

March 5, 1963

W. N. SUTLIFF

3,079,863

APPARATUS FOR ACTUATING A DEEP WELL PUMP

Filed Jan. 11, 1961

2 Sheets-Sheet 1

FIG. 1.

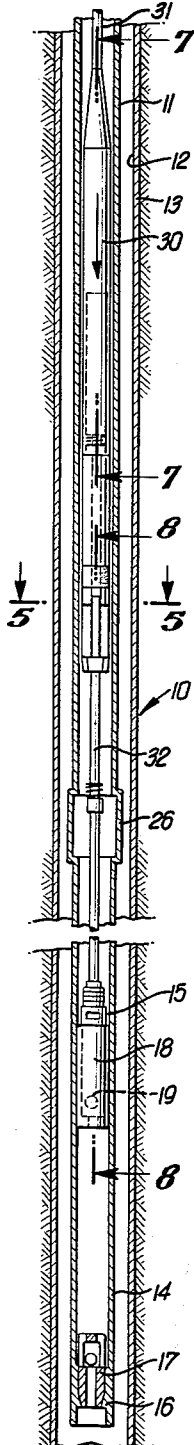


FIG. 2.

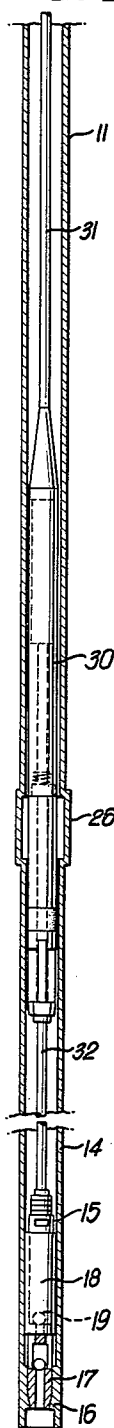


FIG. 3.

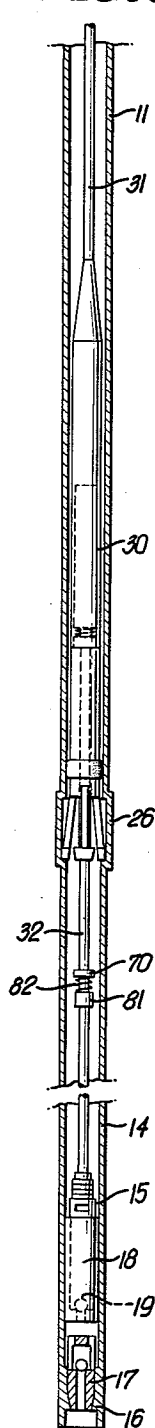


FIG. 4.

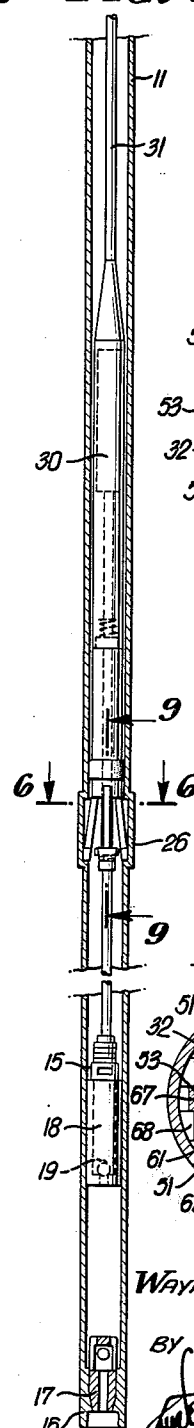


FIG. 5.

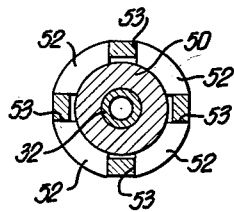
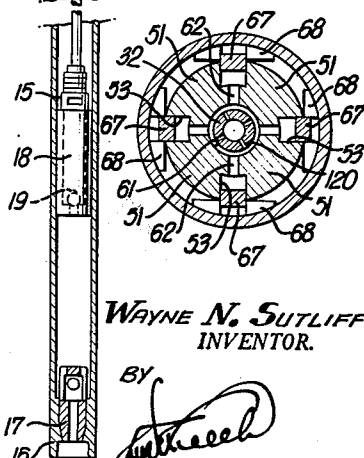


FIG. 6.



WAYNE N. SUTLIFF
INVENTOR.

BY
Wayne N. Sutliff

ATTORNEY.

March 5, 1963

W. N. SUTLIFF

3,079,863

APPARATUS FOR ACTUATING A DEEP WELL PUMP

Filed Jan. 11, 1961

2 Sheets-Sheet 2

FIG. 7.

