April 6, 1954 C. J. COBERLY 2,674,192

WELL PUMPING SYSTEM WITH GAS SEPARATOR

Filed Nov. 25, 1949 2 Sheets-Sheet 1

Fig. 1

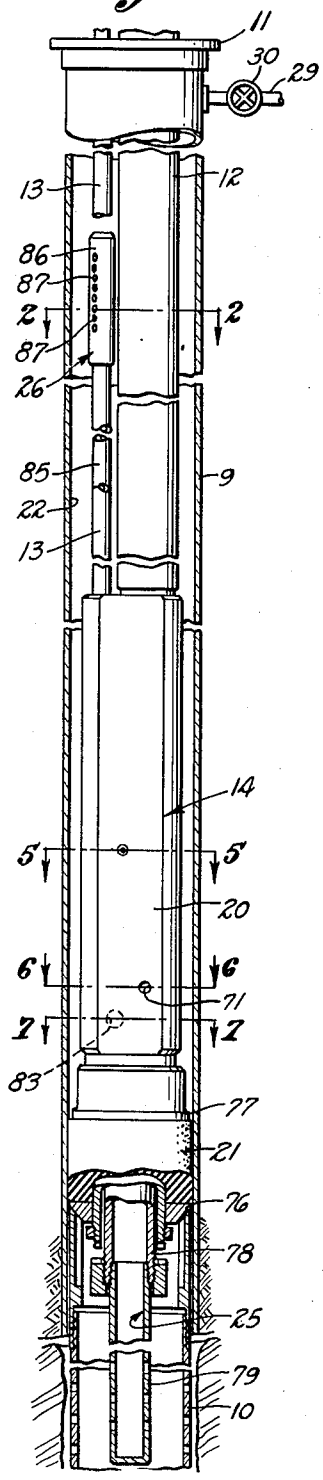


Fig. 2

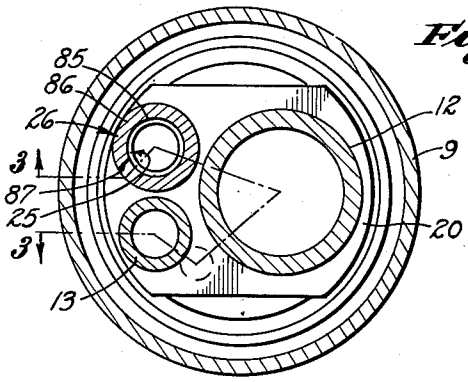


Fig. 5

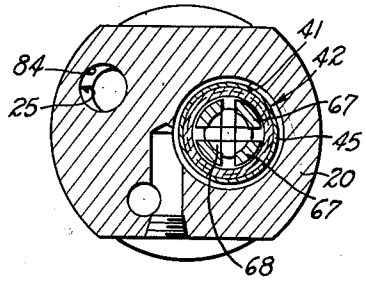


Fig. 6

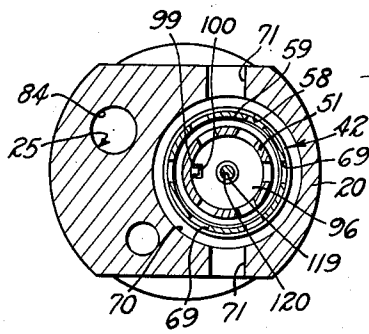
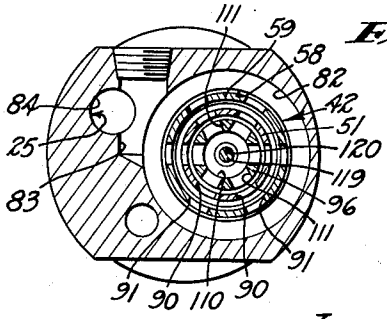


