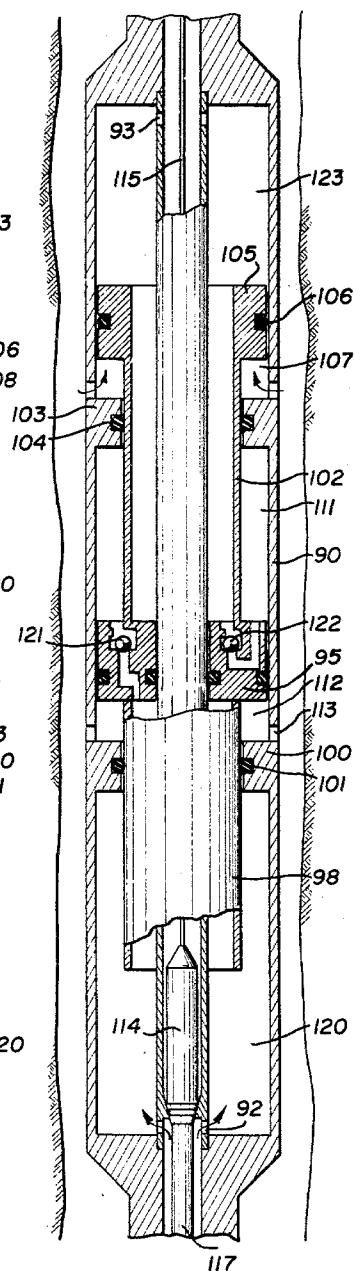


Fig. 7

INVENTOR

Gilman A. Hill

BY

McBrew & Edwards

ATTORNEYS

May 3, 1966

G. A. HILL

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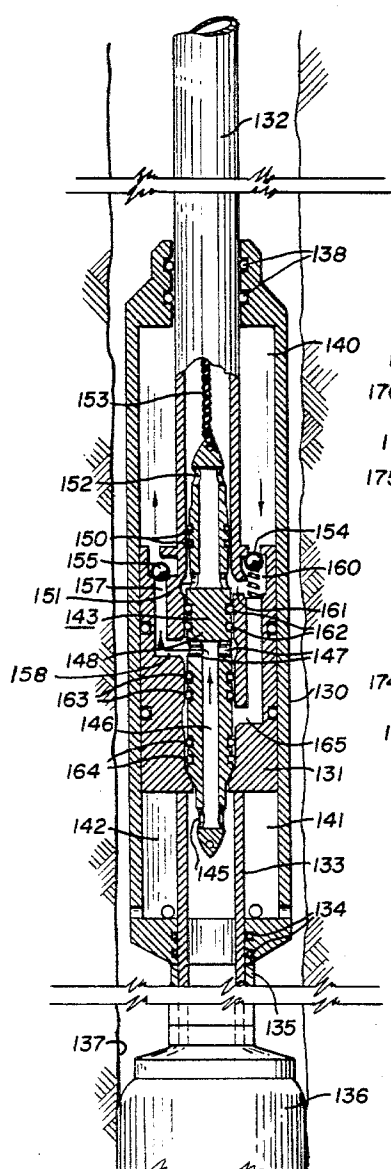


Fig. 8

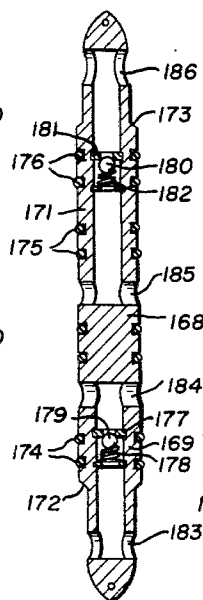


Fig. 10

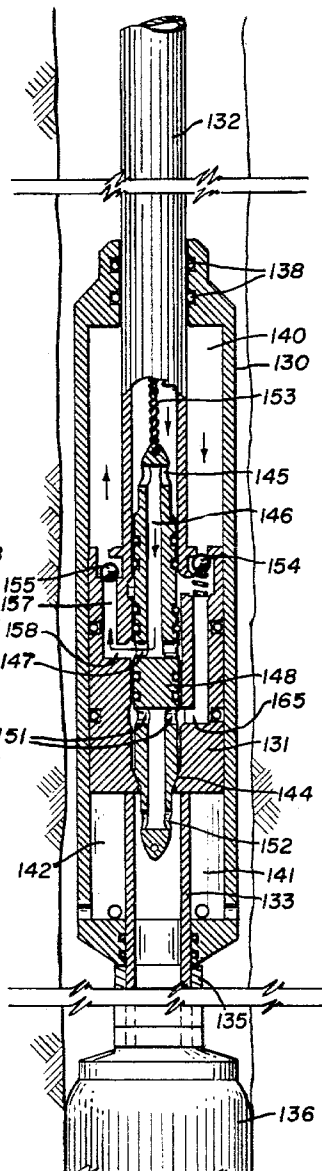


Fig. 9

INVENTOR

Gilman A. Hill

BY

McGraw-Hill

ATTORNEYS

May 3, 1966

G. A. HILL

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PUMP

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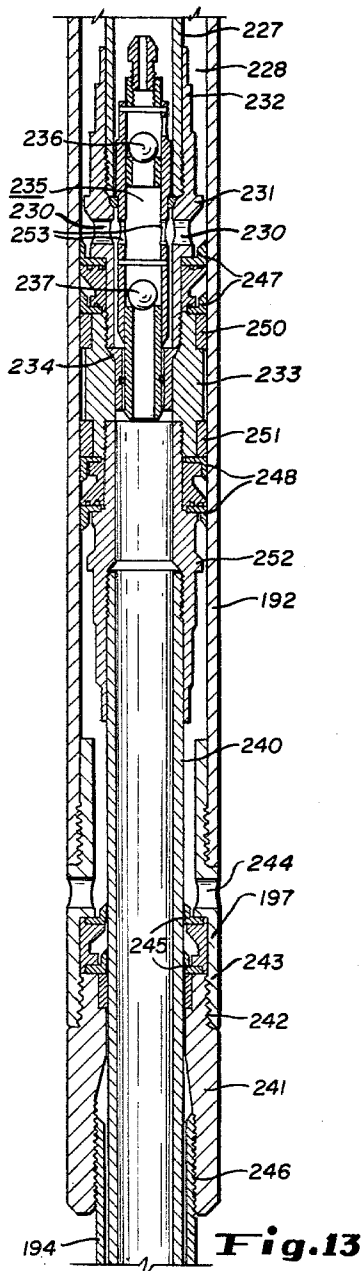
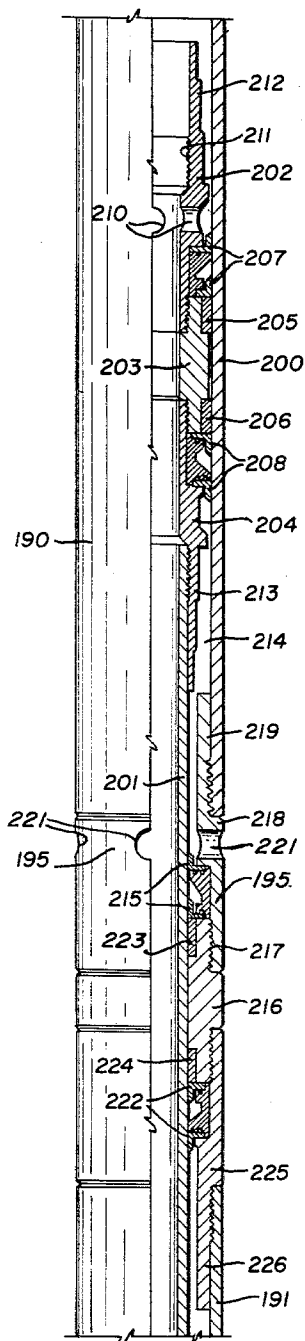
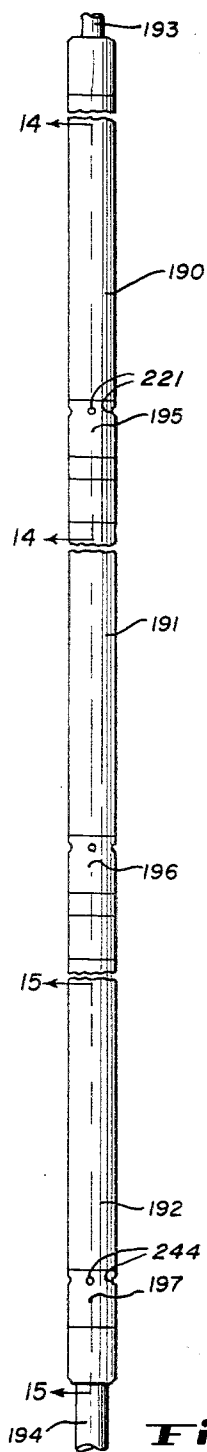