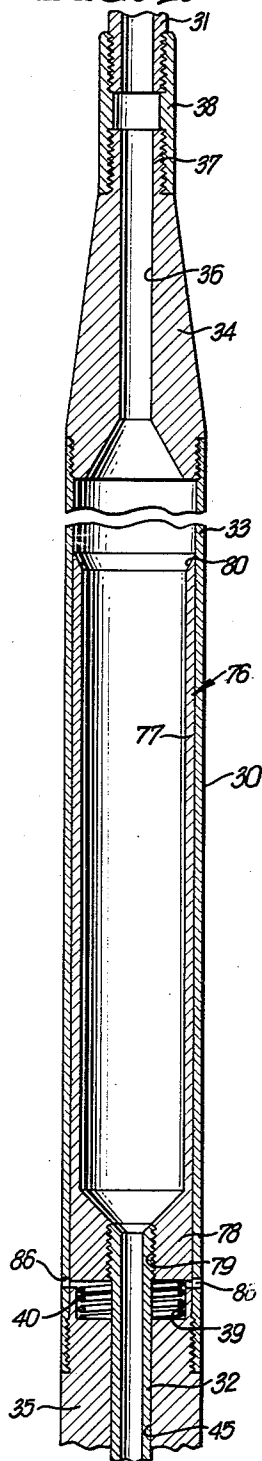


FIG. 8.

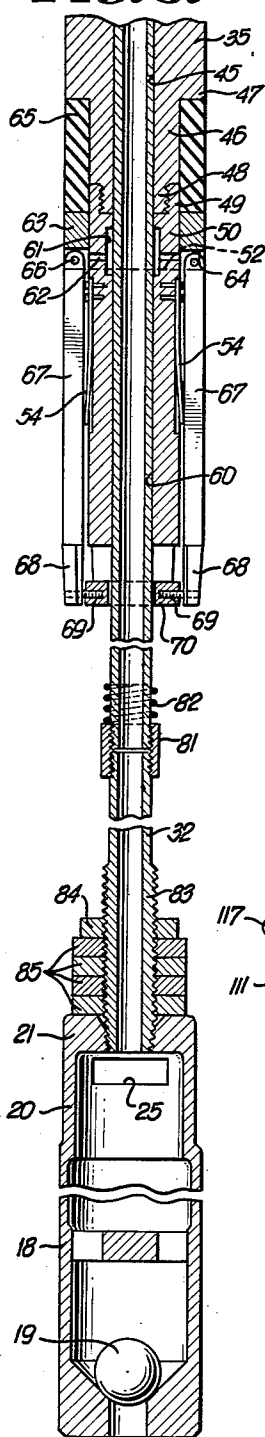


FIG. 9.

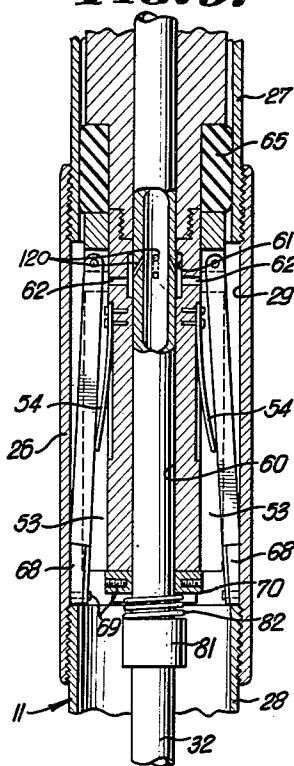
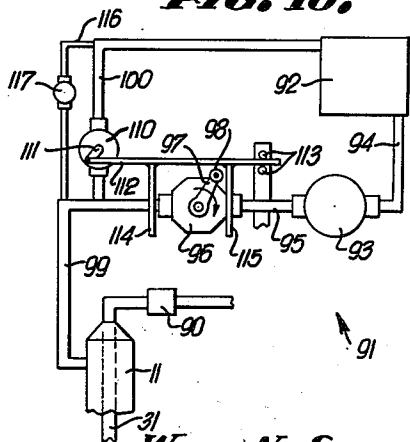


FIG. 10.



WAYNE N. SUTLIFF
INVENTOR.

BY

Wayne N. Sutliff

ATTORNEY.

1

3,079,863

APPARATUS FOR ACTUATING A DEEP WELL PUMP

Wayne N. Sutliff, 2931 Pierce Road, Bakersfield, Calif.
Filed Jan. 11, 1961, Ser. No. 82,050
7 Claims. (Cl. 103—46)

This invention relates to the art of actuating deep well pumps and particularly to such an actuating apparatus which functions for a major portion of the well depth through a pulsating column of liquid.

It is an object of the present invention to provide such an apparatus in which the weight of said pulsating column of liquid is counterbalanced by a parallel column of production liquid.

Prior efforts to hydraulically operate a pump jack at the bottom of a well have resulted in devices which were complicated to install in the well and very difficult to recover without loss of the well.