Fig. 7



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Fig. 3

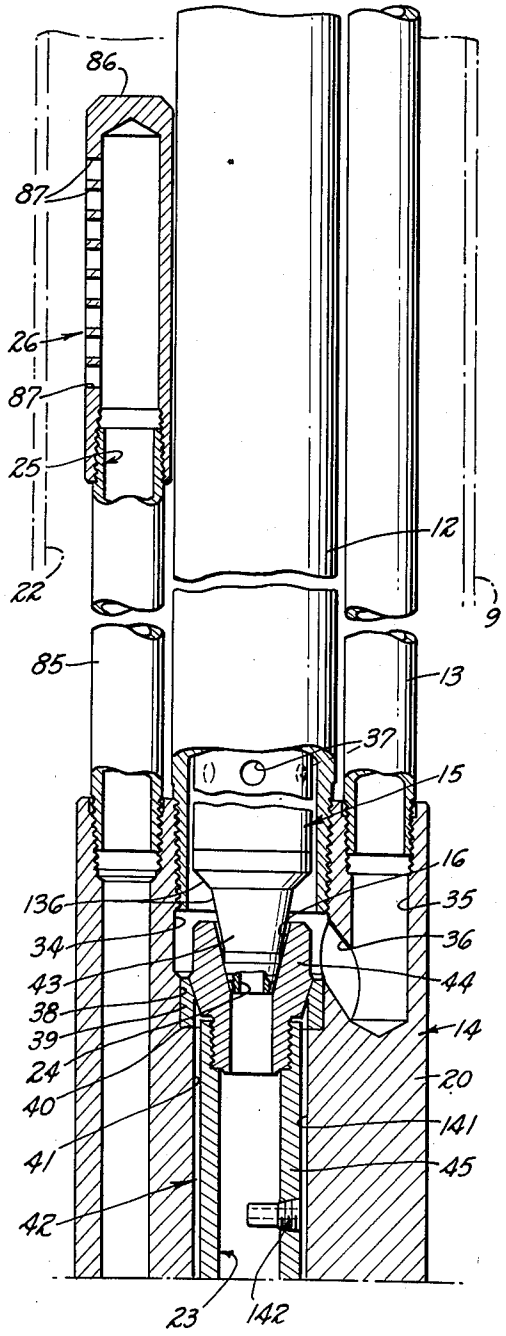
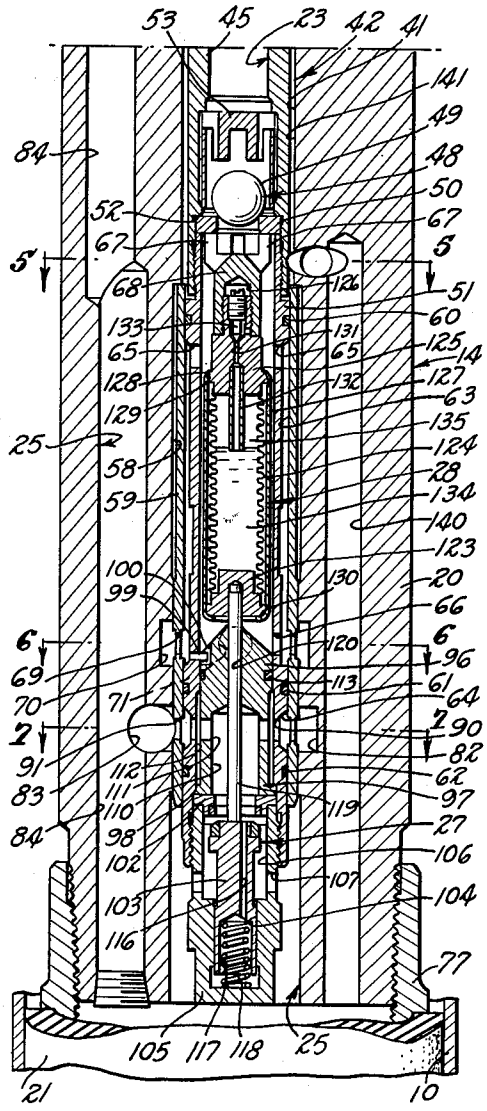


Fig. 4



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WELL PUMPING SYSTEM WITH GAS SEPARATOR

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Application November 25, 1949, Serial No. 129,375

19 Claims. (Cl. 103—46)

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The present invention relates in general to well pumping systems and, more particularly, to an apparatus for delivering well fluid to the inlet of a well pump, my present invention embodying improvements on that disclosed in my Patent No. 2,179,481, granted November 14, 1939 and entitled "Pump Inlet Means."

Although my invention is susceptible of other applications, it is of particular utility in the oil industry and will be described in connection with a well pump for pumping oil and other fluids from an oil well for purposes of illustration. As a matter of convenience, the invention will be considered in connection with a fluid-operated well pump of the so-called "free" type, i. e., of the type which is movable hydraulically through a tubing set in the well between the surface and an operating position in the well, although it will be understood that the invention is susceptible of application to other types of well pumps.