Fig. 11

Fig. 12

Fig. 13

INVENTOR

Gilman A. Hill

BY

McGraw & Edwards

ATTORNEYS

May 3, 1966

G. A. HILL

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PUMP

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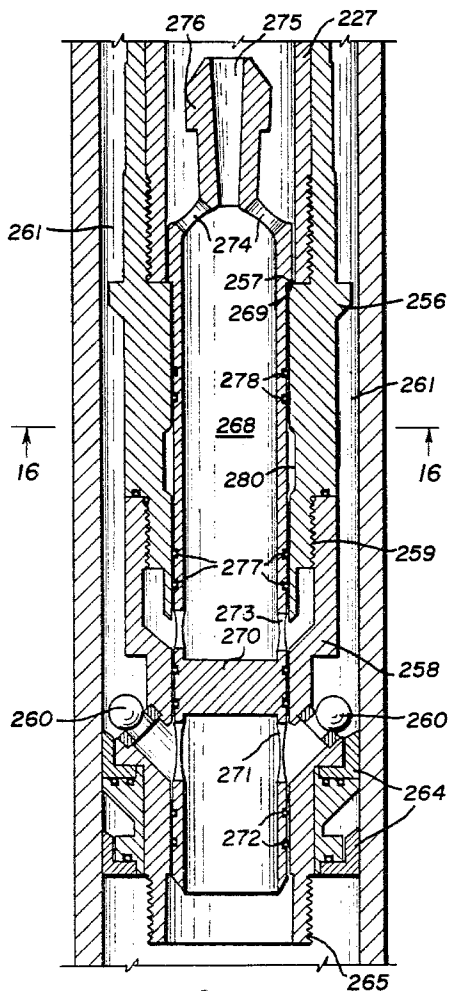


Fig. 14

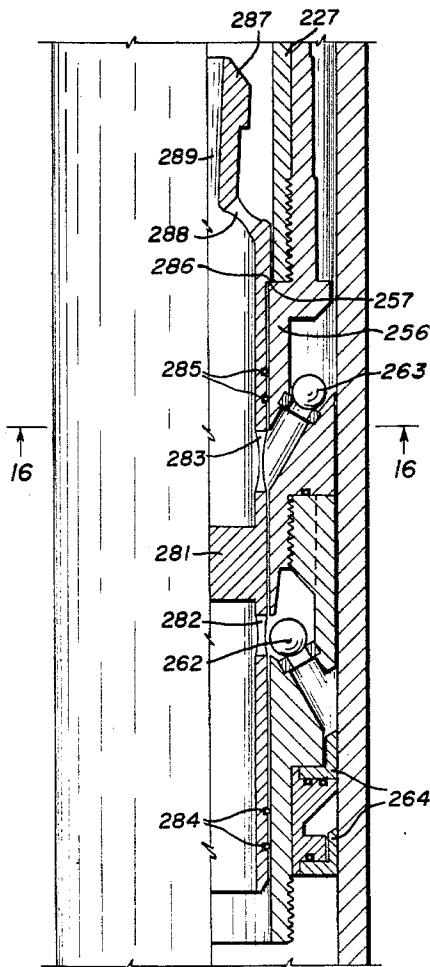


Fig. 15

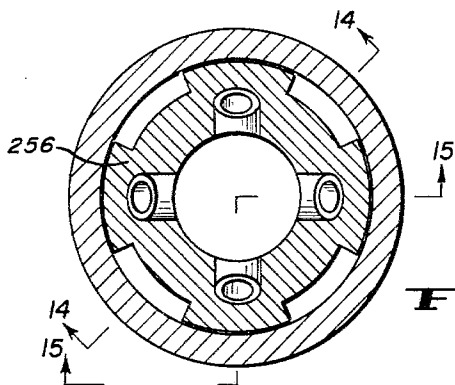


Fig. 16

INVENTOR

Gilman A Hill

BY

McBrew & Edwards

ATTORNEYS

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PUMP

Gilman A. Hill, Englewood, Colo., assignor to Petroleum Research Corporation, Denver, Colo., a corporation of Colorado

Original application Apr. 20, 1962, Ser. No. 189,022. Divided and this application Oct. 4, 1965, Ser. No. 492,574

8 Claims. (Cl. 103—41)

This application is a division of abandoned application Serial No. 189,022 of Gilman A. Hill and Oliver V. Phillips, filed April 20, 1962.

This invention relates to fluid pumping mechanisms and particularly to an improved fluid pump of the deep-well type.

Various operations during the drilling, testing, and production of fluids from deep wells make it desirable to provide a fluid pump for use downhole in the well. Because such pumps are required to operate far below the surface of the ground, it is desirable that they be of simple and rugged construction with a minimum number of moving parts and that they be easy to control from the surface. Production operations have normally required that the pump be removed from the well prior to running instruments to the producing interval below the pump or prior to carrying out any reservoir treating or stimulation work. Drilling and testing operations normally require the time-consuming procedure of removing the pump in preparation for the operation. Accordingly, it is an object of the present invention to provide a fluid pump of the deep-well type including an arrangement for providing access to areas of the well bore below the pump without removing the pump from the well.

It is another object of this invention to provide a deep-well pump of simple and rugged construction including an improved arrangement for effecting a substantially constant rate of production of fluids from a reservoir formation.

It is a further object of this invention to provide a deep-well pump including an improved arrangement for facilitating the circulation of well fluids at controlled rates of flow over the sensing elements of testing instruments employed in the determination of fluid conditions and characteristics at the production zone.

