Oct. 23, 1962 C. J. COBERLY ET AL 3,059,581

COUNTERFLOW FREE PUMP SYSTEM

Filed Nov. 14, 1960 4 Sheets-Sheet 1

FIG. 1.

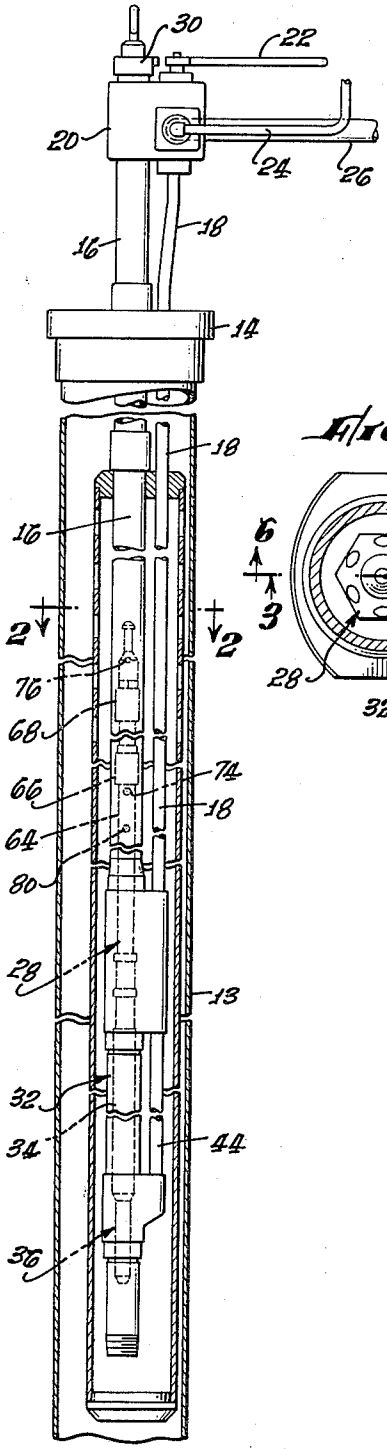


FIG. 2.

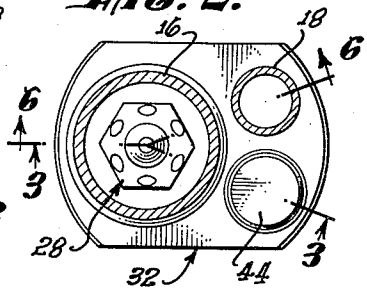
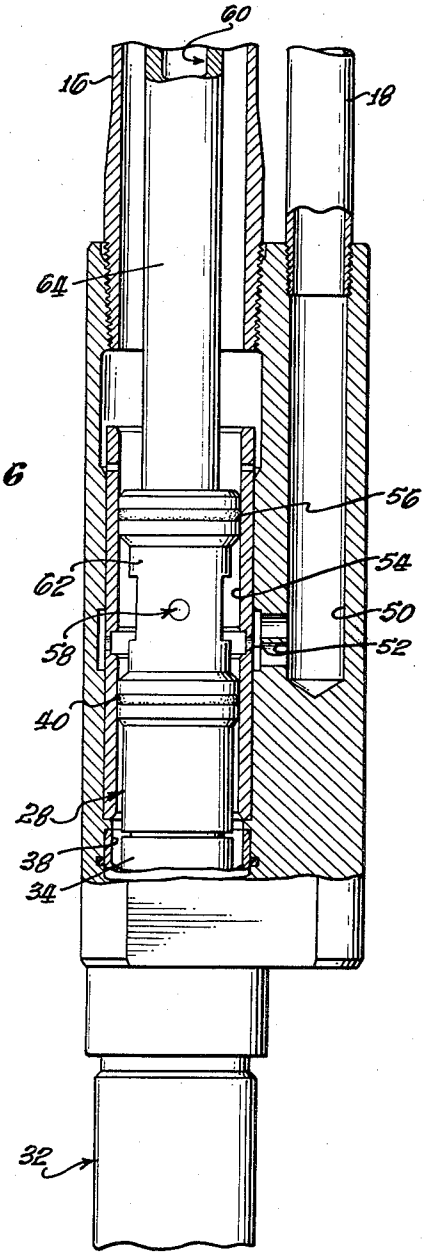


FIG. 6.



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Oct. 23, 1962 C. J. COBERLY ET AL 3,059,581

COUNTERFLOW FREE PUMP SYSTEM

Filed Nov. 14, 1960

4 Sheets-Sheet 2

FIG. 3.

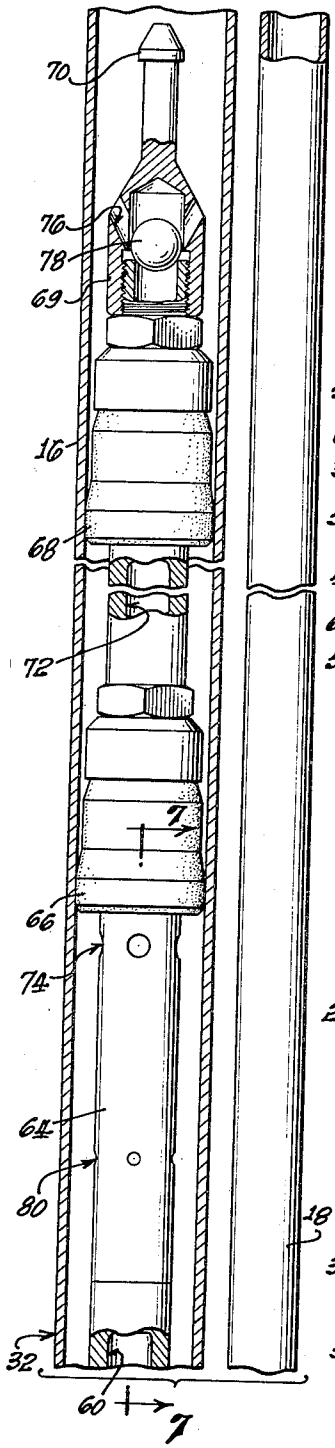


FIG. 4.

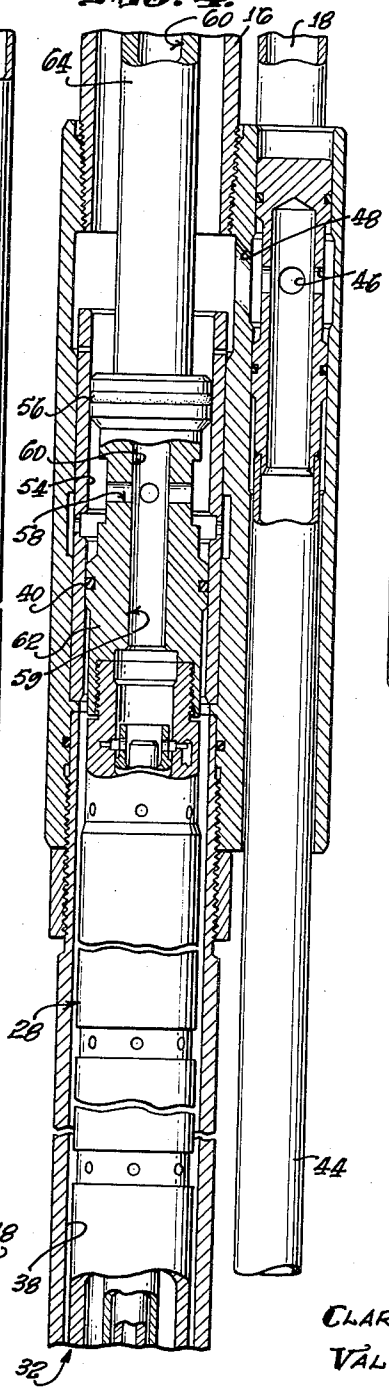
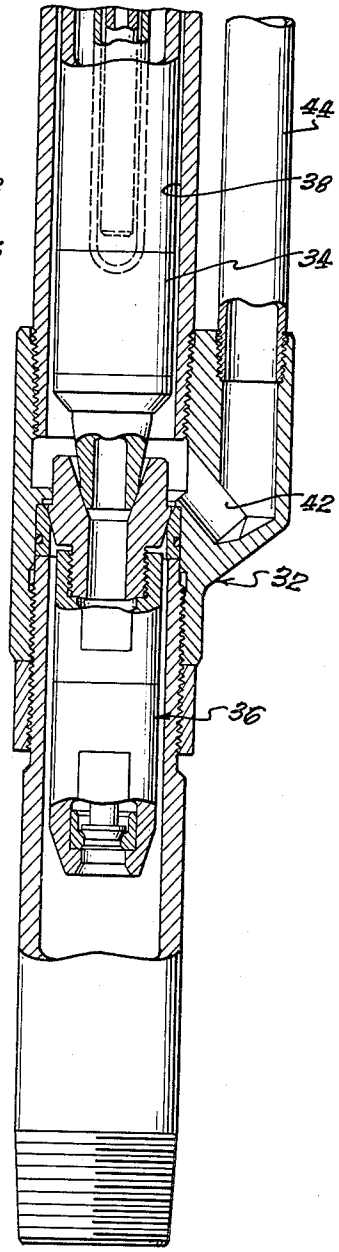