As is well known in the art, the well fluid to be pumped from an oil well frequently includes substantial quantities of gas, the latter either being mixed with the liquid components of the well fluid, or being in solution therein. The amount of gas in solution under equilibrium conditions depends on the amount of gas present in the oil producing formation surrounding the well and on the temperature and pressure conditions obtaining in the well. Also, it is possible for well fluid to be supersaturated with gas, i. e., to have more gas in solution therein than would normally be the case for a given set of conditions. If the pressure on the well fluid is decreased, as by drawing the well fluid into the pump cylinder of the well pump, or if the temperature of the well fluid is increased, or if the well fluid is agitated, large quantities of the gas are frequently liberated and separate from the oil to form a foam or froth. As is well known in the art, such free gas has a number of detrimental effects on the pumping system, one of these being that it reduces materially the volumetric efficiency of the well pump. Another detrimental effect is that the free gas, being highly compressible, tends to cause the pump to race with the attendant possibility of damage to the pump and other components of the pump system. My aforementioned prior patent discloses a gas-liquid separator for removing at least a portion of the gas from the liquid components of the well fluid and a primary object of the present invention is to provide a gas-liquid separator which incorporates improvements on that disclosed in my prior patent.

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In my aforementioned prior patent is disclosed an apparatus for delivering well fluid to the inlet of a well pump which includes a reservoir, passage means for connecting the reservoir to the well in fluid communication therewith so as to convey well fluid from the well to the reservoir, valve means for regulating the flow of well fluid through the passage means and pressure responsive means for actuting the valve means in a manner to maintain the liquid level in the reservoir below the discharge or outlet end of the passage means so that the well fluid entering the reservoir by way of the passage means discharges into gas. By maintaining the pressure of the gas in the reservoir above the liquid level therein at, or only slightly above, atmospheric pressure, the pressure of the well fluid flowing through the passage means is suddenly decreased as it discharges into the gas in the reservoir so that any gas mixed with or in solution in the liquid components of the well fluid is liberated in the reservoir and is thus separated from the liquid components of the well fluid. The well pump is supplied with liquid from the reservoir, which liquid contains a substantially reduced quantity of gas.

An important object of the present invention is to provide a pump inlet apparatus of the foregoing character wherein the valve means controlling the flow of well fluid from the well into the reservoir is made a part of a standing valve assembly employed in connection with a free, fluid-operated pump so that it may be pulled with the standing valve assembly when repairs or adjustments are necessary.

Another object is to provide a pump inlet apparatus wherein the valve means controlling flow from the well to the reservoir includes a hydraulically balanced valve so that it may be operated readily by the actuating means even though the formation pressure is high.

Another important object of the invention is to provide a pump inlet apparatus wherein the actuating means for the balanced valve includes a bellows which contains a liquid and a gas, the bellows containing a volume of liquid equal to at least one-half, and preferably in the neighborhood of three-quarters of its volume. By partially filling the bellows with a liquid, the bellows is protected against damage when it is subjected to high pressures, which may be the case if the pump inlet apparatus is installed in a well filled with liquid to a point materially above the point at which the pump inlet apparatus is installed. As will be apparent, if the bellows contained only

a gas at a pressure of, for example, twenty pounds per square inch and were installed in a well four thousand feet below the liquid level in the well, then the volume of the gas inside the bellows would have to be reduced to approximately 1/100 of its original volume in order to balance the higher pressure, which would result in damage to the bellows. On the other hand, if the bellows initially contains a volume of liquid equal to seventy-five percent of its volume and a volume of gas equal to twenty-five percent of its volume under the same conditions, then the total volume of the bellows would be reduced by only approximately one quarter of its original volume in order to balance the higher pressure. Such relatively slight compression of the bellows will not result in damage thereto, which is an important feature of the invention.

Another object of the invention is to provide a well pumping system which includes power and production tubings for a fluid-operated pump and wherein the passage means for conveying well fluid from the well into the reservoir comprises a third tubing extending upwardly in the reservoir beside the power and production tubings.

A further object is to provide discharge openings at the upper end of such third tubing which are directed toward and located adjacent a wall of the reservoir so that the gas-liquid mixture entering the reservoir through the discharge openings is spread into a relatively thin film over the wall of the reservoir to insure separation of the gas and liquid.