It is a still further object of this invention to provide a downhole pump of simple and rugged construction and including an improved arrangement for facilitating the use of the pump for either production of fluids from the well or for the injection of liquids into the reservoir formation.

Briefly, in carrying out the objects of this invention, in general a fluid pump is provided which comprises an elongated housing having an open passage extending the length thereof and providing space between the outer walls of the passage and the inner walls of the housing. Spaced ports are provided between the passage and the space within the housing, and the pumping mechanism is provided within the space to pump fluid from one of the ports to the other. In order to close the passage and utilize the pumping mechanism for pumping fluid from one end of the passage to the other, a plugging device is provided which may be secured to the passage walls between the ports and thereby isolate the upper and lower portions of the passage except for communication through the pump. Various types of pumps and driving arrangements may be provided, including pumps

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which are driven by rotation or reciprocation of the production tubing and pumps which are driven by periodically changing hydraulic pressure wherein arrangements are also provided so that the plugging device for closing the passage through the pump may be selectively positioned so that the pump will operate either as a production pump to withdraw fluids from a well or as an injection pump to force fluids into the well. The passage provided through the pump makes it possible to lower instruments through the passage into the portion of the well below the pump and also to circulate fluids through the pump during reservoir stimulation operations or during drilling operations, while the pump remains in the production string or drilling string. The intake and discharge valves for controlling the operation of reciprocating pumps may be built into the pump housing structure or in another form may be included in the retrievable plugging device inserted to divide the passage into upper and lower portions. Pumps of this type, including the hydraulically actuated embodiments may be designed to produce substantially constant production of fluids from a reservoir. The hydraulic pump is of simple and rugged construction and may be left in the well for operation over extended periods of time without requiring removal for servicing.

The features of novelty which characterize this invention are pointed out with particularity in the claims annexed to and forming a part of this specification. The invention itself, however, both as to its organization and method of operation together with further objects and advantages thereof will be more fully understood upon reference to the following description taken in connection with the accompanying drawings in which:

FIG. 1 illustrates a drill assembly including a rotary pump embodying the invention;

FIG. 2 illustrates a hydraulically operated pump embodying the invention mounted to produce fluids from a well and illustrates the use of an instrument below the pump;

FIG. 3 is a diagrammatic sectional-elevation view illustrating a further embodiment of the invention including a hydraulically operated pump mounted on a single packer for producing fluids from a reservoir formation and illustrates the use of an instrument below the pump;

FIGS. 4, 5, 6 and 7 are sectional-elevation views of a hydraulically operated pump suitable for operation in the manner indicated in FIGS. 2 and 3, and illustrate four successive positions of the pump during operation;

FIG. 8 is a partial sectional-elevation view of a drill pipe or tubing actuated pump embodying the invention and including an arrangement for reversing the direction of fluid discharged by the pump;

FIG. 9 is a view similar to FIG. 8 of the same pump illustrating the arrangement for injection pumping;

FIG. 10 illustrates another form of plugging device for the pump of FIGS. 8 and 9 wherein the pump valves are included in the plugging device;

FIG. 11 is an elevation view of a further embodiment of the invention;

FIG. 12 is an enlarged view partly in section of one portion of the pump of FIG. 11;

FIG. 13 is an enlarged view similar to FIG. 12 of another portion of the pump of FIG. 11;

FIG. 14 is an enlarged sectional view of a subassembly including a plugging device for employing the pump of FIG. 11 for production pumping;

FIG. 15 is a view of the subassembly of FIG. 14 taken along a plane at an angle of 45 degrees to that of FIG. 14

and illustrates a plugging device for injection pumping; and

FIG. 16 is a sectional view along the line 16—16 of FIGS. 14 and 15 showing the relationship of the valves.

Referring now to the drawing, FIG. 1 illustrates a drill assembly 10 secured within a well 11 on a lower drill tube section 12. Between an upper section 13 of the drill tube and the section 12 there is mounted a pump 14 embodying the invention and which comprises an inner spiral metal member 15 and an external spiral member 16 of rubber or other suitable tough pliable material. This pump is of a type known in the art wherein a spiral path is utilized to effect axial movement of a fluid on relative rotation of the inner and outer members. In the present pump there is provided a clear passage 17 extending longitudinally entirely through the inner member 15 and which provides access from the top section 13 of the tube through the pump to the bottom section 12 and hence outwardly through the drill assembly 10. At the surface, there is provided the usual equipment (not shown) including a rig for raising and lowering the drill assembly 10 on the tubing 13 and an arrangement for rotating the drill tube 13 to effect operation of the drill indicated at 19. For drilling purposes a clutch diagrammatically indicated at 20 is employed to secure the pump casing 16 to the lower section 12 of the drill tube so that it rotates with the pump member 16 and the top section 13; the clutch may be released by lifting the tubing 13. In the event that it is desired to pump liquids from the bottom of the well for testing or other purposes a plug or stop member 21 is lowered into the tubing 13 on a wire line 22 until it rests in position in the passage 17 of the pump intermediate lower ports 23 and upper ports 24 which provide communication between the space between the members 15 and 16 and constitute the intake and discharge ports of the pump. When the plug 21 is seated in the passage 17 it is sealed against leakage by O-rings or other suitable gaskets 25. In addition to the insertion of the plug 21 a packer 26 connected in the tube 12 between the drill 19 and the pump 14 is expanded into engagement with the well bore and holds the tubing 12 and the inner member 15 of the pump against rotation. The tubing is then lifted slightly to disengage the clutch 20; whereupon, when the tube 13 is rotated the outer pump member 16 rotates about the inner member 15 and liquid is pumped upwardly from the tube 12 through the ports 23 into the pump and thence outwardly through the ports 24 and up the tube 13. The fluid produced by operation of the pump is discharged upwardly in the tube 13 and thence out through a production tube or line 27 to a point for use or transportation. In order that the plug 21 and wire line 22 may not be twisted during this operation of the pump the wire line is supplied from a spool 30 around pulleys or like devices and down through the hollow center of the spool to the plug 21. This assembly is mounted on the rotation equipment for tube 13 which equipment can thus rotate without twisting the wire line.

This pump construction makes it possible to lower a tool or instrument through the central passageway down into the area below the pump 14 so that tests may be made of the well reservoir fluids in this area. Such tests may be conducted during operation of the pump which produces a flow of the well fluids over a portion of the instrument package or other device lowered into the well in the manner of the plug 21. When the pump is not being operated and when instruments are not required at the well bottom as is the case during drilling operation the central passage is free from obstruction and may be employed for circulating drilling mud past the drilling zone about the drill 19.

In FIG. 2 there is illustrated a deep-well pump 35 mounted on a pair of straddle packers 36 and 37 to receive fluids from a formation 38 through perforations 40 in an intermediate coupling 41 between the packers. The pump 35 is mounted on the top packer on a short

length of tube 42 and delivers fluids upwardly through a tube or casing 43. The pump 35 is similar to the pump 14 of FIG. 1 in that it has a hollow passage 44 extending longitudinally therethrough and comprises an outer casing having perforations 45 and 46 therein for communication with the annulus about the housing. Within the casing 35 there is arranged a pumping mechanism for moving liquids from ports 47 in the tubing 44 providing the passage through the pump and the open top of the tubing 44 indicated at 48.