It is another object of the present invention to provide an apparatus for actuating a deep well pump by a pulsating liquid column which apparatus may be installed in the well and recovered therefrom by standard production procedures and without danger of damage to the well.

It is still another object of the present invention to provide an apparatus for actuating a deep well pump by a pulsating liquid column which apparatus may be run into the well suspended on a small diameter production fluid pipe line and be located inside the regular pump tubing string and which may be readily lowered into the well on said line and removed therefrom in accordance with standard production procedures.

A yet further object of the present invention is the provision of such an apparatus in which the latter is provided with means for supporting the same in a fixed position in the regular pump tubing string without requiring an enlargement of the diameter of the latter.

Still another object of the present invention is the provision of a hydraulic jack adapted to be lowered in a deep well with an insert pump suspended therefrom and in which said pump is adapted to be locked in place by a downward bumping action.

A yet further object of the invention is to provide such a hydraulic pump jack having means responsive to the installation of an insert pump suspended therefrom as aforesaid to activate means provided on said jack for supporting the same within the ordinary pump tubing string and forming a packer between said jack and said string whereby said string may be utilized as a passage for operating liquid to actuate said jack from the surface of the ground.

It is still another object of the present invention to provide an apparatus for actuating a deep well pump by a pulsating liquid column which will utilize a continuous flow of operating liquid such as generated by a rotary pump for the pulsation of said liquid column.

Yet another object of the invention is the provision of an apparatus for actuating a deep well pump by a pulsating liquid column which is adapted for pumping wells in which the production fluid carries a heavy component of sand.

A still further object of the invention is the provision of an apparatus for actuating a deep well pump by a pulsating liquid column embracing means for preventing a gas cushion forming beneath the packing between the jack and the pump tubing string, from hindering the operation of the pump, by introducing gas from this space into the production fluid being pumped, thereby facilitating the upward movement of production fluid through the actuating jack and the small diameter production fluid pipe line from which said jack is suspended when introduced into the well.

2

This application is a continuation-in-part of my co-pending application Serial No. 2,185 filed January 13, 1960, now abandoned, for Method and Apparatus for Actuating a Deep Well Pump by a Pulsating Liquid Column.

The manner of accomplishing the foregoing objects as well as further objects and advantages will be made manifest in the following description taken in connection with the accompanying drawings in which

FIG. 1 is a diagrammatic fragmentary vertical elevational view of a preferred embodiment of the apparatus of the invention as this is being lowered through a regular string of pump tubing previously installed within a well casing of a deep well.

FIG. 2 is a view similar to FIG. 1, with the showing of the well casing omitted for purposes of simplicity, and showing the pump actuating jack of the invention and the pump plunger suspended thereon lowered to a point where said plunger rests upon a standing valve at the lower end of said pump tubing string so as to release the pump jack supporting mechanism for subsequent use in supporting the jack on said tubing string and in expanding the packer provided on said jack to seal off the space between said jack and said tubing string.

FIG. 3 is a view similar to FIG. 2 and illustrates the completion of the operation of mounting the hydraulic jack in the pump tubing string and setting the packer between the jack and said string. This view also illustrates the pump plunger located at the lower end of its normal downstroke.

FIG. 4 is a view similar to FIG. 3 illustrating the pump plunger at the top of its normal upstroke.

FIG. 5 is an enlarged horizontal sectional view taken on the line 5—5 of FIG. 1 and shows the four supporting legs of the jack as when these are held in retracted position.

FIG. 6 is an enlarged horizontal sectional view taken on the line 6—6 of FIG. 4 and shows said legs expanded into the special coupling provided in said pump tubing string for receiving the same so that said legs may rest on a length of said tubing which connects with the lower end of said special coupling and thus set the packer on the jack in sealing relation between said jack and the section of said pump tubing connecting with the upper end of said coupling.

FIG. 7 is an enlarged vertical sectional view taken on the line 7—7 of FIG. 1 and illustrating an upper portion of the pump actuating jack of the invention.

FIG. 8 is an enlarged vertical sectional view taken on the line 8—8 of FIG. 1 and illustrates a lower portion of said jack and the pump plunger suspended therefrom and shows the supporting legs of the jack held together prior to these being released as aforesaid by the bumping of said pump plunger on the standing valve at the bottom of said pump tubing string.

FIG. 9 is an enlarged vertical sectional view taken on the line 9—9 of FIG. 4 and illustrates the lower portion of said jack after it has been installed in said pump tubing string and said packer set against the latter and illustrates the hollow piston rod of said jack as located at the completion of an upstroke of the pump plunger at which time a portion of any gas accumulated at high pressure just below said packer is introduced into the production fluid flowing upwardly through said hollow piston rod.

FIG. 10 is a diagrammatic view illustrating a preferred apparatus of the invention for pulsating the liquid column through which the jack of the invention is actuated.