Still another object is to position the discharge openings relative to the wall of the reservoir toward which they are directed in such a manner that the axes of the discharge openings make acute angles with the reservoir wall so that the fluid discharge is approximately tangential to the reservoir wall to enhance spreading over the reservoir wall and to attain essentially a cyclone separator effect.

The foregoing objects and advantages of the present invention, together with various other objects and advantages which will become apparent, may be attained through the utilization of the exemplary embodiment of the invention which is illustrated in the accompanying drawings and which is described in detail hereinafter. Referring to the drawings:

Fig. 1 is a utility view of a well pumping system, as installed in a well, which incorporates the pump inlet apparatus of the invention;

Fig. 2 is an enlarged, transverse sectional view taken along the broken line 2—2 of Fig. 1;

Fig. 3 is a vertical sectional view taken along the irregular broken line 3—3 of Fig. 2;

Fig. 4 is a downward continuation of Fig. 3;

Figs. 5, 6 and 7 are transverse sectional views respectively taken along the broken lines 5—5, 6—6 and 7—7 of Figs. 1 and 4.

Referring particularly to Fig. 1, the numeral 9 designates a casing which is set in an oil well, a liner 10 extending below the lower end of the casing and being perforated to communicate with an oil producing formation surrounding the well. The casing 9 is provided at its upper end with a casing head 11 from which are suspended power and production tubings 12 and 13, the power and production tubings being connected at their lower ends to a pump inlet apparatus 14 for a well pump 15, which is shown in Fig. 3. In the particular construction illustrated, the well pump 15 is a fluid-operated free pump which is movable through the power tubing 12 between the surface and an operating position adjacent the lower end of the power tubing, the pump 15 being seated on a pump seat 16 carried by the pump inlet apparatus 14 when the pump is in its operating position. As will be discussed in more detail hereinafter, the power tubing 12 is adapted to convey an operating fluid, such as oil, under relatively high pressure downwardly to the fluid-operated pump 15 to operate it and the production tubing 13 is adapted to convey upwardly to the surface fluid discharged by the pump. The fluid-operated free pump 15 may be of any suitable type and will not be considered in detail.

In general, the pump inlet apparatus 14 includes a housing 20 which, as best shown in Figs. 1 and 3, carries a casing packer 21, the latter engaging the inner wall of the casing 9 to provide above the packer a reservoir 22 from which well fluid is supplied through a passage means 23 to an inlet 24 of the pump 15. As shown in Figs. 1, 3 and 4, the reservoir 22 is supplied with well fluid from below the packer 21 through a passage means 25, the latter extending upwardly in the reservoir 22 and being provided at its upper end with a discharge means 26. The pump inlet apparatus 14 includes a valve means 27 which regulates the flow of well fluid into the reservoir 22 through the passage means 25 and includes means 28 responsive to the pressure of the well fluid in there reservoir for actuating the valve means 27 to maintain the level of the liquid components of the well fluid in the reservoir at a point below the discharge means 26 so that the well fluid entering the reservoir through the passage means 25 discharges into gas in the reservoir. As shown in Fig. 1, the casing 9 communicates at its upper end with a pipe 29 through which gas may be drawn off from the casing under the control of a valve 30 to maintain any desired pressure in the casing and in the reservoir 22, the pressure in the reservoir preferably being maintained at substantially atmospheric pressure for reasons to be discussed hereinafter.

Referring particularly to Fig. 3, the housing 20 of the pump inlet apparatus 14 is provided at its upper end with a counterbore 34 into which the lower end of the power tubing 12 is threaded and is provided adjacent the counterbore 34 with a bore 35 into which the lower end of the production tubing 13 is threaded, the housing being provided with a port 36 which connects the bore 35 to the counterbore 34 so that production fluid discharged from an outlet 37, which may comprise a plurality of ports, of the pump 15 may enter the production tubing 13 to be conveyed upwardly thereby to the surface. It will be understood that sealing means (not shown) is provided between the pump 15 and the power tubing 12 above the outlet 37 to separate the operating fluid from the production fluid, as is well known in the art.