The pump 35 is of a type which utilizes differential hydraulic pressure for actuating pistons within the pump and which pressure is supplied to the apparatus through a conduit 50 by operation of a pump 51 from a sump or other suitable source of relatively noncompressible liquids indicated at 52. Pump 51 has at its outlet a valve 53 for controlling the fluid pressure supplied through the pipe 50 to alternately pressurize and relieve the liquids within the tube 43. In order to remove fluids produced from the formation, a production line 54 is also connected in communication with the tubing 43 at the top through the pipe 50 and the valve 53. In order to actuate the pump 35 a plug indicated at 55 is lowered into the pump passage 44 and remains in position on a wire line 56 controlled by suitable apparatus (not shown). The details of construction of the hydraulic pump 35 are pointed out below in connection with the description of other figures of the drawings. When it is not required that the fluids be pumped through the tube 43 the plug 55 is removed from the passage 44 and clear access is thereby made available through the tubing and down through the packer 36 to the area adjacent the formation through the perforations 40.

FIG. 3 illustrates a pump 60 of the same construction as the pump 35 of FIG. 2 suspended in a well casing 61 on a tubing 62 and supported within the casing on a packer 63 connected within the pump casing by a length of tubing 64. Immediately below the packer 63 a fitting 65 is provided which has a plurality of perforations 66 for receiving reservoir fluids from a portion of the formation 67 through perforations 68. The pump 60 is provided with a tube 70 providing an internal longitudinal passage in the same manner as the pump 35 of FIG. 2. The pump housing is provided with a ring of upper perforations 71 and a ring of lower perforations 72 for communication with the annulus between the casing 61 and the pump housing. In order to actuate the pump 60, relatively incompressible fluids are supplied alternately to the tubing 62 through a conduit 73 and to the annulus about the tubing 62 and pump 60 through a conduit 74. The pressurized liquid supplied to the conduits 73 and 74 is pumped from a tank 76 by operation of a pump 77 and the direction of flow is controlled by a change-over valve 78 whereby the high-pressure fluids discharged from the pump are delivered through the valve either through the conduit 73 or 74 and the other conduit is connected back through the valve and a selected one of two conduits 80 and 81 to the tank 76. Production fluid is removed from the tank through a production line connection 82.

During the operation of the pump 60 the differential pressure between the annulus within the casing 61 and the tubing 62 is alternately reversed and the pump operates on this differential pressure to produce fluid from the formation 67 through the perforations 66 and 68 and the pump 60. The fluid enters the pump 60 through ports 84 which communicate with the space between the pump housing and the tube 70 within the pump and operation of the pump discharges the fluids upwardly into the tube 62 through an annular opening 85 at the top of the tube 70.

All three of the pump installations described above employ pumps having longitudinal passages extending entirely through the pump and which afford a passage for instruments or tools directly through the pump without removing the pump from the tubing string. The loca-

tion of the passage, whether centrally of the pump or to one side, depends upon the type of pumping equipment mounted within the space between the longitudinal tubing and the pump casing. For most purposes the central opening is desirable and is therefore employed. In addition to providing a readily controlled pump by the insertion and removal of a plug as illustrated in these figures other devices such as instruments for determining characteristics of the fluids produced from the well may be inserted and secured within the pump passage to contact the liquids.

FIG. 3 illustrates the manner in which an instrument or instrument package may be suspended below the pump in the production zone during operation of the pump. An instrument package has been shown at 86 suspended on a wire line 87 which extends downhole through the pump plug indicated at 88; the plug is provided with a suitable packing which seals the wire line while allowing it to move up and down through the plug. Thus, while the pump is in operation the wire line may be moved to adjust the position of the instrument 86 which can thus sense conditions or characteristics of the well fluids below the pump during production.

The construction and operation of hydraulic pumps of the types indicated in FIGS. 2 and 3 will be understood from the embodiment illustrated in FIGS. 4, 5, 6 and 7.

The figures illustrate diagrammatically a hydraulically operated pump comprising an elongated cylindrical housing 90 having a central tube 91 concentric about the same axis as 90 and which tube provides a space within the housing 90 communicating with the interior of the tube through ports 92 at the bottom end of the tube 91 and ports 93 at the top. Within the space between the housing 90 and the tube 91 and slidable along the tube is provided a piston assembly comprising a central head 95 slidable both with respect to the tube 91 and housing 90 and provided with O-rings or other suitable gaskets indicated at 96 and 97 for sealing the head to the tube 91 and housing 90, respectively. Extending downwardly from the head 95 and spaced both from the tube and the housing there is provided a lower cylinder 98 which slides within an annular ring or abutment 100 extending inwardly from the housing 90 and having an O-ring or other gasket 101 for sealing the cylinder 98 with respect to the housing 90. Extending upwardly from the head 95, a second cylinder 102 is provided of the same diameter as the cylinder 98 and which is slidable within an annular abutment 103 secured to the inside wall of the housing 90 in spaced relation to the top of the housing and the annular abutment 100. A gasket 104 is provided to seal the sleeve 102 to the abutment 103 in a sliding engagement therewith. At the upper end of the cylinder 102 there is provided a piston head 105 having a sealing ring 106 for sliding engagement with the inner wall of the housing 90. It will now be seen that this construction provides a series of pressure cylinders within the housing 90. The several cylinders are indicated clearly in FIG. 5 and include a top cylinder 107 having a port 108 communicating with the annulus outside the housing 90 between the housing and the well bore 109, a cylinder 111 between the annular abutment 103 and the head 95 and a cylinder 112 between the head 95 and the lower annular abutment 100. A cylinder 112 is ported to the annulus between the housing 90 and the formation by ports 113 at the bottom of the cylinder adjacent the annular abutment 100.

When it is desired to operate the pump, the passage through the tube 91 is closed by a plugging device indicated at 114 and which is lowered into the tube on a wire line 115 until it rests against a stop or "no go" 116 in the lower end of the tube adjacent the ports 92. The plug 114 has been indicated as having an extension 117 of reduced diameter and which lies within the pump housing end below the pump body. The plug 114 is provided with a sealing gasket indicated at 118 which engages