Referring specifically to the drawings and particularly to FIG. 1, a preferred embodiment 10 of the apparatus of the invention is best shown as incorporated with a pump tubing string 11 installed in a well bore 12 having a casing 13.

Embodied with and suspended from the lower end of the pump tubing string 11 is the barrel 14 of a plunger

pump 15, this barrel forming a downward continuation of the tubing string 11 and carrying a shoe 16 at its lower end having a conical seat supporting a standing valve 17. Reciprocable in the pump barrel 14 is a plunger 18 having a traveling valve 19. At its upper end the plunger 18 has a cage 20 which terminates in a threaded socket 21 (FIG. 8). The external diameter of the cage 20 is slightly less than that of the balance of the plunger 18 so that one or more openings 25 provided in said cage provide a communication between the interior of the plunger 18 and the space within the barrel 14 above said plunger.

While the pump tubing string 11 is shown diagrammatically in FIG. 1 as integral with the pump barrel 14 it is to be understood that this tubing string is made up of sections joined together by threaded collars and that a similar collar connects the lower end of the string to the pump barrel 14. At a level substantially below the midpoint in the well 12 and possibly several hundred feet above the pump 15 a special coupling 26 is provided for connecting juxtaposed ends of adjoining tubing sections 27 and 28 (FIG. 9) the coupling 26 being identical with an ordinary tubing coupling but somewhat longer to provide an annular recess 29 between the adjacent ends of said sections.

The apparatus 10 includes a hydraulic jack 30 which fits loosely within pump tubing string 11 and which is suspended on the lower end of a production fluid pipeline 31 of relatively small diameter which extends downwardly within the pump tubing string 11, said jack having a hollow piston rod 32 which extends downwardly therefrom and the lower end of which is threaded and screws into the threaded socket 21 of the pump plunger 18 (FIG. 8). Thus the plunger 18 is suspended on the hollow piston rod 32 and jack 30 so that all of these elements are suspended on the production fluid pipeline 31 while being introduced into the well as shown in FIG. 1.

The hydraulic jack 30 has a relatively long thin walled tubular cylinder 33 which is internally threaded at its opposite ends so as to screw onto an upper head 34 at its upper end and onto a lower head 35 at its lower end. The upper head has an axial fluid passage 36 and tapers upwardly to an externally threaded nipple 37 which is connected by an ordinary pipe coupling 38 to the lower end of the production fluid pipeline 31 (FIG. 7).

The lower cylinder head has a spring confining recess 39 in its upper end for confining a coiled expansion spring 40 the purpose of which will be made clear hereinafter.

The lower cylinder head 35 is of the same external diameter as the cylinder 33 and has an axial bore 45 which extends throughout its length.

At its lower end, the cylinder head 35 is turned down to provide a cylindrical packer mandrel 46 and an annular packer compression shoulder 47. The lower end of mandrel 46 has a threaded nipple 48 which screws into a threaded socket 49 provided in the upper end of a cylindrical downward extension 50 of said mandrel. The mandrel extension 50 has four spaced guides 51, with flat upper faces 52, between which guides leg guideways 53 are provided in each of which guideways a flat leaf spring 54 is mounted. The mandrel extension 50 is provided with an axial bore 60 which is of the same diameter as the bore 45 and forms a downward continuation of the latter. A short internal counterbore 61 is provided in the bore 60 which counterbore is vented to the outer cylindrical surface of extension 50 by horizontal ports 62.

Slidably mounted on the mandrel extension 50 so as to normally rest on upper flat faces 52 of leg guides 51 is a leg mounting ring 63 having four notches 64 formed in the lower edge thereof. The ring 63 has the same outside diameter as the lower cylinder head 35 and a rubber packer 65, which is normally of the same outside diameter, fills the space between shoulder 47 and ring 63. Pivoted at their upper ends by pins 66 in the notches 64 are four legs 67 which are disposed opposite and rest in the guideways 53 as shown in FIGS. 5 and 6. Each of the

legs 67 has an arcuate footing 68 welded to its lower end which is adapted to fit into the recess 29 when legs 67 are swung outwardly as shown in FIG. 9 so that footings 68 overlies and rest upon substantial areas of the upper end of tubing section 28.

Springs 54 are biased to constantly engage legs 67 and swing these outwardly when such movement is not restrained. Such restraint is furnished when the apparatus is being lowered into the well 12 by shear screws 69 which are screwed through suitable tapped holes provided in the footings 68 and in a ring 70 which is spaced downwardly from the lower end of the packer mandrel extension 50, while functioning to hold the legs 67 in retracted position as shown in FIG. 8.