FIG. 5.



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Oct. 23, 1962 C. J. COBERLY ET AL 3,059,581

COUNTERFLOW FREE PUMP SYSTEM

Filed Nov. 14, 1960 4 Sheets-Sheet 3

FIG. 7.

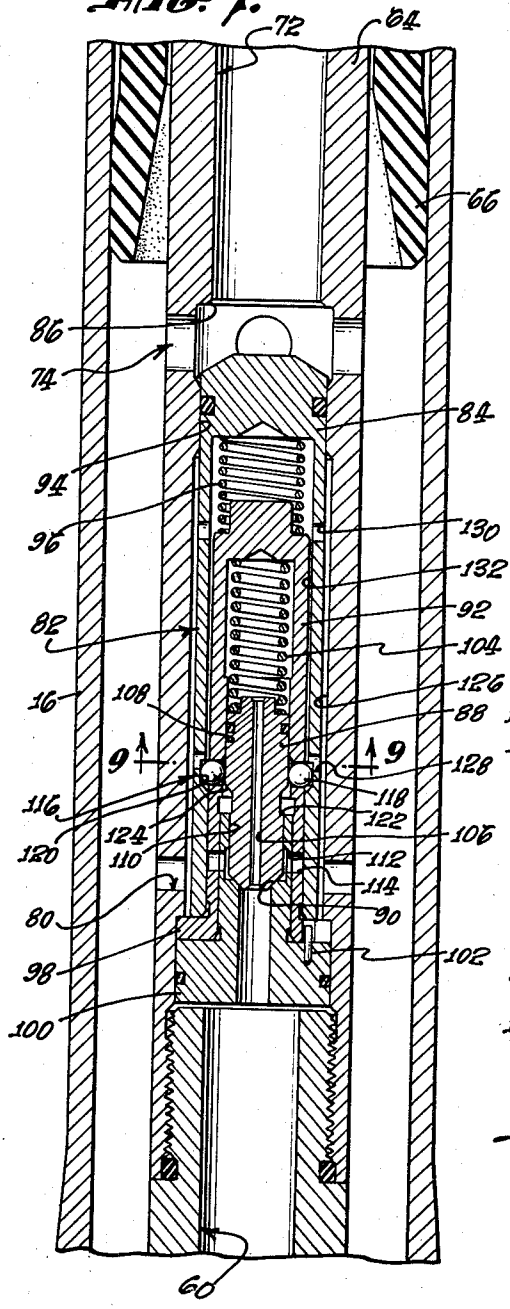


FIG. 8.

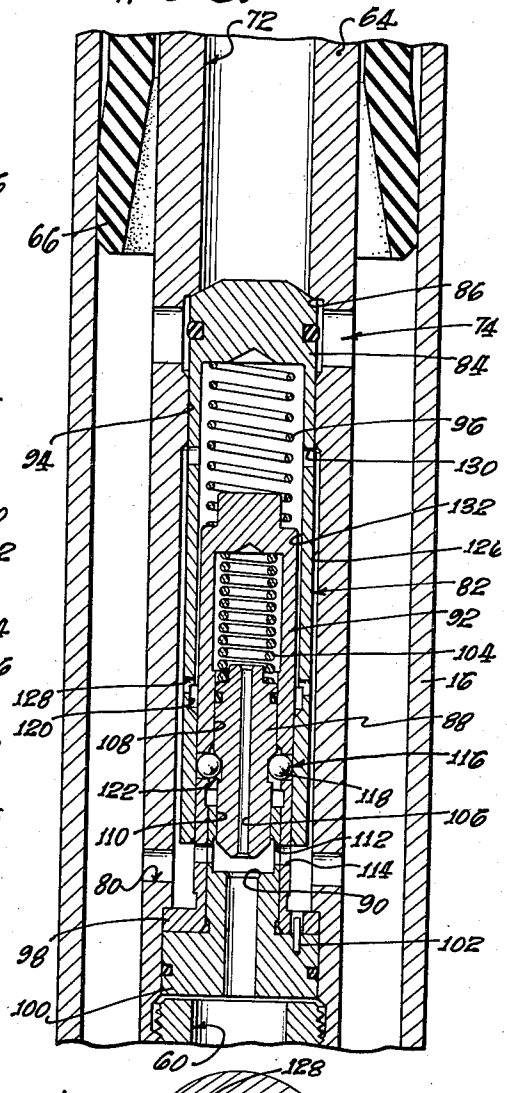
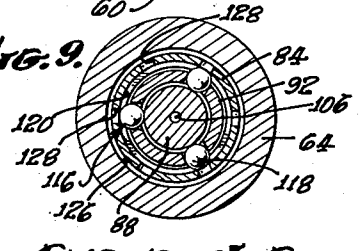


FIG. 9.



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Oct. 23, 1962 C. J. COBERLY ET AL 3,059,581

COUNTERFLOW FREE PUMP SYSTEM

Filed Nov. 14, 1960

4 Sheets-Sheet 4

FIG. 10.

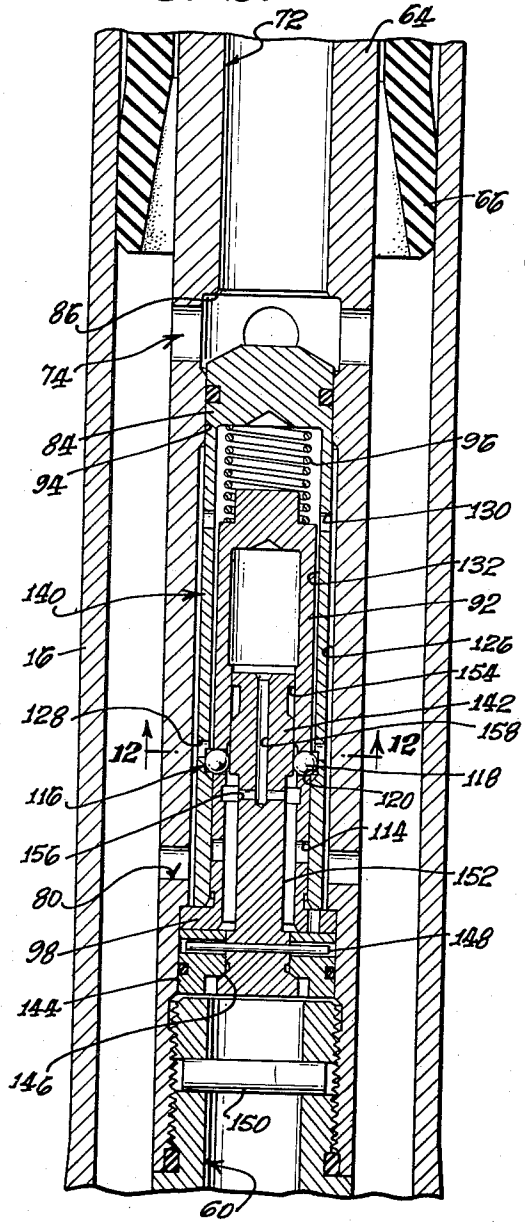


FIG. 11.