the sloping wall of the "no go" 116. When the plug is in position as shown, the pump is effective to circulate fluid from ports 92 through a lower chamber or a cylinder 120 to the interior of the sleeve 98 and thence out through a ball check valve 121 to the cylinder 111. A reciprocation of the pump forces fluid from the cylinder 111 through a check valve 122 into the cylinder sleeve 102 which is in open communication with an upper chamber of the pump indicated at 123 which in turn communicates with the tubing outlet of the pump through the port 93. The cylinders 107 and 112 are employed as driving cylinders which force their respective pistons upwardly when pressure is admitted to them through the ports 108 and 113, respectively. When the pressure is released from the annulus of the housing 90, the pressure in the chambers 107 and 112 falls and the pressure of the liquid head of the pump in the tubing connected with the tube 91 is impressed on the top of the piston head 95 within the cylinder 102 and forces the head 95 downwardly. Under this condition the differential pressure between the tube 91 and the power cylinders 107 and 112 is such that greater total pressure is exerted on the top side of the piston than on the bottom side thereof. Here it will be noted that the valve 122 closes upon the reversal of the pressure difference so that there is no communication between the space within the sleeve 102 and the chamber 111. In FIG. 4 the piston assembly is shown in its uppermost position wherein the chambers 111 and 123 are in their minimum or effective zero volume positions; this is the maximum upward position of the piston assembly. When the pressure is reversed by release of the pressure on the annulus about the housing 90, the piston assembly begins to descend. This release of pressure may be effected by either of the pressure supplying systems indicated in FIGS. 2 and 3 both of which are arranged to provide periodic changes in the direction of the differential pressure between the interior of the tube through the pump and the annulus about the pump housing. As the pump assembly moves downwardly, the liquid from the annulus is forced up through the ports 108 and 113 and the cylinder 98 and piston head 95 move downwardly so that the cylinder moves into the chamber 120 and liquid is displaced from this chamber upwardly through the valve 121 into the cylinder 111. As the cylinder 98 descends it displaces a cross section equal to its cross section less the cross section of the tube times the length of the downward stroke. In this pump the relative areas of the annular cross section area of the cylinder 98 and of the outer portion of the piston about the cylinder 102 are designed to secure the characteristics of each application. By way of example the first area may be made one-half that of the second and in the following description this proportioning of the areas is assumed. As the cylinder moves downwardly it displaces one-half of the volume required to fill the chamber 111, the other half of the volume being secured by flow from the formation through the ports 92. The position of the piston assembly as it moves downwardly is shown in FIG. 5 where all of the chambers may be seen clearly in section. While the piston assembly is moving downwardly a volume of liquid is returned from the tubing above the pump and enters the chamber 123 behind the downward moving piston 105. The volume returned to the chamber 123 is equal to the full annular area between the tube 91 and the housing 90 times the distance of the stroke. The piston assembly moves downwardly until it reaches its lowermost position as indicated in FIG. 6 wherein the cylinder chambers 107 and 112 have reached their minimum or effective zero volume positions. At this point the pressure differential between the annulus about the housing and the interior of the tube 91 is again reversed and pressure fluid enters through the ports 108 and 113 to drive the piston assembly again toward its upper position. The position of this assembly after this reversal is indicated in FIG. 7. On this upward stroke the volume of the cham

ber 112 is driven into the chamber 123 through the valve 122. At the same time a volume is displaced by the rising piston assembly which is equal to the annular area of the chamber 123 times the length of stroke. Thus on the upward stroke the change in the volume of the chamber 123 plus the change in the volume 112 is discharged into the tube 91 through the ports 93. In accordance with the design of the embodiment illustrated and as shown in FIG. 6 the volume of the full chamber 112 is equal to twice the volume of the annular space around the tube 91 within the cylinder 102 between the end planes of the cylinder 112. Thus as the piston assembly moves up and down through the chamber 123 a volume equal to the volume of the chamber 123 is moved in and out on each stroke while a volume equal to the volume of chamber 112 is discharged through the ports 93 on each upward stroke.

On the downward stroke as the piston assembly moves from its position in FIG. 4 through its position of FIG. 5 to its position in FIG. 6 the head 95 and cylinder 98 displaced from the chamber 120 a volume equal to the annular area of the sleeve 98 times the distance of the stroke, this volume being the same as the volume contained within the sleeve 102 and displaced from the cylinder 123 on the upward stroke. While the piston assembly is moving downwardly, the chamber 111 is filled with a liquid volume equal to twice that within the sleeve 98. Thus the additional volume must be received from the formation through the ports 92. After the assembly has reached its bottom position of FIG. 6 and starts upwardly, the removal of the cylinder 98 from the chamber 120 draws its volume into the chamber 120 through ports 92. Thus there is withdrawn from the formation on each upward and each downward stroke of the piston assembly a unit volume of reservoir fluid equal to the annular area of the sleeves 98 and 102 times the length of stroke. This arrangement provides a continuous substantially constant rate withdrawal of fluids from the formation.

Another pump embodying the invention and suitable for operation in installations where it is desirable to provide access to the zone of the well below the pump is illustrated in FIGS. 8 and 9. This pump is driven by reciprocation of the production tube and may be operated either to produce fluids from the formation or to inject fluids into the formation. FIG. 8 illustrates the pump as employed for producing fluids from the formation. In his figure the pump is illustrated as comprising an elongated cylindrical housing 130 having a reciprocable piston 131 mounted for sliding movement therein and secured at its top to the production tubing, indicated at 132, and having a portion of the tubing, indicated at 133, extending downwardly through the casing 130 through a packing comprising O-rings 134 and thence into a tube 135 mounted on a packer 136 which has been shown as expanded against the walls of the well indicated at 137. At the upper end of the housing 130 the tubing 132 is sealed against leakage by a pair of O-rings 138. The entire pump assembly and piston 131 may be moved up and down within the casing 130, the bottom tube 133 sliding within the tube 135. The pump housing 130 is divided into an upper cylinder 140 and a lower cylinder 141 below the piston 131. The cylinder 141 is provided with a plurality of ports 142 providing communication through the walls of the housing to the annulus about the housing at the bottom of the cylinder. The tube 133 comprises an active piston which displaces fluids from the formation to the cylinder 140 and thence to the tubing 132 above the pump. The piston 131 is provided with a passage extending centrally therethrough and, in the illustration of FIG. 8, a plugging device 143 has been illustrated as positioned in the central opening of piston 131 resting against collar or stop 144. Plug 143 has lower ports 145 opening into the interior of the tubing 133 and connected by a central passage 146 with ports 147 adjacent the central

solid portion 148. Above the solid portion 148 there is an extension 150 having a passage therethrough between lower ports 151 and upper ports 152. The plug 143 is lowered and raised from the position in the pump on a wire line indicated at 153. The upper cylinder 140 is provided with a discharge valve 154 and an intake valve 155, these being spring pressed ball valves as illustrated diagrammatically. The inlet valve 155 is arranged in a passage 157 providing communication between the chamber 140 and the port 158 in the piston 131. In the position of the plug 143 indicated, the port 158 is in registry with the ports 147 in the plug. The discharge valve 154 is connected in a passage 160 to a port 161 which in FIG. 8 is in registry with the ports 151. It will now be apparent that, on the downstroke of the piston, liquid moves upwardly through the passages 146 and the passage 157 through the valve 155 and into the chamber 140. On the upstroke of the piston 131 the valve 155 closes and the valve 154 opens to allow the liquid in the chamber 140 to be discharged through the valve 154, the port 151, the passage 150, and ports 152 to the tube above the block 148. The tube adjacent the block 143 is sealed by O-rings or other suitable gaskets 162 fitted about the block 143. The lower extension of the plug is provided with two pairs of O-rings 163 and 164, respectively, above and below the central portion of the extension which is adjacent a port 165 which is closed and sealed by the plug in this position so that liquid cannot go either way therefrom.

It will thus be seen that in FIG. 8 a simple and rugged pumping installation has been provided for installation by reciprocation of the production tool and which is provided with the passage through the pump facilitating the positioning of instruments within the production fluids below the pump or with access to the portion of the well below the pump without removing the pump.