The jack 30 includes a hollow piston 76 which comprises a thin-walled cylindrical shell 77 integrally united with a lower piston head 78 which is provided axially with a tapped bore 79 into which the threaded upper end of hollow piston rod 32 screws. The piston rod 32 has an outside diameter which slidably fits the bores 45 and 60, these bores being of sufficient length that a relatively fluid-tight seal is formed just by the sliding fit between the piston rod and the lower cylinder head 35. The piston shell 77 is relatively long compared with its diameter and the upper edge thereof has a sharp bevel 80 for a purpose to be made clear hereinafter.

The hollow piston rod 32 is preferably formed in at least two sections which provides an opportunity for incorporating therewith a shear collar 81 which supports a short coiled expansion spring 82 which is coiled about the hollow rod 32 just above this collar.

The portion of the hollow piston rod 32 located above the collar 81 slides freely through the ring 70. A portion 83 of the hollow piston rod 32 adjacent its lower end is upset and externally threaded to receive a nut 84 which is adapted to be tightened downwardly upon a varying number of annular weights 85 to secure these weights in place on the upper end of the plunger 18.

Holes 86 are provided in the cylinder 33 near its lower end and just above lower cylinder head 35.

Operation

The operation of the apparatus 10 involves first the method of installing the same in the well 12 and second the method of actuating the jack 30 in order to cause this to operate the pump 15 for the production of petroleum from said well.

For purposes of simplification let us first consider the installation of the apparatus 10 as this is diagrammatically shown in FIG. 1. This shows the apparatus being lowered into the well with the plunger 18 suspended on the lower end of hollow piston rod 32, the latter being suspended from the piston 76 so as to compress spring 40 as shown in FIGS. 1 and 7 and with the jack 30 suspended on the production fluid pipeline 31. As diagrammatically shown, the barrel 14 of the pump 15 has already been incorporated with the lower end of the tubing string 11 and the standing valve 17 has already been installed supported by the shoe 16 at the bottom of the barrel. The assembled apparatus 10 is thus allowed to descend in the well until the piston 18 comes to rest on top of the standing valve 17 as shown in FIG. 2 and the jack 30 descends, sliding downwardly on the hollow piston rod 32 until the restraining ring 70 comes to rest on the spring 82 and compresses this downwardly against the shear collar 81. As shown in FIG. 2 the legs 67 at this time are disposed below the special coupling 26 in the pump tubing string 11.

The operator now lifts on the pipeline 31 to lift the jack 30 a foot or two and then suddenly lowers the jack to bring the ring 70 downwardly on the shear collar 81 with a bump which shears the threaded screws 69 connecting the lower ends of legs 67 to ring 70 thereby freeing these legs and permitting them to swing outwardly in response to springs 54 until their footings 68 engage

the inner surface of the pump tubing string 11. The operator then lifts again on the production fluid line 31 until the legs 67 are expanded into the recess 29 when these legs come opposite said recess. It is to be understood that the special coupling 26 is located in relation to the lower end of the pump tubing string 11 with particular reference to the distance the lower end of the plunger 18 is from the lower ends of said legs, when said plunger is suspended on the hollow piston rod 32 from the jack 30. The apparatus 10 is so designed that the latter distance is such that when the jack 30 has been lifted until the legs 67 expand into the annular recess 29 and the weight of the jack is then allowed to come to rest on said legs which transmits said weight to the section 28 of tubing string 11 and produces an expansion of the packer 65 to form a seal between jack 30 and section 27 of tubing string 11, the lower end of the piston 18 will be spaced a slight distance upwardly from the top of the standing valve 17.

Upon the shearing of shear screws 69 in the bumping operation above described, to release legs 67 from inward restraint, the ring 70 is no longer supported by said legs and drops downwardly to thereafter rest on top of the spring 82 as shown in FIG. 3.

As shown diagrammatically in FIG. 10, the upper end of the tubing string 11 is closed and the upper end of pipe string 31 is supported at the upper end of said tubing string by any suitable well known means, after the apparatus 10 has been installed in the lower portion of the tubing string 11 as shown in FIG. 3. A pressure control valve 90 is provided in pipe 31 by which a regulated degree of back pressure may be imposed on a column of production fluid contained in said pipe. Before pumping operations may be commenced the line 31 must be filled with a column of production fluid or its equivalent and the pump tubing string 11 filled with a column of jack operating liquid. Any suitable pulsating mechanism may then be connected with the upper end of tubing string 11 to produce the necessary vertical pulsation of the column of operating liquid therein which is required for actuating the jack 30. A preferred mechanism 91 is diagrammatically shown in FIG. 10 for performing this function.