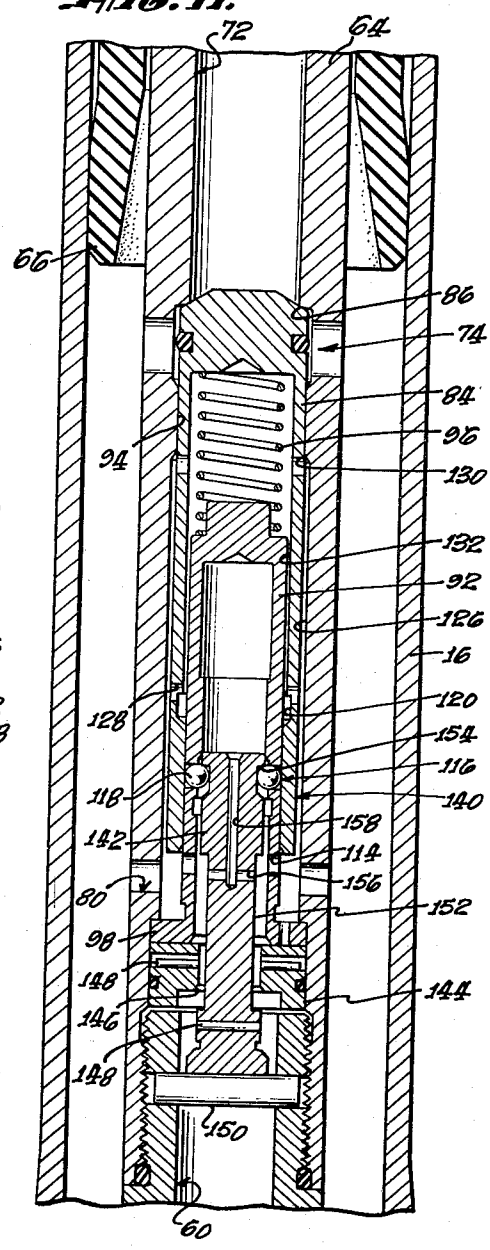
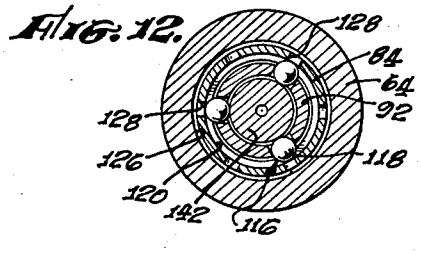


FIG. 12.



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United States Patent Office 3,059,581 Patented Oct. 23, 1962

3,059,581

COUNTERFLOW FREE PUMP SYSTEM

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Filed Nov. 14, 1960, Ser. No. 68,947
14 Claims. (Cl. 103—46)

The present invention relates in general to fluid operated free pump systems for oil wells and, more particularly, to a free pump system which utilizes the counterflow or reversed flow principle of Patents Nos. 2,851,954 and 2,869,470, respectively granted September 16, 1958 and January 20, 1959 to Clarence J. Coberly, one of the inventors of the present free pump system, the latter being an improvement on those disclosed in the patents mentioned.

Any fluid operated free pump system includes at least two tubings one of which is of a size to permit sliding movement of a free pump unit therethrough between the surface and an operating position in the well. The limited space normally available in the well requires that the remaining tubing or tubings of the system be relatively small, at least in a parallel tubing system wherein the tubings are located side by side.

In a conventional or standard free pump system of the foregoing nature, the relatively large tubing through which the free pump unit is circulated between the surface and its operating position in the well is also utilized to supply operating fluid under pressure to a fluid operated pump incorporated in the free pump unit. Consequently, the production fluid and the spent operating fluid discharged by the pump must be conveyed to the surface in a tubing or tubings which are smaller than the pump tubing. In an open system, to which the present invention is particularly applicable, the production fluid and the spent operating fluid are mixed and conveyed to the surface by a single relatively small tubing.

As discussed in detail in the aforementioned patents, the foregoing conventional or standard free pump system is subject to undesirably high friction losses and reduced efficiencies, particularly with high viscosity oils and/or high pump-to-engine area ratios, arising out of the use of a relatively small tubing for conveying the production fluid and the spent operating fluid to the surface.

As also discussed in detail in the aforementioned patents, a free pump system utilizing the counterflow or reversed flow principle avoids the foregoing disadvantages of the conventional or standard free pump system by conveying the production fluid and the spent operating fluid to the surface through the relatively large pump tubing, instead of through a relatively small tubing, the latter being utilized under such circumstances as a supply tubing for conveying operating fluid under pressure downwardly in the well to the pump. This produces no undesirably high friction losses in either the relatively large production tubing, or the relatively small supply tubing, because each has adequate capacity to handle the necessary flow therethrough.

In any free pump system, it is necessary, in circulating the pump out of the well, to introduce fluid under pressure into the pump tubing below the pump by way of a second tubing externally of the pump tubing. With a conventional or standard free pump system, wherein the pump tubing is the supply tubing and the second tubing is the production tubing, this poses no problem since it is merely necessary to circulate fluid under pressure downwardly through the production tubing to propel the pump upwardly through the supply tubing to the surface. Consequently, an ordinary or standard free pump can be used, suitable standard free pumps being disclosed in

Patents Nos. 2,230,830 and 2,338,903, respectively granted on February 4, 1941 and January 11, 1944 to Clarence J. Coberly.

However, with a counterflow free pump system, wherein the pump tubing is the production tubing and the second tubing is the supply tubing, a standard free pump cannot be used because such a free pump would be circulated out of the well through the production tubing by the operating fluid introduced through the supply tubing to operate it. Consequently, it is necessary to provide a free pump unit, preferably incorporating such a standard free pump, having means for preventing circulation out of the well by way of the production tubing until removal is desired.

The aforementioned Patent No. 2,869,470 discloses a free pump unit having means for latching the unit in its operating position in the well against a constant upward force applied to the unit by the operating fluid pressure in the supply tubing, until such time as removal is desired. This latching means is released by increasing the pressure in the production tubing until it is higher than the pressure in the supply tubing to a predetermined extent.

The aforementioned Patent No. 2,851,954 discloses a free pump unit including normally closed valve means which, when opened, establishes fluid communication between the supply tubing and a downwardly-facing area of the pump unit to displace the pump unit upwardly through the production tubing. This valve means is opened by applying to the production tubing a pressure higher than that in the supply tubing by a predetermined amount.

With the foregoing as background, a primary object of the present invention is to provide a counterflow free pump system wherein the free pump unit has a downwardly-facing area which is adapted to have the pressure of the operating fluid in the supply tubing applied thereto to circulate the pump unit out of the well, but which is exposed to the flow of production fluid by the pump during normal operation of the pump so that the pressure of the operating fluid in the supply tubing cannot act thereon under such conditions.

Another object of the invention is to provide the free pump unit with production fluid bypass passage means for bypassing the flow of production fluid discharged by the pump upwardly past the downwardly-facing area mentioned during normal operation of the pump so that the flow of production fluid discharged by the pump will not unseat the free pump unit.

A further object is to provide the free pump unit with means responsive to a pressure in the production tubing higher than that in the supply tubing by a predetermined amount for closing the bypass passage means and for placing the downwardly-facing area of the pump unit in fluid communication with the supply tubing.

Still another object is to provide the free pump unit with an operating fluid supply passage means for conveying operating fluid from the supply tubing to the downwardly-facing area, and with valve means responsive to a pressure in the production tubing higher than that in the supply tubing by a predetermined amount for closing the bypass passage means and opening the supply passage means, whereupon the free pump unit may be circulated out of the well through the production tubing by restoring the pressure in the supply tubing to a value higher than that in the production tubing.