When it is desired to inject fluids into the reservoir formation below the pump instead of producing fluids as in FIG. 8 the plug assembly 143 is lowered into the tube in the opposite direction, the ports 143 communicating with the tube above the block 148 and the ports 152 with the tubing 133 below the piston. FIGS. 8 and 9 are views of the same pump, the only difference being in the connection of the wire line 153 to the opposite end of the plug assembly. When the plug is in the position shown in FIG. 9 downward movement of the piston draws fluids through the conduit 146 and past the valve 155 into the chamber 140 thereby filling the chamber 140 from the fluid supply in the tube 132. As the piston descends into the chamber 141 and the tube 143 moves downwardly the valve 154 closes and the liquid within the tubing 152 acting as a piston forces liquid into the formation. On the upward stroke of the piston after it has reached its bottom position liquid is again admitted to the area below the pump through the valve 154, the valve 155 being closed so that the liquid is forced downwardly into the tube 133 below the piston. Because the volume of the chamber 140 is greater than the displacement volume of the piston 133 more liquid is driven into the tube 133 than is drawn from the formation by the rising movement of the piston. Thus the piston 131 operates to drive liquid into the formation both on the up and down strokes.

Under some conditions of operation it may be desirable to locate the valves for the pump in the plug assembly rather than in the piston assembly. A plug arrangement for this type of assembly is shown in FIG. 10. The plug assembly comprises a solid body portion 168 having a short arm 169 and a longer arm 171. The arm 169 is provided with a shoulder or rest portion 172 and the portion 171 is provided with a stop or rest portion 173. These stops are arranged to engage the shoulders 144 in the pump assembly shown in FIGS. 8 and 9 so that when the short end 169 is at the bottom position the portion 168 is in the same position as the portion 148 in FIG. 9, and when the plug is reversed with the portion 171 downward the

plug 168 is in the position of the plug 148 in FIG. 8. At the same positions as those of the gaskets in the plug of FIGS. 8 and 9 the plug of FIG. 10 is provided with a pair of O-rings or gaskets 174 on the short portion and with two pairs 175 and 176 on the long portion. The short portion of plug 169 is provided with a ball valve 179 urged against a seat 177 by a spring 178. The long portion 171 is provided with a ball valve 180 urged upwardly against a seat 181 by a spring 182. The valve 179 of the short end of the plug prevents the passage of fluid from ports 183 at the end through the central passage in the arm to ports 184 adjacent the plug section 168 and the valve 182 prevents the passage of fluid from a set of ports 185 adjacent the plug 168 through the central passage to a set of end ports 186.

It will now be seen that, if the plug of FIG. 10 is employed in the pump of FIG. 8, the valves 154 and 155 of the pump of FIG. 8 being removed to provide free passages, the functions of the valves 154 and 155 will be performed by the valves 179 and 180. Thus, as the pump piston 131 falls the ball valve 180 will move from its seat and allow liquid to flow from below the pump through the ports 186, the valve 180 and the ports 185 through the port 158 and into the passage 157 and thence to the piston chamber 140. At the same time the valve 179 will be held securely against its seat to prevent passage of fluids from the tubing 132 into the chamber 140. On the rising stroke of the piston the valve 180 will be held against its seat by the pressure within the chamber 140 and fluid will be discharged from the chamber through the valve 179 which is moved from its seat to allow the fluid to pass upwardly through the ports 184 and 183 to the tube 132 and thence upwardly.

When it is desired to pump fluids into the formation for injection purposes the plug of FIG. 10 is attached at its opposite end to the wire line 153 in the same manner as the plug shown in FIG. 9, whereupon the valve 180 acts to admit fluids from the tube 132 to the chamber 140 to draw fluid into the chamber 140 on the downstroke of the piston and to force the fluid out of the chamber 140 through the valve 179 on the upstroke of the piston. It will be noted that on the downstroke of the piston the valve 179 closes so that the downstroke forces liquid from the interior of the tube 133 downwardly into the formation.

It will thus be seen that the plug arrangement of FIG. 10 provides a simple arrangement for mounting the spring pressed check valves within the plug so that they may readily be brought to the surface for servicing or repair while the pump cylinder and valve passages remain down-hole in position.

It is desirable that the pump embodying the invention, and which is to be employed in the field under various conditions of operation and in wells of various depths and flow capacity, be made so that its operating conditions can be changed as desired, and in FIG. 11 there is illustrated an embodiment of the pump wherein a plurality of units or sections of the same construction are employed and are connected in a manner to provide a unitary pump structure.

Referring now to FIG. 11, the pump comprises a plurality of sections, three being shown by way of example at 190, 191, and 192. These sections are of essentially identical construction and each may be of a length of, say, twenty feet. The pump as illustrated is hung on a production string 193 and is arranged to receive well fluids through a tube or connection 194 extending downwardly from the section 192 of the pump. Each of these sections includes a power or driving portion indicated at 195, 196 and 197 in the sections 190, 191 and 192, respectively.

The pump assembly of FIG. 11 comprises in effect an outer elongated cylindrical casing and an inner casing or tube spaced from the outer casing. The pump-driving cylinders and pumping cylinders are arranged between the two casings and the passage to the inner tube or casing

constitutes the free passageway through the pump which makes it possible to pass instruments or other devices entirely through the pump to the area or zone of the well below the pump. In order to effect pumping a plugging arrangement similar to that employed in the pumps heretofore described is utilized and the pump may be employed either to act as a production pump to remove fluids from the reservoir or as an injection pump to force fluids into the reservoir.

FIGS. 12 and 13 are detailed views showing the internal construction of the indicated sections of the units 190 and 192. The construction of section 191 is the same except for the end fittings and the two figures will serve to show the construction of the entire unit. As shown in FIG. 12, the pump 190 comprises an outer casing 200 and an inner tube 201 to which is secured an assembly comprising a top sleeve 202, an annular ring 203 and a sleeve 204 connecting the tubing 201 and the ring 203. The ring 203 is slidably fitted within the casing 202 and has annular bronze bearings 205 and 206 provided to afford easy sliding movement. On the upper side of the bearing 205 there is provided a pair of running cup seals 207 and a similar pair of seals indicated at 208 is provided between the ring 203 and the sleeve 204 adjacent the lower bearing ring 206. The sleeve 202 is provided with a plurality of ports 210 opening between the interior of the tubing and the space between the tubing and the casing 200. An internal threaded fitting 211 is provided on the sleeve 202 for the attachment of a further pump section at the top, this being a part common to all the pump section assemblies. The outside of the sleeve 202 is provided with a series of steps 212 which are employed to hydraulically slow down the piston at the end of its stroke. In a similar manner the sleeve 204 is provided with stepped portions 213 which in FIG. 12 lie in a pump chamber 214 formed between the seals 208 and a second set of running cup seals 215 mounted in an external mounting ring 216 which is threadedly secured at 217 to the lower end of an external sleeve 218. The sleeve 218 constitutes a continuation of the casing 200 and is threaded, welded, brazed, or otherwise suitably secured to the bottom end of the sleeve 200 to provide a portion of the hydraulic slow-down device in the form of an annular shoulder 219. The chamber 214 is in open communication with the zone about the casing 200 through a plurality of ports 221, and when the liquid entering the chamber 214 through the port 221 is at sufficiently high pressure the entire internal tube assembly is forced upwardly. The lower end of the stationary annular ring 216 is provided with a pair of running cup seals 222 and with a pair of bronze rings 223 and 224 for running engagement with the tube 201. Below the ring 216 there is mounted a pump-casing sleeve element 225 on which is threadedly carried the casing of the intermediate unit 191. The sleeve 225 provides an internal shoulder or piston element 226 similar to the element 219 of the unit 190.