Communicating with the counterbore 34 in the housing 20 is a counterbore 38 in which is disposed an annular seat element 39, the latter being seated on a shoulder 40 formed at the junction of the counterbore 38 with a bore 41 in the housing. Seated on the annular seat element 39 and disposed in the bore 41 is a standing valve assembly 42 which carries the valve means 27 and the pressure responsive means 28, this being an important feature of the invention. The pump seat 16, which is tapered to receive a tapered lower end 43 of the pump 15,

is formed in a tubular seat element 44 at the upper end of the standing valve assembly 42, the tubular seat element 44 having a tapered external surface which seats on a complementarily tapered surface of the annular seat element 39. The interior of the tubular seat element 44 communicates with the inlet 24 of the pump 15 and has threaded onto its lower end a tube 45 which forms part of the passage means 23 for delivering fluid from the reservoir 22 to the pump inlet 24. As shown in Fig. 4, disposed within the lower end of the tube 45 is a standing valve 48 comprising a ball check valve 49 which is adapted to seat on an annular seat element 50 to prevent flow through the passage means 25 back into the reservoir 22. The annular seat element 50 is retained by being clamped between the upper end of a tubular housing 51 of the valve means 27 and the pressure responsive means 28 and a shoulder 52 in the tube 45. Upward movement of the ball check valve 49 is limited by a cage 53 which is disposed in the tube 45 above the annular seat element 50. The cage 53 is also a permanent magnet which holds the ball check valve 49 off its seat when the pump is in operation, the valve 49 seating only when the pump is stopped so that a back flow of fluid occurs to pull the valve away from the magnet and seat it. Thereafter, the ball check valve 49 is held seated by fluid pressure until such time as the fluid pressure thereabove is again reduced by the pump.

As shown in Fig. 4, the bore 41 in the housing 20 communicates at its lower end with a counterbore 58 therein in which is pressed or otherwise secured, a liner 59, the tubular housing 51 carrying three annular sealing elements, such as O-rings 60, 61 and 62 which make fluid-tight seals between the tubular housing 51 and the liner 59. The external diameter of the tubular housing 51 is reduced between the sealing elements 60 and 61 and between the sealing elements 61 and 62 to provide annular spaces 63 and 64, respectively. The annular space 63 forms part of the passage means 25 for conveying fluid from the reservoir 22 to the pump inlet 24 and communicates with the interior of the tubular housing 51 through one or more ports 65 adjacent the sealing element 60 and one or more ports 66 adjacent the sealing element 61. Fluid may flow from the interior of the tubular housing 51 between arms 67 of an element 68 of the pressure responsive means 28 and through the annular seat element 50 into the tube 45 leading to the pump inlet 24. The annular space 63 communicates adjacent its lower end through ports 69 in the liner 59 with an internal annular groove 70 in the housing 20. As shown in Fig. 4 and as best shown in Fig. 6, the internal annular groove 70 communicates through radial ports 71 in the housing 20 with the reservoir 22. Thus, the passage means 23 for conveying fluid from the reservoir 22 to the inlet 24 of the pump 15 includes the ports 71, the internal annular groove 70, the ports 69, the annular space 63, the ports 65 and 66 in the tubular housing 51, the interior of the tubular housing 51, the spaces between the arms 67 of the element 68 of the pressure responsive means 28, the annular seat element 50, the tube 45 and the tubular seat element 44. The magnetic cage 53 for the ball check valve 49 is, of course, of open construction so that fluid may flow therethrough.

Referring to Fig. 1, the liner 10 is provided at its upper end with an annular seat 76 for the packer 21, the packer being carried by a tubular shell 77 having a portion which, as best shown in Fig. 4, is threaded onto the lower end of the housing 20 of the pump inlet apparatus 14. This packer arrangement, which is generally similar to that shown in my aforementioned prior patent, is merely illustrative and any suitable type of packer arrangement may be substituted therefor. Threaded into or otherwise connected to the tubular shell 77 is an inlet tubing 78 extending to the bottom of the well and having a perforated lower section 79 through which well fluid from the interior of the liner 10 may enter the interior of the inlet tubing, the latter forming part of the passage means 25. As is conventional, the inlet tubing 78 acts as a gas-lift flow tubing through which the well fluid may be lifted substantial distances with relatively low formation pressures.