Yet another object of the invention is to provide a free pump unit wherein the aforementioned valve means includes a normally open bypass valve movable to a closed position to close the bypass passage means, means for biasing the bypass valve toward its closed position,

means for latching the bypass valve in its open position, a normally closed supply valve movable to an open position to open the supply passage means, means retaining the supply valve in its closed position, means responsive to a pressure in the production tubing higher than that in the supply tubing by a predetermined amount for unlatching the bypass valve and for moving the supply valve to its open position in opposition to the action of the retaining means, and means for latching the supply valve in its open position.

Another object of the invention is to provide a free pump unit wherein the aforementioned retaining means is either a spring or a shear pin.

An important object of the invention is to provide a free pump unit of the foregoing nature wherein the downwardly-facing area, the production fluid bypass passage means, the operating fluid supply passage means and the valve means for opening the supply passage means and closing the bypass passage means are all carried by and/or located within a packer mandrel connected to the upper end of a standard fluid operated free pump and carrying downwardly-facing packer cups engageable with the production tubing, one of such packer cups forming the downwardly-facing area mentioned.

An important feature of the present invention is that, with the foregoing construction, a standard fluid operated free pump may be used in a counterflow free pump system merely by substituting a packer mandrel constructed in accordance with the invention for a standard packer mandrel, no modification of the standard fluid operated free pump itself being required.

The foregoing objects, advantages, features and results of the present invention, together with various other objects, advantages, features and results thereof which will be evident to those skilled in the free pump art, may be achieved with the exemplary embodiments of the invention described in detail hereinafter and illustrated in the accompanying drawings, in which:

FIG. 1 is a vertical sectional view on a reduced scale illustrating a fluid operated free pump system of the invention as installed in a well;

FIG. 2 is an enlarged horizontal sectional view taken along the arrowed line 2—2 of FIG. 1;

FIG. 3 is a vertical sectional view taken along the arrowed line 3—3 of FIG. 2;

FIGS. 4 and 5 are downward continuations of FIGS. 3 and 4, respectively;

FIG. 6 is a vertical sectional view taken along the arrowed line 6—6 of FIG. 2;

FIGS. 7 and 8 are enlarged vertical sectional views taken along the arrowed line 7—7 of FIG. 3 and illustrating various components of the invention in different operating positions;

FIG. 9 is a horizontal sectional view taken along the arrowed line 9—9 of FIG. 7;

FIGS. 10 and 11 are vertical sectional views respectively corresponding to FIGS. 7 and 8, but illustrating another embodiment of the invention; and

FIG. 12 is a horizontal sectional view taken along the arrowed line 12—12 of FIG. 10.

Referring particularly to FIG. 1 of the drawings, the numeral 13 designates a well casing which is set in a well and which is provided with perforations, not shown, to admit into the casing, fluids from surrounding, productive formation. The casing 13 is equipped with a casing head 14 which supports parallel production and supply tubings 16 and 18 in the casing, these tubings extending downwardly below the well fluid level in the casing. The production and supply tubings 16 and 18 communicate at their upper ends with a four-way valve 20 operated by a handle 22, this valve selectively connecting the production tubing and the supply tubing with an operating fluid supply line 24 and a production fluid disposal line 26. Thus, by means of the valve 20, either the production tubing 16, or the supply tubing 18, may be pressurized with operating fluid from the supply line 24.

In accordance with the invention, the production tubing 16 is of relatively large diameter to accommodate an elongated, piston-like, fluid operated, free pump unit 28 which may be inserted into the upper end of the production tubing by removing a closure 30 which may contain the usual free pump catcher. The pump unit 28 is circulated downwardly through the production tubing 16 by connecting the upper end of the production tubing to the supply line 24 until the pump unit arrives at its operating position in a bottom hole housing which is designated generally by the numeral 32. The housing 32 is connected to the lower end of the production tubing 16 and is also connected to the supply tubing 18, all as will be discussed in more detail hereinafter.

The pump unit 28 includes a fluid operated pump 34 which may, for example, be similar to those disclosed in the aforementioned Patents Nos. 2,230,830 and 2,338,903. Alternatively, the pump 34 may be of the type disclosed in Patent No. 2,311,157, granted February 16, 1943 to Clarence J. Coberly. Consequently, a detailed description of the pump 34 herein is unnecessary.

Briefly, when the free pump unit 28 is in its operating position in the housing 32, the lower end of the pump 34 is seated on a standing valve assembly 36, FIG. 5, located within the housing 32 at the lower end thereof and in fluid communication with the well so that production fluid from the well may enter the pump 34 by way of the standing valve assembly. The production fluid discharged by the pump 34, and the spent operating fluid discharged thereby, enter an annulus 38, FIGS. 4 and 5, between the pump and the housing 32, the upper end of this annulus being closed by an annular seal 40, FIG. 4, carried by the pump unit 28 and engageable with the housing. The mixture of production fluid and spent operating fluid flows downwardly through the annulus 38 and through a port 42, FIG. 5, in the housing 32 at the lower end of the annulus, into the lower end of a bypass pipe 44. The mixture of production fluid and spent operating fluid flowing upwardly in the bypass pipe 44 leaves the upper end of this pipe through ports 46, FIG. 4, therein which communicate with a port 48 for conveying the mixture in question into the interior of the housing 32 and thence into the lower end of the production tubing 16. The production fluid and spent operating fluid mixture flows upwardly through the production tubing 16 in a manner to be described hereinafter.

As shown in FIG. 6 of the drawings, the supply tubing 18 communicates at its lower end with a passage 50 in the housing 32. The housing is provided therein at the lower end of the passage 50 with ports 52 connecting the passage 50 to an annulus 54 around the pump unit 28. The operating fluid under pressure entering the annulus 54 from the supply tubing 18 is separated from the production fluid and spent operating fluid mixture in the annulus 38 by the annular seal 40, and is separated from the mixture in question in the production tubing 16 by another annular seal 56 carried by the pump unit 28 and engaging the housing 32. The pump unit 28 is provided with an operating fluid inlet 58 which admits operating fluid under pressure from the annulus 54 into an operating fluid supply passage means 59, FIG. 4, in the pump unit. The lower end of the supply passage means 59 communicates with the pump 34 to deliver thereto operating fluid under pressure for operating the pump in the usual manner.

The operating fluid inlet 58 is formed in, and the annular seals 40 and 56 are carried by, and adapter 62 the lower end of which is connected to the upper end of the pump 34. Connected to the upper end of the adapter 62 is a packer mandrel 64, FIGS. 3, 4 and 6, which extends upwardly into the production tubing 16 a relatively short distance, the corresponding portion of the production tubing being regarded herein as forming a part of the

bottom hole housing 32. The packer mandrel 64 carries downwardly-facing packer cups 66 and 68, FIG. 3, which engage the production tubing 16. As is well known in the art, the packer cups 66 and 68 make fluid-tight seals with the production tubing 16 when subjected to pressures therebeneath higher than the pressures thereabove in circulating the free pump unit 28 upwardly through the production tubing 16 to the surface. On the other hand, the packer cups 66 and 68 will permit fluid to flow downwardly therepast when the pressures thereabove are higher than the pressures therebeneath. The packer mandrel 64 terminates at its upper end in the usual packer nose cap 69 having thereon a tapered head 70 which is engageable by the aforementioned pump catcher on the closure 30 when the free pump unit 28 reaches the surface.

The packer mandrel 64 is provided therein with an axial production fluid bypass passage means 72 provided with an inlet 74 below the lower packer cup 66 and an outlet 76 in the packer nose cap 69 above the upper packer cup 68. As will be described in more detail hereinafter, the bypass passage means 72 is normally open so that the production fluid and spent operating fluid mixture discharged by the pump 34 may bypass the packer cups 66 and 68 and flow upwardly therepast into the production tubing 16 above the packer cups. Consequently, there is no tendency for the production fluid and spent operating fluid mixture to act on the downwardly-facing areas of the packer cups 66 and 68 to tend to unseat the free pump unit 28. The packer mandrel 64 carries a standing valve 78, FIG. 3, which prevents downward flow of fluid through the bypass passage means 72.