The bottom end of the unit 191 is of the same construction as the bottom end of the unit 190 illustrated in FIG. 12 and the top end of the unit 192 is of the same construction as the top end of the unit 191 shown in FIG. 12. FIG. 13 illustrates the unit 192, the upper end of which is of the same construction as the upper end of the unit 190 of FIG. 12 and has been shown connected to a tube sleeve 227 which is the sleeve of the unit 191 corresponding to the sleeve 201 of the unit 190. It will now be seen that the bottom of the unit 190 cooperates with the unit below it as represented by the unit 192 to provide a chamber 228 opening into the central passage through a plurality of ports 230 formed in a sleeve member 231 which is of the same construction as the sleeve member 202 of the unit 190 in FIG. 12, and it will be seen that the cylinder sleeve 226 of the unit 190 which is of the same construction as the corresponding sleeve of the unit 191 (not shown) will cooperate with stepped portions 232 of the sleeve 228 to decrease the hydraulic

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shock in steps as the stepped piston moves into position. In the space between the sleeve 226 and the sleeve 227. Sleeve 231 is mounted in an annular base or ring 233 which is modified in construction over that of the ring 203 of the unit 190 in order to provide a "no-go" stop shoulder 234 on which may be positioned a plug 235 in which are mounted ball check valves 236 and 237 for effecting a pumping action utilizing the cylinder 228 to pump fluids from below the ring 233 into the tube 227 above the plug 235. The lower end of the section 192 is also different from that of the other sections in that it is the terminal section of the pump and is provided with a terminal sleeve 241 threadedly secured at 242 to a cylinder sleeve 243 of the driving portion 197 of the unit 192 which is provided with a plurality of ports 244 for admitting driving fluid from the annulus surrounding the housing 192. A pair of running cup seals 245 are provided and locked in position between the sleeve 243 of the terminal sleeve 241. The reservoir fluid tube 194 is threaded into the inner lower end of the terminal sleeve 241 as indicated at 246 and the sleeve 240 in the position indicated extends into the upper end of the tube 194.

When the plug 235 is in position as indicated, the ring assembly 233 and the parts attached thereto constitute the main piston assembly of the pump. This assembly is provided with running cup seals 247 at the upper side of the ring 233 and 248 on the lower side, these seals being oppositely faced and sealing the upper and lower sides of the piston head, respectively. In order to provide minimum friction and a good bearing for the piston assembly, annular bearing rings 250 and 251 of bronze or other suitable material are provided on the ring 233 for engagement with the casing of the unit 192. The running cup seals 248 are secured in position on a sleeve assembly 252 which is of the same construction as the sleeve 204 of the unit of FIG. 12.

The pump is actuated by the pressure difference between the fluid outside the pump casing and within the tube 193. Thus, when pressure is increased outside the casing liquid enters from the annulus about the pump through the ports of the portions 195, 196 and 197, and forces the piston assembly upwardly. When the pressure differential is reversed and is greater on the inside of the pump assembly, liquid enters the center of the pump and the plug 235 acts as a piston, the valve 236 being closed against its lower seat as shown in the drawing. In addition the port of the unit 191 which corresponds with the ports 210 and 230 of the units 190 and 192 also admits liquid to the interior of its piston chamber which is of the same construction as the chamber 228 of the unit 192. This then forces the piston assembly downwardly. The downward movement of the piston opens the valve 237 so that liquid from the formation flowing upwardly through the tube 240 flows out through the plug 235 which has ports 253 registering with the ports 230 so that the liquid flows into the pump cylinder 228 between the tubing 227 and the casing 192. When the pressure is again reversed and the piston assembly is forced upwardly by the admission of fluid under pressure to the ports of the portions 195, 196 and 197 the upward movement forces the liquid out of the piston chamber 228 past the valve 236 which is opened by the differential pressure and into the tubing above the plug 235 to the production string 193. It will thus be apparent that the pump can be actuated hydraulically by alternate reversal of the pressure differential between the outside of the pump casing and the inner tube in a manner essentially the same as that employed in connection with the pump of FIGS. 4, 5, 6 and 7.

This pump may also be employed for injection purposes by providing a plug corresponding to the plug 235 but with the valve reversed so that the pumping action is down instead of up. This plug is not illustrated; however, it will be understood that its action is essentially similar to the reverse acting plug of the pump of FIGS. 8 and 9

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when employing the plug of FIG. 10 for injection action.

In FIGS. 14, 15 and 16 there is illustrated a subassembly carrying ball check valves which may be inserted in the pump of FIGS. 11, 12 and 13 in place of the subassembly mounted on the ring 233 of FIG. 13 in order to incorporate the valves in the pump assembly, whereupon the pump may be rendered effective by inserting a plug of a type generally similar to that employed in the pump of FIGS. 8 and 9.

In FIGS. 14 and 15 the inner tube 227 is shown with a sleeve 256 threaded to the lower end thereof and providing a shoulder 257 within the inner passage. A valve-carrying sleeve 258 is threaded to the lower end of the sleeve 256 at 259 and carries three sets of four valves comprising inlet valves 260 providing communication with an annular cylinder 261 corresponding to the cylinder 228 of FIG. 13 and four discharge valves 262 which lie at forty-five degrees in the horizontal plane from the valves 260 and are higher in the sleeve assembly 258 than the valves 260. At a substantial distance above the valves 260 and 262 and mounted within the sleeve assembly 256 there is provided another set of four valves 263 which act as intake valves during the injection operation of the pump. Around the lower end of the valve assembly 258 there is provided a pair of running cup seals 264 which may be held in place by an annular block (not shown) but essentially similar to the block 233 which is attached on threads 265 at the lower end of the valve sleeve 258 and holds the seal assembly 244 in position on threads 265.

The operation of the pump with the valve assembly of FIG. 14 employed instead of the plug assembly 235 of FIG. 13 is the same as that of the pump of FIG. 13 except that the valves are in the pump assembly rather than in the plug assembly. In order to effect a pumping operation with the valve assembly of FIG. 14 a plug 268 is lowered into position in the passage so that an annular shoulder 269 on the plug engages the shoulder 257 in the sleeve element 256. The plug 268 is hollow and is provided with a closure block 270 extending across the lower end thereof and positioned adjacent the valves 260 so that ports 271 in the plug assembly are in registry with the valves 260. The skirt of the plug below the ports 271 is provided with a set of O-rings or gaskets 272 which seal the plug to the walls of the unit 258. A set of plugs 273 just above the closure plug 270 register with the ports of the valve 262 and the plug is provided with outlet ports 274 at the top thereof as well as a central passage 275 in an overshot connection 276 provided for lowering and removing the plug from its position in the assembly. The upper portion of the plug above the closure 270 is provided with two pairs of O-rings 277 and 278 which seal off an annular passage 280 which communicates with the ports of the valves 263. When the piston of this valve assembly is reciprocated by alternately reversing the hydraulic pressure differential between the annulus outside the housing and the passage within the housing, fluid is drawn into the cylinder 261 on the downstroke, the fluid flowing from the formation through the central tube below the closure plug 270, and on the upstroke the fluid is discharged through the valves 262 and the ports 273 into the central passage above the closure plug 270.