The pulsating mechanism 91 includes an operating liquid storage tank 92 from which a continuously operating rotary pump 93 draws liquid through a pipe 94 and discharges this through a discharge pipe 95 which connects with a metering device 96 which may be of the gear-liquid-motor type and which rotates a crank 97 having a roller 98 on its end in the direction of the arrow applied thereto, the rate of this rotation being regulated so that crank 97 will turn 180° each time an amount of liquid passes through the meter 96 which is sufficient when it flows inwardly through the holes 86 in the lower end of cylinder 33 to lift piston 76 from its lowermost to its uppermost position in said cylinder. Extending from the discharge end of meter 96 to the upper end of pump tubing string 11 is a pipe 99. Connecting pipe 99 to storage tank 92 is a by-pass pipe 100 having a valve 110 which is turned from "on" to "off" and vice versa by a 90° rotation thereof. Connected to a crank 111 provided on valve 110 is a rod 112 the other end of which is guided between rollers 113, said rod having lateral members 114 and 115 which lie in the same vertical plane with the orbit of roller 98 and are responsive to said roller at the opposite horizontal limits of said orbit to alternately close and open the valve 110. Connecting to the pipe 99 and to the pipe 100 so as to by-pass the valve 110, is a pipe 116 having a safety valve 117.

The distance which the coupling 26 is placed above the standing valve 17 varies in accordance with the weight which it is desired to incorporate in the hollow piston rod 32 so as to produce a satisfactory balance between the

fluid head of the production fluid column which presses downwardly on jack piston 76 and that of the operating liquid column which presses upwardly on said piston. A study of the character of the operating fluid to be produced from a given well is made before the apparatus 10 is designed for use in that well and the piston 76 is loaded with enough weight provided by the length of hollow piston rod 32 and the number of weights 85 applied to the plunger 18 so that this weight added to the fluid head of the production fluid column in production fluid line 31 downwardly against the piston 76 is sufficient to rapidly return this piston from its upward to its downward positions in the jack cylinder 33 when the valve 110 is actuated so as to cause the flow of operating liquid discharged from the meter 96 into pipe 99 to by-pass through the pipe 100 to the tank 92 and thus allow an amount of operating liquid equal in volume to that expelled through holes 86 when the piston 76 descends, to flow from the upper end of the tubing string 11 through the pipe 99 and pass through the by-pass pipe 100 to the tank 92.

The piston 76 is so balanced in the design of the apparatus 10 above discussed that there will be a sufficient preponderance of downward forces applied to the piston 76 to move this downwardly during its downstroke so that the latter will be completed during the one-half revolution of the crank 97 during which the valve 110 is open. Then when the valve 110 is again closed by the crank 97 and operating liquid again flows from the meter 96 through the pipe 99 to the tubing string 11, the piston 76 is at the bottom of the cylinder 33 and ready to start another upstroke. The completion of the latter occurs simultaneously with the opening of valve 110 which starts another downstroke of piston 76.

The piston 76, hollow piston rod 32 and plunger 18 move vertically together and with each downstroke of the plunger 18 the standing valve 17 closes and the traveling valve 19 opens and production fluid (sucked into barrel 14 below the plunger 18 during its immediately prior upstroke) flows upwardly through the plunger 18 and out of the openings 25 therein and into the tubing string 11 located between the plunger 18 and the packer 65. With the downstroke of the piston 76 there is also a falling of the level of the production fluid in the pipe 31 at the upper end of the latter. This is necessary to fill the expanding chamber within the cylinder 33 which takes place with the downward movement of the piston 76 therein.

During the upstroke of the pump plunger 18 the standing valve 17 opens and the traveling valve 19 is closed and the production fluid which occupies the space within the pump tubing string 11 and the pump barrel 14 between the plunger 18 and the packer 65 is caused to flow through the openings 25 into the plunger 18 and upwardly therefrom through the hollow piston rod 32 and into the jack piston 76. Thus during the upstroke of the jack piston 76, not only does the production fluid occupying the portion of the cylinder 33 between the upper end of piston 76 and the level of this reached at the end of its upstroke, have to be expelled upwardly into the production tubing string 31 but a volume of production fluid equal to that flowing inwardly through openings 25 into the plunger 18 during the upstroke of the latter must also be propelled upwardly into said production fluid string 31. This causes the upper level of the production fluid column in the line 31 to not only return upwardly to the point from which it fell during the downstroke of the piston 76 but said production fluid column at the upper end of string 31 will deliver through the pressure valve 90 a volume of production fluid approximately equal to that volume which was pumped upwardly from the plunger 18 into the lower end of hollow piston rod 32 during the upstroke of said plunger.

From the above description of the operation of the present invention, it may be readily seen that the production fluid pumped upwardly from the jack 30 to the top of the well travels at an accelerated pace through a pipe

31 of relatively restricted diameter thereby causing said fluid to carry a relatively heavy burden of sand from the well without the sand having any opportunity for choking the apparatus. In wells where gas would develop under substantial pressure beneath the packer 65 of the apparatus 10, the invention provides for utilizing this gas to substantially assist the flow of production fluid upward through pipe 31. This is accomplished by providing orifices 120 in the wall of the hollow piston rod 32 at a point therein which will bring these orifices within the annular counterbore 61 in the axial bore 60 of the cylindrical extension 50 of the packer mandrel 46, at the conclusion of each upstroke of the plunger 18 (FIG. 9).