An operating fluid supply passage means 60 extends upwardly from the operating fluid inlet 58 through the adapter 62 and into the lower end of the packer mandrel 64. The supply passage means 60 terminates at its upper end in an operating fluid outlet 80 communicating with the production tubing 16 below the inlet 74 of the bypass passage means 72. The supply passage means 60 is normally closed, i.e., is closed when the pump 34 is in operation. However, when it is desired to circulate the free pump unit 28 out of the well, the bypass passage means 72 is closed and the supply passage means 60 is opened, as will be described hereinafter. Consequently, operating liquid under pressure from the supply tubing 18 may be delivered to the production tubing 16 below the lower packer cup 66 to act upwardly on such packer cup so as to circulate the free pump unit 28 upwardly through the production tubing 16 and out of the well.

Turning now to FIGS. 7 to 9 of the drawings, the packer mandrel 64 contains valve means 82, responsive to a fluid pressure in the production tubing 16 higher by a predetermined amount than that in the supply tubing 18, for closing the normally open bypass passage means 72 and for opening the normally closed supply passage means 60. Consequently, when the pressure in the supply tubing 18 is subsequently increased to a value higher than that in the production tubing 16, operating fluid under pressure from the supply tubing 18 may flow through the supply passage means 60 and out the operating fluid outlet 80 into the production tubing 16 below the lower packer cup 66 so as to act on the downwardly-facing area at the lower end of such packer cup to circulate the free pump unit 28 upwardly through the production tubing 16 to the surface.

Considering the valve means 82 in a general way, it includes a bypass valve 84 which normally occupies an open position, as shown in FIG. 7, but which is movable into a closed position, FIG. 8, wherein it engages a valve seat 86 in the bypass passage means 72 to prevent upward flow through the bypass passage means from the annular space around the packer mandrel 64 below the lower packer cup 66. The valve means 82 also includes a supply valve 88 which normally occupies a closed position, as shown in FIG. 7, wherein it engages a valve seat 90 in the supply passage means 60, but which is movable to an open position, as shown in FIG. 8, to permit upward flow of operating fluid under pressure from the supply tubing 18 into the annular clearance below the lower packer cup 66 by way of the operating fluid outlet 80 in the packer mandrel.

In the construction illustrated, the bypass valve 84 has the form of an inverted cup which is telescoped over an inner guide 92, the upper end of the bypass valve being slidable in an axial bore 94 in the packer mandrel 64 and the lower end of the bypass valve being slidable on the guide 92. A compression spring 96 within the bypass valve 84 and seated on the upper end of the guide 92 biases the bypass valve toward its closed position.

The guide 92 also has the form of an inverted cup and is provided at its lower end with an annular flange 98 clamped between an annular shoulder on the packer mandrel 64 and a member 100 through which the supply passage means 60 extends and which provides the valve seat 90 for the supply valve 88. The guide 92 is held against rotation relative to the member 100 by a pin 102.

The supply valve 88 is disposed within the guide 92 and is biased downwardly into engagement with the valve seat 90 by a compression spring 104 disposed within the guide and seated against the upper end of the supply valve. An axial passage 106 through the supply valve 88 applies the operating fluid pressure in the supply passage means 60 to the upper end of the supply valve when the latter is in its closed position, whereby the operating fluid pressure assists the spring 104 in maintaining the supply valve seated since the operating fluid pressure acts on an area at the lower end of the supply valve which is less than the area of the upper end thereof.

The upper portion of the supply valve 88 has a larger diameter than the lower portion thereof and is slidable in a major bore 108 in the guide 92. The smaller lower portion of the supply valve 88 is slidable in a minor bore 110 in a portion of the member 100 which extends upwardly into the guide 92. This portion of the member 100 and the guide 92 are provided therethrough with registering ports 112 and 114 which are covered by the lower end of the bypass valve 84 when it is in its open position, but which are uncovered and communicate with the operating fluid outlet 80 in the packer mandrel 64 when the bypass valve 84 is in its closed positon, as shown in FIG. 8.

During operation of the pump 34, the bypass valve 84 is latched in its open position by a latch means 116 actuated by the supply valve 88. Movement of the supply valve 88 to its open position results in releasing the latch means 116 so that the bypass valve 84 may be moved to its closed position by the spring 96. When the bypass valve 84 is in its closed position, it, in turn, causes the latch means 116 to hold the supply valve 88 in its open position in opposition to the action of the spring 104.

Considering the latch means 116 in more detail, it includes circumferentially spaced ball detents 118 disposed in radial openings in the guide 92 intermediate the major bore 108 in the guide and the minor bore 110 in the member 100. When the supply valve 88 is in its closed position and the bypass valve 84 is in its open position, the major diameter of the supply valve displaces the ball detents 118 outwardly, as shown in FIG. 7, into an internal annular groove 120 in the bypass valve 84, thereby latching the bypass valve in its open position. Upon movement of the supply valve 88 into its open position, as shown in FIG. 8, the ball detents 118 may move radially inwardly into an external annular groove 122 in the supply valve intermediate its major and minor diameters. Under such conditions, the spring 96 displaces the bypass valve 84 upwardly into its closed position, at the same time moving the internal annular groove 120 in the bypass valve upwardly out

of register with the ball detents 118. Under such conditions, the ball detents 118 latch the supply valve 88 in its open position.

Considering the manner in which the supply valve 88 is moved upwardly into its open position to release the bypass valve 84, this is accomplished by applying to a downwardly-facing annular area 124 of the supply valve 88, which area is equal to the difference between the areas of the major bore 108 and the minor bore 110, a fluid pressure which is sufficiently higher than the fluid pressure in the supply passage means 60 to overcome the spring 104. As will be explained, the higher pressure applied to the area 124 is developed by increasing the pressure in the production tubing 16 above that which exists during pumping and by decreasing the pressure in the supply tubing 18 to a value below that in the production tubing 16. This higher pressure in the production tubing 16 reaches the area 124 by way of the operating fluid outlet 80 in the packer mandrel 64, an annular clearance 126 between the packer mandrel and the bypass valve 84, ports 128 through the bypass valve, the internal annular groove 120 in the bypass valve, and the radial openings in the guide 92 in which the ball detents 118 are disposed. The ports 128 in the bypass valve 84, and ports 130 therein, also interconnect the annular clearance 126 with an annular clearance 132 between the bypass valve and the guide 92 so that the pressure existing in the production tubing 16 is communicated to the interior of the cup-shaped bypass valve 84. The bypass valve is therefore hydraulically balanced when it is in its open position, and is hydraulically held in its closed position during circulation of the free pump unit 28 out of the well.

Operation

Prior to running the free pump unit 28 into its operating position in the housing 32, the bypass and supply valves 84 and 88 must, of course, be in their open and closed positions, respectively, as shown in FIG. 7. If they are initially in their closed and open positions, respectively, as shown in FIG. 8, they may be re-set by unscrewing the packer nose cap 69, dropping a long bar, not shown, into the packer mandrel, and pushing downwardly thereon to return the bypass valve 84 to its open position. This results in unlatching of the supply valve 88 so that its spring 104 may return it to its closed position, the latch means 116 then latching the bypass valve in its open position. This accomplished, the resetting bar is removed and the packer nose cap 69 is replaced.

Next, the closure 30 for the upper end of the production tubing 16 is removed, the free pump unit 28 is inserted into the upper end of the production tubing, and the closure is replaced. Thereupon, the valve 20 is operated to connect the upper end of the production tubing 16 to the operating fluid supply line 24, the valve 20 simultaneously connecting the supply tubing 18 to the production fluid disposal line 26. Preferably, the valve 20 is provided with some means, not shown, for limiting the operating fluid pressure which can be applied to the production tubing 16 under such conditions to a value less than the predetermined minimum pressure required to open the supply valve 88 while the free pump unit 28 is being run in and seated, thereby insuring against any possibility of opening the supply valve 88 and closing the bypass valve 84 inadvertently.

Under the foregoing conditions, the pump unit 28 moves downwardly through the production tubing 16 into the housing 32 and seats on the standing valve assembly 36, fluid in the production tubing 16 beneath the pump unit being displaced upwardly through the supply tubing 18. The pump unit 28 is now ready for operation.