FIG. 15 illustrates the plug employed with the assembly of FIG. 14 when the pump is to be employed for injection purposes. This plug is of a construction similar to that of the plug 268 but comprises a closure plug 281 having ports 282 arranged to register with the valves 262 in the same manner as the ports 273 of the plug 268, the ports 282 being below the closure plug 281. A short distance above the closure plug 281 there are provided a plurality of ports 283 which are arranged in a position to register with the ports of the valves 263. The plug is provided with a pair of O-rings 284 which seal the plug and the walls of the tubing below the ports 282 and with

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a pair of O-rings 285 which seal the plug and the walls of the passage above the ports 283. The plug is provided with a shoulder 286 which rests on the shoulder 257 in the same manner as the shoulder 269 of the plug 268. The upper end of the plug is provided with a fitting 287 for engaging an overshot and has ports 288 for communication with the interior of the tube above the plug as well as the central passage 289 through the overshot connection.

During the operation of the pump with the plug of FIG. 15 in position on the upstroke of the piston assembly, liquid is drawn into the chamber 261 through the valves 263 and ports 283, and on the downward stroke of the pump this liquid is driven out through the valves 262 and the ports 282 to the tubing below the closure member 281. Thus by changing the plugs from the plug 268 to the plug shown in FIG. 15 the operation of the pump is changed over from production pumping to injection pumping.

The pump of FIG. 11 can thus be employed for a wide range of purposes, it being understood that it may be secured in a well with packers in the same manner as the pumps previously described. By a simple interchange of parts the pump may be employed with the valves mounted either within the pump housing structure or within the plugging element. Because the pump is built in units it is a simple matter to construct an overall pump with the required number of units merely by adding or subtracting units from the pump assembly and providing the required terminal units and units for holding the particular type of plug assembly to be employed. In all cases the pump may be employed with a free central passage so that instruments or tools may be lowered through the pump without removing the pump from its position in the well. This simple and rugged construction of the pump is particularly suited to use in the field where quick changes with respect to capacity and direction of pumping are desirable.

The plugging devices employed to close the passages in the pumps described above are constructed and arranged to be held in position against any difference in pressure tending to move them out of position. For this purpose, particularly during use of the pump for well injection, any suitable hold-down device may be employed; for example, an expansible hydraulic packer or a mechanical latching device may be assembled on the plug.

While the invention has been disclosed in connection with various types of pumps and pump operators, other modifications and applications will occur to those skilled in the art. Therefore, it is not desired that the invention be limited to the particular details illustrated and described and it is intended by the appended claims to cover all modifications which fall within the spirit and scope of the invention.

I claim:

1. A pumping unit for oil wells and the like comprising an elongated housing having open ends, a pump arranged within said housing and having an inlet and an outlet in communication with respective ends of said housing, means forming a passage through said unit for providing a bypass around said pump from one end of said housing to the other and for affording the passage of sensing instruments and the like through said unit, means for actuating said pump to circulate fluid from said inlet to said outlet, removable closure means positioned in said bypass for closing said bypass whereby said pump is effective to pump fluid into said unit at one end and out the other, and means operatively associated with said closure means for facilitating the control from outside said housing of the removal of said closure means from said bypass whereby said pumping unit may be left in position in a well and said closure means removed to afford access to the reservoir formation below the pump unit.

2. A pump comprising an elongated housing, means within said housing and spaced from the wall thereof for

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forming an open passage extending longitudinally through said housing from one end to the other, said passage and the space between said passage-forming means and said wall of said housing being in open communication at two spaced locations in said passage, fluid-propelling means arranged between said housing and said passage-forming means for pumping fluid from one of said locations to the other, means for actuating said fluid-propelling means, means including a removable plugging means in said passage for closing said passage between said two locations whereby said fluid-propelling means is rendered effective to pump fluid through said housing around said plugging means, and means operatively associated with said plugging means for facilitating the control from outside said housing of the removal of said plugging means from said passage.

3. A pump as set forth in claim 2 having porting means providing communication with said passage for the flow of fluids between said fluid-propelling means and said passage, and wherein said plugging means includes means providing ports for directing fluid from one end of said passage into said fluid-propelling means and fluid from said fluid-propelling means into the other end of said passage.

4. A pump as set forth in claim 3 wherein said plugging means is constructed and arranged to be inserted in said passage and seated with either end toward said one end of said passage whereby fluid may be pumped selectively in either direction along said passage.

5. A pump as set forth in claim 3 wherein said plugging means further includes check valves for preventing reverse flow of fluids through said passage.

6. A pump unit comprising an elongated housing, means within said housing forming an open passage extending longitudinally therethrough from one end to the other, an expansible chamber pump mounted in said housing between said last mentioned means and the inner wall of said housing for pumping fluid from a first position in said passage to a second position therein spaced from said first position, means for actuating said pump, removable plugging means mounted in said passage between said first and second positions for preventing the direct flow of fluid between said first and second positions whereby said pump is effective to produce a flow of fluid from one end of said passage to the other, and means operatively associated with said plugging means for facilitating the control from outside said unit of the removal of said plugging means from said passage to afford access through said passage from one end of said housing to the other.

7. A pump comprising an elongated cylindrical housing, means within said housing forming an open passage extending longitudinally through said housing and a closed space between said means and the wall of said housing, said passage forming means having two ports therein spaced from one another and providing communication between said passage and said space within said housing, removable means for closing said passage between said ports, said last mentioned means being movable through said passage to and from its position between said ports, pumping mechanism in said closed space for forcing fluid from one of said ports to the other, means operatively associated with said closing means for facilitating the control from outside said housing of the removal of said closing means from said passage, whereby when said passage is closed between said ports said pumping mechanism is effective to pump fluid from said passage on one side of said removable closing means to said passage on the other side of said closing means, said passage when said closing means is removed being open and affording free access through said housing.

8. A pump comprising an elongated cylindrical housing, means forming a central passage extending longitudinally through said housing, longitudinally spaced ports in said passage forming means providing communication between said passage and the annular space between said housing

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and said means, removable means for selectively closing said passage between said ports, said last mentioned means being movable through said passage to and from its position between said ports, a pumping mechanism in said annular space and surrounding said passage forming means 5 for forcing fluid from one of said ports to the other, whereby when said passage is closed between said ports said pumping means is effective to pump fluid from said passage on one side of said closing means to said passage on

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the other side of said closing means, said central passage when open affording access through said housing to the well bore below said pump, and means operatively associated with said removable means for facilitating the control from outside said housing of the removal of said removable means from said passage.

No references cited.

LAURENCE V. EFNER, *Primary Examiner*.