Any pocket of gas under high pressure accumulated just below the packer 65 within the tubing string 11 will have access through the ports 62 to the counterbore 61 and from this will force its way through orifices 120 into the stream of production fluid within the hollow tube 32 at and above the level of the orifices 120. The orifices 120 are preferably very small in cross section (such as $\frac{1}{32}$ inch in diameter) and may be inclined upwardly as shown in FIG. 9 to take advantage of any jet action which the gas may have in facilitating upward movement of the production fluid as said gas is introduced into said fluid.

FIG. 9 shows the collar 81 elevated to the level where it forces the ring 70 against the lower end of packer mandrel extension 50 and snugly compresses the spring 82. This of course is the extreme upper limit of movement of the collar 81 and the apparatus is preferably operated to conclude the upstroke of the piston 76 without tightly compressing spring 82 and still bring the orifices 120 into the counterbore 61 to permit discharge of compressed gas through said orifices as above described. The coiled spring 40 acts as a cushion for decelerating the piston 76 at the conclusion of its downstroke.

Entire plunger pumps are available which are known as insert pumps and are adapted to be suspended on a sucker rod or otherwise for insertion into a well and bumped downwardly against a shoe at the lower end of the pump tubing string to lock the pump in place preliminary to starting pumping operations. The above described apparatus is well adapted for suspending such an insert pump from the lower end of the tubular piston rod 32, the locking of the insert pump in place being effected by the bumping operation which shears the shear screws 69 and frees the legs 67 for outward expansion.

The withdrawal of the jack 30 and parts suspended therefrom may be accomplished any time following the installation thereof by simply withdrawing the pipeline 31 from the well.

While only a single embodiment of the invention is disclosed herein, it is to be understood that various modifications and changes may be made in this without departing from the spirit of the invention or the scope of the appended claims.

The claims are:

1. In an oil well the combination of a pump including a pump standing valve, a pump barrel and a pump plunger; a pump tubing string having means at its lower end for embodying the aforesaid pump with said string so as to control admission of production fluid to the lower end of said string; a hydraulic jack including a tubular cylinder having apertured upper and lower heads and fitting loosely into said string, a piston slidably reciprocable in said cylinder, a hollow piston rod connected to said piston and extending downward axially through the aperture in said lower head, a plurality of legs having retracted and expanded positions, and an annular packer unit responsive to the weight of said jack when the latter is supported in said tubing string by said legs to form an annular seal between said jack and said string, said string having an annular internal radial recess for receiving said legs when the latter expand; a ring surrounding said hollow rod behind lower ends of said legs; shear screw means securing said legs to said

ring to temporarily retain said legs retracted; spring means for expanding said legs when the latter are free from restraint; a shear collar embodied with said hollow rod so as to engage said ring when said piston is near the end of its upstroke in said cylinder, said pump plunger being connected with the lower end of said hollow piston rod; a production fluid pipe of relatively small diameter extending downwardly in said pump tubing string to attach to said upper cylinder head and connect with the aperture therein, said pipe supporting said jack during the installation and withdrawal of said jack, the further lowering of said jack after said plunger comes to rest at the lower end of said pump tubing string causing shearing of said shear screw means by said collar engaging said ring, thereby releasing said legs for use in supporting said jack by said legs expanding into said recess as said jack is lifted following said shearing of said screw means, passages being provided in said jack connecting the lower end of said jack cylinder below said piston with the space between said jack and said tubing string, said passages being located above said packer, the free space within said pump tubing string being filled with an operating liquid, the free spaces inside said pipe, jack cylinder, hollow rod, pump and the space surrounding said hollow rod below said jack being filled with production fluid, there being an aperture connecting the interior of said pump plunger with the space within said pump tubing string below said packer; and means at the top of the well for producing a pulsation in said column of operating liquid to cause reciprocation of said piston in said jack cylinder and the operation of said pump to pump production fluid upwardly through said hollow piston rod, said jack cylinder and said production pipe to the top of the well.

2. A combination as in claim 1 in which said pump plunger is provided with a series of weights by which a varying amount of weight may be applied to said plunger in each installation so as to produce the proper balance between the fluid heads of the production fluid column and the operating liquid column so that the fluid head of the production fluid column on the downstroke of the jack plus the weights applied to said plunger will overcome the fluid head of said operating liquid column and cause the ready return downwardly of the jack piston and the pump plunger to their lowermost positions.