To operate the pump 34, the control valve 20 at the surface is set in a position to place the supply tubing 18 in communication with the operating fluid supply line 24 and to place the production tubing 16 in communication with the production fluid disposal line 26. Consequently, operating fluid under pressure is delivered to the pump 34 through the supply tubing 18 to operate the pump, the spent operating fluid and the production fluid discharged by the pump being conveyed to the surface by way of, among other elements, the bypass pipe 44, the production tubing 16 below the packer cups 66 and 68, the bypass passage means 72 in the packer mandrel 64, and the production tubing 16 above the free pump unit 28.

When it is desired to remove the free pump unit 28 from the well, the control valve 20 at the surface is again operated to place the production tubing 16 in communication with the operating fluid supply line 24 and to place the supply tubing 18 in communication with the production fluid disposal line 26. Under these conditions, the pressure in the production tubing 16 is considerably higher than that in the supply tubing 18, and such higher pressure also exists in the production tubing 16 below the packer cups 66 and 68 since such cups will not seal against the reversed application of pressure. The relatively low pressure in the supply tubing 18 is applied to the upper end of the supply valve 88 through the supply passage means 60 and the axial passage 106 through the supply valve. On the other hand, the relatively high pressure in the production tubing 16 is applied to the downwardly-facing annular area 124 of the supply valve 88, in the manner hereinbefore described, to open the supply valve in opposition to the action of the spring 104, this spring being designed to yield to a predetermined pressure differential between the production tubing and the supply tubing. Opening of the supply valve 88 results in unlatching of the bypass valve 84, whereupon the bypass valve is moved to its closed position by the spring 96. Simultaneously, the bypass valve 84 causes the latch means 116 to latch the supply valve in its open position. Thus, the various components of the valve means 82 now occupy the positions shown in FIG. 8 of the drawings.

The next step is to again set the control valve 20 at the surface in a position to connect the supply tubing 18 in communication with the operating fluid supply line 24 and to connect the production tubing 16 in communication with the production fluid disposal line 26. Operating fluid under pressure is now delivered downwardly through the supply tubing 18 to the production tubing 16 below the lower packer cup 66 by way of the supply passage means 60, this being possible because the supply valve 88 is now in its open position. The operating fluid thus delivered to the production tubing 16 below the packer cup 66 is confined beneath this packer cup because of the fact that the bypass passage means 72 is now closed by the bypass valve 84. Consequently, the free pump unit 28 is caused to move upwardly through the production tubing 16 to the surface and is ultimately caught by the aforementioned pump catcher on the closure 30. Upon removal of this closure, the free pump unit 28 may be removed.

Thus, the present invention provides the advantages of using the large pump tubing 16 as the production tubing in a fluid operated free pump system of the open type, without any modification of the fluid operated pump 34, other than to substitute for the usual packer mandrel the disclosed packer mandrel 64 incorporating the valve means 82 of the invention. This is an important feature since it means that any standard fluid operated pump may be utilized, without modification of the pump itself, to achieve the advantages of a large production tubing.

Another advantage of the present invention is that it permits the packer cups 66 and 68 to remain in sealing engagement with the production tubing 16 at all times, except when downward flow therepast occurs in the course of pressurizing the production tubing to close the bypass valve 84 and to open the supply valve 88. In other words, since the production fluid and spent operating fluid mixture bypasses the packer cups 66 and 68 during

normal operation by way of the bypass passage means **72**, it is unnecessary to locate the packer cups in an enlarged housing, as disclosed in the aforementioned Patents Nos. 2,851,954 and 2,869,470. With the structures of these patents, it is necessary for the free pump unit to move up several inches before the upper packer cup engages the production tubing to produce a fluid tight seal which would lift the pump unit upwardly through the production tubing. Such prior structures therefore require an auxiliary seal adjacent the bottom of the free pump unit against which the fluid pressure utilized to lift the pump unit can act until sealing engagement between the upper packer cup and the production tubing is achieved. With the present invention, since the packer cups **66** and **68** are always in sealing engagement with the production tubing **16** with respect to a higher fluid pressure therebeneath, no auxiliary sealing means of the nature mentioned is required.

FIGS. 10 to 12

Referring to FIGS. 10 to 12 of the drawings, the packer mandrel **64** in this embodiment of the invention incorporates a valve means **140** which is similar to and performs the same functions as the valve means **82**. More particularly, the valve means **140** includes the same bypass valve **84**, guide **92** and bypass valve spring **96** as the valve means **82**, the valve means **140** differing only in substituting a different supply valve **142** for the supply valve **88** and a different member **144** for the member **100**.

The supply valve **142**, instead of being movable upwardly from its closed position to its open position as is the case with the supply valve **88**, is movable downwardly from its closed position, shown in FIG. 10, to its open position, shown in FIG. 11 When the supply valve **142** is in its closed position, it is seated on a valve seat **146** provided by the member **144**, being held against such seat by the operating fluid pressure in the supply passage means **60** during operation of the pump **34**. Thus, no spring is necessary. The supply valve **142** is maintained substantially in seating engagement with the valve seat **146** when the pump **34** is not in operation by a shear pin **148** which extends through the supply valve into the member **144** and which makes a loose fit in the member **144** so that the shear pin will not interfere with proper seating of the supply valve on the valve seat **146** under the influence of operating fluid pressure in the supply passage means **60**. When the supply valve **142** is in its open position, as shown in FIG. 11, it engages a stop pin **150** which limits downward movement thereof, this stop pin being carried by the adapter **62**. With the supply valve **142** in its open position, fluid may flow from the supply passage means **60** into the production tubing **16** below the packer cup **66** by way of an annular clearance between the member **144** and a reduced-diameter portion **152** of the supply valve, by way of the ports **114** in the guide **92**, and by way of the operating fluid outlet **80** in the packer mandrel **64**.

As long as the supply valve **142** is in its closed position, as shown in FIG. 10, the portion thereof above the reduced-diameter portion **152** maintains the ball detents **118** in their radially outward positions within the internal annular groove **120** in the bypass valve **84** to latch the bypass valve in its open position. However, when the supply valve **142** is moved downwardly into its open position, as shown in FIG. 11, the ball detents **118** move radially inwardly into an external annular groove **154** in the supply valve **142**. When this occurs, the bypass valve spring **96** closes the bypass valve **84**, whereupon the bypass valve holds the ball detents **118** in their radially inward positions to latch the supply valve **142** in its open position.

Considering the manner in which the supply valve **142** is moved from its closed position to its open position, the first step is to increase the pressure in the production tubing **16** below the packer cup **66** above the pressure in the supply tubing **18** by a predetermined amount, this being accomplished in the manner hereinbefore described. Under these conditions, the lower end of the supply valve **142** is exposed to a relatively low pressure in the supply passage means **60**, while a relatively high pressure is present in the production tubing **16**. This higher pressure enters the annulus around the reduced-diameter portion **152** of the supply valve **142** by way of the operating fluid outlet **80**, the annular clearance **126** between the packer mandrel **64** and the bypass valve **84**, the ports **128** in the bypass valve, the internal annular groove **120** in the bypass valve, and the radial openings in the guide **92** in which the ball detents **118** are disposed. From the annular clearance around the reduced-diameter portion **152** of the supply valve **142**, the relatively high pressure fluid in the production tubing **16** flows through radial ports **156** and an axial passage **158** in the supply valve to the upper end thereof. The pressure in the guide **92** above the supply valve **142** ultimately builds up to a valve sufficiently high to shear the pin **148**, whereupon the supply valve **142** drops downwardly into its open position. The rate at which the supply valve **142** moves downwardly is determined by the flow resistance offered by the ports **156** and the passage **158**.

When the supply valve **142** reaches its open position, it unlatches the bypass valve **84**, which then moves to its closed position to close the bypass passage means **72**, and which at the same time causes the latch means **116** to latch the supply valve **142** in its open position.

The operation of the invention utilizing the valve means **140** is the same as the operation of the invention utilizing the valve means **82**. Consequently, a further description will not be required.