3. A combination as in claim 1 in which gas passage means is provided in said lower jack cylinder head communicating with the axial aperture therein at a certain level located below said packer, and in which relatively small diameter orifices are provided in the wall of said hollow rod said orifices being so located that they arrive opposite said passage means and in communication therewith just as the upstroke of said jack and pump terminates whereby gas accumulated under high pressure just beneath said packer will be conveyed through said passage means and said orifices into the production fluid flowing upwardly through said hollow piston rod thereby accelerating the upward flow of said fluid throughout the rest of its upward travel.

4. In a deep well pumping apparatus the combination of: a pump tubing string; a reciprocating pump mounted in the lower end of said string and including a standing valve, a pump barrel and a pump plunger vertically slidable in said barrel; a head carrying a packer; means for lowering said head downwardly through said tubing string to a point spaced above said pump, said head having an axial bore; means for setting said packer against said tubing string; a hollow tubular rod slidably mounted in said bore and extending downwardly from said head to said plunger to which said rod is attached so as to communicate with the interior of said plunger, there being an opening in said plunger communicating with the interior of said tubing string below said packer; means for reciprocating said hollow rod to operate said pump and pump production fluid upwardly to the top of said well,

there being relatively fine orifices provided in said hollow tubing at a level therein which is located close below said packer when said pump plunger reaches the upper limit of its upstroke so that said orifices will communicate with any gas collected under pressure just below said packer and transmit a portion of this gas into the production fluid flowing upwardly through the interior of said hollow rod thereby giving a gas-lift effect to said flow and accelerating the pumping action.

5. In a deep well pumping apparatus, the combination of: a pump tubing string; a reciprocating pump including a pump barrel which constitutes a downward extension of said tubing string, a standing valve in the lower end of said barrel, and a valved pump plunger slidable in said barrel, said tubing string having an inside diameter permitting vertical travel of said plunger throughout the length of said tubing string when installing the plunger in or withdrawing it from said barrel; a production fluid tube suspended in said tubing string; a jack cylinder suspended on and connected at its upper end with said tube, said cylinder having an axially apertured head at its lower end; a jack piston slidable in said cylinder; a hollow piston rod connected to said piston and extending slidably downward through said aperture in said head, the lower end of said rod being connected to said pump plunger, said rod providing a production fluid passage connecting said plunger with said cylinder above said piston; packer means for packing off the space between said cylinder and said tubing string, there being aperture means in said cylinder for connecting the interior thereof beneath said piston to the space between said cylinder and said string above said packer means, there being aperture means in said plunger connecting the interior thereof above the plunger valve with the space between said hollow rod and said tubing string below said cylinder, a body of production fluid filling said tube and spaces connected therewith, a body of operating liquid filling the tubing string above said packer means; and means for imparting a pulsating motion to said operating liquid to reciprocate said piston in said cylinder and said plunger in said barrel thereby pumping production fluid upwardly through said tube.

6. In a deep well pumping apparatus the combination of: a pump tubing string; a reciprocating pump including a pump barrel which constitutes a downward extension of said tubing string, a standing valve in the lower end

of said barrel, and a valved plunger slidable in said barrel, said tubing string having an inside diameter permitting vertical travel of said plunger throughout the length of said tubing string when installing said plunger in or withdrawing it from said barrel; a head having an axial bore and carrying a packer, said packer being adapted to travel vertically in said tubing string when not expanded; a hollow tubular rod slidably mounted in said bore and extending downwardly from said head to unite with said plunger so as to suspend said plunger on the lower end of said tubular rod, the latter communicating with the space within said tubing string close above said plunger; suspension means for lowering said head, with said packer, said hollow rod and said plunger suspended thereon, downwardly through said tubing string to operationally install said plunger in said barrel; means for then setting said packer against said tubing string; and means for reciprocating said hollow rod to operate said pump and pump production fluid upwardly to the top of the well.

7. A combination as recited in claim 6 wherein a hydraulic jack is provided which comprises the means for reciprocating said hollow rod, said jack including a cylinder, of which said head comprises a lower head, said jack also including a piston mounted on said rod and reciprocating in said cylinder; and wherein a pipe extending downwardly into said tubing string and connecting to said cylinder comprises a suspension means for lowering said jack and said plunger to install the latter in said barrel, and wherein said pipe divides the space above said packer within said tubing string into two vertical hydraulic passages, one of the latter being occupied by a column of operating liquid for transmitting power hydraulically to said jack from the top of the well and the other being occupied by a column of production fluid resulting from increments of such fluid being delivered thereto from said hollow rod.

References Cited in the file of this patent

UNITED STATES PATENTS

1,673,856	Winsor	June 19, 1928
2,247,238	Johnston	June 24, 1941
2,279,057	Reed	Apr. 7, 1942
2,747,511	Turner et al.	May 29, 1956
2,917,000	English	Dec. 15, 1959
2,980,027	Dulaney	Apr. 18, 1961