It should be noted that the pressure utilized to open the supply valve **142** acts on the entire area of the upper end thereof to shear the pin **148**. On the other hand, the pressure for opening the supply valve **88** acts only on the relatively small area **124** thereof, the reason being to avoid an excessively heavy spring for the supply valve spring **104**.

In order to re-set the valve means **140**, the packer mandrel **64** is first unscrewed from the adapter **62**, whereupon the various parts of the valve means **140** may be removed. The parts of the sheared pin are then removed and a new pin installed to interconnect the member **144** and the supply valve **142**. The parts of the valve means **140** are then reassembled, with the supply valve **142** held substantially in its closed position by the shear pin **148**, by compressing the bypass valve spring **96** sufficiently to latch the bypass valve **84** in its closed position relative to the guide **92**. The resulting assembly is then inserted into the packer mandrel **64** and the packer mandrel is reconnected to the adapter **62**. The valve means **140** is now ready for re-use.

Although exemplary embodiments of the invention have been disclosed herein for purposes of illustration, it will be understood that various changes, modifications and substitutions may be incorporated in such embodiments without departing from the spirit of the invention as defined by the claims which follow.

We claim:

1. In a fluid operated free pump system for a well, the combination of: a supply tubing and a production tubing set in the well with said supply tubing externally of said production tubing, said production tubing having a housing at the lower end thereof with which said supply tubing communicates; a free pump unit, including a fluid operated pump, slidable through said production tubing into said housing, said pump being operable in said housing by operating fluid under pressure supplied thereto through said supply tubing to pump production fluid from the well into said production tubing, said pump unit having a downwardly-facing area exposed to the flow of production fluid discharged by said pump when said pump is in operation in said housing; production

fluid bypass passage means in said pump unit for bypassing the flow of production fluid discharged by said pump past said downwardly-facing area; and means carried by said pump unit for closing said bypass passage means and for placing said downwardly-facing area in fluid communication with said supply tubing.

2. In a fluid operated free pump system for a well, the combination of: a supply tubing and a production tubing set in the well with said supply tubing externally of said production tubing, said production tubing having a housing at the lower end thereof with which said supply tubing communicates; a free pump unit, including a fluid operated pump, slidable through said production tubing into said housing, said pump being operable in said housing by operating fluid under pressure supplied thereto through said supply tubing to pump production fluid from the well into said production tubing, said pump unit having a downwardly-facing area exposed to the flow of production fluid discharged by said pump when said pump is in operation in said housing; production fluid bypass passage means in said pump unit for bypassing the flow of production fluid discharged by said pump past said downwardly-facing area; and means carried by said pump unit and responsive to a pressure in said production tubing higher than that in said supply tubing for closing said bypass passage means and for placing said downwardly-facing area in fluid communication with said supply tubing.

3. In a fluid operated free pump system for a well, the combination of: a supply tubing and a production tubing set in the well with said supply tubing externally of said production tubing, said production tubing having a housing at the lower end thereof with which said supply tubing communicates; a free pump unit, including a fluid operated pump, slidable through said production tubing into said housing, said pump being operable in said housing by operating fluid under pressure supplied thereto through said supply tubing to pump production fluid from the well into said production tubing, said pump unit having a downwardly-facing area exposed to the flow of production fluid discharged by said pump when said pump is in operation in said housing; production fluid bypass passage means in said pump unit for bypassing the flow of production fluid discharged by said pump past said downwardly-facing area; operating fluid supply passage means in said pump unit for conveying operating fluid from said supply tubing to said downwardly-facing area; and valve means carried by said pump unit and responsive to a pressure in said production tubing higher than that in said supply tubing for closing said bypass passage means and opening said supply passage means.

4. In a fluid operated free pump system for a well, the combination of: a supply tubing and a production tubing set in the well with said supply tubing externally of said production tubing, said production tubing having a housing at the lower end thereof with which said supply tubing communicates; a free pump unit, including a fluid operated pump, slidable through said production tubing into said housing, said pump being operable in said housing by operating fluid under pressure supplied thereto through said supply tubing to pump production fluid from the well into said production tubing, said pump unit having a downwardly-facing area exposed to the flow of production fluid discharged by said pump when said pump is in operation in said housing; production fluid bypass passage means in said pump unit for bypassing the flow of production fluid discharged by said pump past said downwardly-facing area; operating fluid supply passage means in said pump unit for conveying operating fluid from said supply tubing to said downwardly-facing area; and valve means carried by said pump unit and responsive to a pressure in said production tubing higher than that in said supply tubing for closing said bypass passage means and opening said supply passage means, said valve means including a normally open bypass valve movable to a closed position to close said bypass passage means, means for biasing said bypass valve toward its closed position, means for latching said bypass valve in its open position, a normally closed supply valve movable to an open position to open said supply passage means, means retaining said supply valve in its closed position, and means responsive to a pressure in said production tubing higher than that in said supply tubing for unlatching said bypass valve and for moving said supply valve to its open position in opposition to the action of said retaining means.

5. In a fluid operated free pump system for a well, the combination of: a supply tubing and a production tubing set in the well with said supply tubing externally of said production tubing, said production tubing having a housing at the lower end thereof with which said supply tubing communicates; a free pump unit, including a fluid operated pump, slidable through said production tubing into said housing, said pump being operable in said housing by operating fluid under pressure supplied thereto through said supply tubing to pump production fluid from the well into said production tubing, said pump unit having a downwardly-facing area exposed to the flow of production fluid discharged by said pump when said pump is in operation in said housing; production fluid bypass passage means in said pump unit for bypassing the flow of production fluid discharged by said pump past said downwardly-facing area; operating fluid supply passage means in said pump unit for conveying operating fluid from said supply tubing to said downwardly-facing area; and valve means carried by said pump unit and responsive to a pressure in said production tubing higher than that in said supply tubing for closing said bypass passage means and opening said supply passage means, said valve means including a normally open bypass valve movable to a closed position to close said bypass passage means, means for biasing said bypass valve toward its closed position, means for latching said bypass valve in its open position, a normally closed supply valve movable to an open position to open said supply passage means, means retaining said supply valve in its closed position, and means responsive to a pressure in said production tubing higher than that in said supply tubing for unlatching said bypass valve and for moving said supply valve to its open position in opposition to the action of said retaining means, said retaining means comprising a spring.

6. In a fluid operated free pump system for a well, the combination of: a supply tubing and a production tubing set in the well with said supply tubing externally of said production tubing, said production tubing having a housing at the lower end thereof with which said supply tubing communicates; a free pump unit, including a fluid operated pump, slidable through said production tubing into said housing, said pump being operable in said housing by operating fluid under pressure supplied thereto through said supply tubing to pump production fluid from the well into said production tubing, said pump unit having a downwardly-facing area exposed to the flow of production fluid discharged by said pump when said pump is in operation in said housing; production fluid bypass passage means in said pump unit for bypassing the flow of production fluid discharged by said pump past said downwardly-facing area; operating fluid supply passage means in said pump unit for conveying operating fluid from said supply tubing to said downwardly-facing area; and valve means carried by said pump unit and responsive to a pressure in said production tubing higher than that in said supply tubing for closing said bypass passage means and opening said supply passage means, said valve means including a normally open bypass valve movable to a closed position to close said bypass passage means, means for biasing said bypass valve toward its closed position, means for latching said bypass valve in its open position, a normally closed sup-

ply valve movable to an open position to open said supply passage means, means retaining said supply valve in its closed position, and means responsive to a pressure in said production tubing higher than that in said supply tubing for unlatching said bypass valve and for moving said supply valve to its open position in opposition to the action of said retaining means, said retaining means comprising a shear pin.

7. An elongated, piston-like free well pump unit movable through a tubing set in a well between the surface of the ground and an operating position in the well, said movable pump unit including a fluid operated pump operable by an operating fluid under pressure to pump production fluid from the well through said tubing, said movable pump unit having an area which faces downwardly when said movable pump unit is in its operating position and which is adapted to be exposed to the flow of production fluid discharged by said pump when said pump is in operation, said movable pump unit being provided therein with production fluid bypass passage means for bypassing the flow of production fluid discharged by said pump past said downwardly-facing area, said movable pump unit being provided therein with an operating fluid supply passage means for conveying operating fluid to said downwardly-facing area, said movable pump unit being provided therein with valve means for closing said bypass passage means and opening said supply passage means, said bypass passage means, said supply passage means, and said valve means being entirely within the confines of said movable pump unit.

8. A free well pump unit, including: a fluid operated pump having upper and lower ends and having an operating fluid inlet adjacent its upper end, said pump being operable by operating fluid under pressure supplied thereto through said operating fluid inlet to pump production fluid from a well; a packer mandrel having upper and lower ends and connected at its lower end to the upper end of said pump; at least one downwardly-facing packer cup on said packer mandrel; production fluid bypass passage means in said packer mandrel and having a production fluid inlet below said packer cup and a production fluid outlet above said packer cup; operating fluid supply passage means in said packer mandrel communicating with said operating fluid inlet in said pump and having an operating fluid outlet below said packer cup; and valve means in said packer mandrel for closing said bypass passage means and opening said supply passage means.

9. A free well pump unit, including: a fluid operated pump having upper and lower ends and having an operating fluid inlet adjacent its upper end, said pump being operable by operating fluid under pressure supplied thereto through said operating fluid inlet to pump production fluid from a well; a packer mandrel having upper and lower ends and connected at its lower end to the upper end of said pump; at least one downwardly-facing packer cup on said packer mandrel; production fluid bypass passage means in said packer mandrel and having a production fluid inlet below said packer cup and a production fluid outlet above said packer cup; operating fluid supply passage means in said packer mandrel communicating with said operating fluid inlet in said pump and having an operating fluid outlet below said packer cup; and valve means in said packer mandrel for closing said bypass passage means and opening said supply passage means, said valve means including a normally open bypass valve movable to a closed position to close said bypass passage means, means for biasing said bypass valve toward its closed position, means for latching said bypass valve in its open position, a normally closed supply valve movable to an open position to open said supply passage means, means retaining said supply valve in its closed position, and means for unlatching said bypass valve and for moving said supply valve to its open position in opposition to the action of said retaining means.

10. A free well pump unit, including: a fluid operated pump having upper and lower ends and having an operating fluid inlet adjacent its upper end, said pump being operable by operating fluid under pressure supplied thereto through said operating fluid inlet to pump production fluid from a well; a packer mandrel having upper and lower ends and connected at its lower end to the upper end of said pump; at least one downwardly-facing packer cup on said packer mandrel; production fluid bypass passage means in said packer mandrel and having a production fluid inlet below said packer cup and a production fluid outlet above said packer cup; operating fluid supply passage means in said packer mandrel communicating with said operating fluid inlet in said pump and having an operating fluid outlet below said packer cup; and valve means in said packer mandrel for closing said bypass passage means and opening said supply passage means, said valve means including a normally open bypass valve movable to a closed position to close said bypass passage means, means for biasing said bypass valve toward its closed position, means for latching said bypass valve in its open position, a normally closed supply valve movable to an open position to open said supply passage means, means retaining said supply valve in its closed position, and pressure differential responsive means for unlatching said bypass valve and for moving said supply valve to its open position in opposition to the action of said retaining means.

11. A free well pump unit, including: a fluid operated pump having upper and lower ends and having an operating fluid inlet adjacent its upper end, said pump being operable by operating fluid under pressure supplied thereto through said operating fluid inlet to pump production fluid from a well; a packer mandrel having upper and lower ends and connected at its lower end to the upper end of said pump; at least one downwardly-facing packer cup on said packer mandrel; production fluid bypass passage means in said packer mandrel and having a production fluid inlet below said packer cup and a production fluid outlet above said packer cup; operating fluid supply passage means in said packer mandrel communicating with said operating fluid inlet in said pump and having an operating fluid outlet below said packer cup; and valve means in said packer mandrel for closing said bypass passage means and opening said supply passage means, said valve means including a normally open bypass valve movable to a closed position to close said bypass passage means, means for biasing said bypass valve toward its closed position, means for latching said bypass valve in its open position, a normally closed supply valve movable to an open position to open said supply passage means, means retaining said supply valve in its closed position, and pressure differential responsive means for unlatching said bypass valve and for moving said supply valve to its open position in opposition to the action of said retaining means, said retaining means comprising a spring.

12. A free well pump unit, including: a fluid operated pump having upper and lower ends and having an operating fluid inlet adjacent its upper end, said pump being operable by operating fluid under pressure supplied thereto through said operating fluid inlet to pump production fluid from a well; a packer mandrel having upper and lower ends and connected at its lower end to the upper end of said pump; at least one downwardly-facing packer cup on said packer mandrel; production fluid bypass passage means in said packer mandrel and having a production fluid inlet below said packer cup and a production fluid outlet above said packer cup; operating fluid supply passage means in said packer mandrel communicating with said operating fluid inlet in said pump and having an operating fluid outlet below said packer cup; and valve means in said packer mandrel for closing said bypass passage means and opening said supply passage means, said valve means including a normally open bypass valve movable to a closed position to close said bypass passage

means, means for biasing said bypass valve toward its closed position, means for latching said bypass valve in its open position, a normally closed supply valve movable to an open position to open said supply passage means, means retaining said supply valve in its closed position, and pressure differential responsive means for unlatching said bypass valve and for moving said supply valve to its open position in opposition to the action of said retaining means, said retaining means comprising a shear pin.

13. In a fluid operated free pump system for a well, the combination of: a supply tubing and a production tubing set in the well with said supply tubing externally of said production tubing, said production tubing having a housing at the lower end thereof with which said supply tubing communicates; a free pump unit, including a fluid operated pump, slidable through said production tubing into said housing, said pump being operable in said housing by operating fluid under pressure supplied thereto through said supply tubing to pump production fluid from the well into said production tubing, said pump unit having a downwardly-facing area exposed to the flow of production fluid discharged by said pump when said pump is in operation in said housing; production fluid bypass passage means in said pump unit for bypassing the flow the production fluid discharged by said pump past said downwardly-facing area; operating fluid supply passage means in said pump unit for conveying operating fluid from said supply tubing to said downwardly-facing area; and valve means carried by said pump unit and responsive to a pressure in said production tubing higher than that in said supply tubing for closing said bypass passage means and opening said supply passage means, said valve means including a normally open bypass valve movable to a closed position to close said bypass passage means, means for biasing said bypass valve toward its closed position, means for latching said bypass valve in its open position, a normally closed supply valve movable to an open position to open said supply passage means, means retaining said supply valve in its closed position, means responsive to a pressure in said production tubing higher than that in said supply tubing for unlatching said bypass valve and for moving said supply valve to its open position in opposition to the action of said retaining means, and means for latching said supply valve in its open position upon movement of said bypass valve to its closed position.

14. A free well pump unit, including: a fluid operated pump having upper and lower ends and having an operating fluid inlet adjacent its upper end, said pump being operable by operating fluid under pressure supplied thereto through said operating fluid inlet to pump production fluid from a well; a packer mandrel having upper and lower ends and connected at its lower end to the upper end of said pump; at least one downwardly-facing packer cup on said packer mandrel; production fluid bypass passage means in said packer mandrel and having a production fluid inlet below said packer cup and a production fluid outlet above said packer cup; operating fluid supply passage means in said packer mandrel communicating with said operating fluid inlet in said pump and having an operating fluid outlet below said packer cup; and valve means in said packer mandrel for closing said bypass passage means and opening said supply passage means, said valve means including a normally open bypass valve movable to a closed position to close said bypass passage means, means for biasing said bypass valve toward its closed position, means for latching said bypass valve in its open position, a normally closed supply valve movable to an open position to open said supply passage means, means retaining said supply valve in its closed position, means for unlatching said bypass valve and for moving said supply valve to its open position in opposition to the action of said retaining means, and means for latching said supply valve in its open position upon movement of said bypass valve to its closed position.

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