As shown in Fig. 4, the well fluid flowing through the inlet tubing 78 enters the counterbore 58 at the lower end of the housing 20 and flows upwardly therein through the valve means 27, as will be discussed hereinafter, into an internal annular groove 82 in the housing 20, the latter communicating through a port 83 with a longitudinal passage 84 in the housing. As shown in Fig. 3, threaded into the upper end of the passage 84 is a third tubing 85 which is positioned side by side with the power and production tubings 12 and 13, which is a feature of the invention. The third tubing 85 extends upwardly a substantial distance in the reservoir 22 and terminates at its upper end in the discharge means 26, the latter comprising an elongated cap 86 which is threaded onto the upper end of the third tubing. The cap 86 is provided with a row of discharge openings 87 therein through which well fluid from the passage means 25 may enter the reservoir. The cap 86 is positioned in close proximity to the casing 9, which forms one wall of the reservoir 22, with the discharge openings 87 therein directed toward the casing so that the well fluid entering the reservoir is spread over the casing in a thin film to promote better gas separation, as will be discussed in more detail hereinafter. Preferably, the axes of the discharge openings 87 are inclined with respect to the casing 9 so that the well fluid discharged therethrough impinges on the casing tangentially to attain some cyclone separator effect and an even film of well fluid over the entire inner surface of the casing between the discharge means 26 and the fluid level in the reservoir 22. In view of the foregoing description, it will be noted that the passage means 25 for conveying well fluid from the well to the reservoir 22 comprises the inlet tubing 78, the counterbore 58 at the lower end of the housing 20, the internal annular groove 82 in the housing 20, the lateral port 83, the longitudinal passage 84, the third tubing 85, the cap 86 and the discharge openings 87 in the cap. The well fluid flows from the counterbore 58 into the internal annular groove 82 in the housing 20 under the control of the valve means 27 by way of ports 90 in the tubular housing 51, the annular space 64, and ports 91 in the liner 59, the annular space 64 and the ports 90 and 91 also forming part of the passage means 25.

Referring to Fig. 4, the valve means 27 for controlling the flow of well fluid through the passage means 25 comprises a valve body which includes an upper valve body element 96 disposed in the tubular housing 51, the upper valve body element having a shoulder 97 which seats against

a shoulder 98 in the tubular housing 51 to limit insertion of the upper valve body element into the tubular housing. Rotation of the upper valve body element 96 is prevented by a pin 99 carried by the tubular housing 51 and extending into a notch 100 in the upper valve body element.

Seated against the lower end of the upper valve body element 96 is an annular seat element 102 for a valve 103 which is reciprocable in a bore 104 in a lower valve body element 105, the latter being threaded into the lower end of the tubular housing 51 and engaging the annular seat element 102 to clamp the annular seat element between the upper end of the lower valve body element 105 and the lower end of the upper valve body element 96. The lower valve body element 105 is provided with a counterbore 106 therein which provides an annular space around the valve 103, this annular space communicating through ports 107 with the counterbore 58 in the lower end of the housing 20 so that well fluid may enter the counterbore 106 from the counterbore 58 through the ports 107. The well fluid flows from the counterbore 106 through the annular seat element 102 at a rate determined by the position of the valve 103 relative to the annular seat element, and enters a counterbore 110 in the upper valve body element 96. From the counterbore 110, the well fluid flows through ports 111 into an annular space 112 between the upper valve body element 96 and the tubular housing 51. The annular space 112 communicates with the ports 90 in the tubular housing 51 and is sealed at its upper end by an annular sealing element 113 between the upper valve body element 96 and the tubular housing, the annular space 112 being sealed at its lower end by the threaded connection between the tubular housing 51 and the lower valve body element 105.

The valve 103 is provided with a passage 116 therethrough so that the fluid pressures applied to opposite ends thereof are substantially equalized, thereby substantially hydraulically balancing the valve. This is an important feature of the invention since it permits the pressure responsive means 28 to actuate the valve with the same effectiveness for any formation pressure, i. e., for any pressure of the well fluid flowing through the passage means 25. The valve 103 is provided with a bore 117 in its lower end in which is disposed a compression spring 118, the latter being seated at one end on the inner end of the bore 117 and at its other end on the inner end of the bore 104 in the lower valve body element 105. It will be noted that the compression spring 119 biases the valve 103 toward its closed position wherein it is seated on the annular seat element 102.

The force applied to the valve 103 by the compression spring 118 is opposed by the pressure responsive means 28 through a rod 119 which engages the upper end of the valve, the rod 119 being reciprocable in a bore 120 through the upper valve body element 96. The rod 119 is connected at its upper end to a lower head 123 of a bellows 124 having an upper head 125 which is threaded into a bore 126 in the element 68 of the pressure responsive means 28. It will be noted that the compression spring 118 acts through the valve 103, the rod 119 and the bellows 124 to hold the element 68 seated against the lower face of the annular seat element 50 of the standing valve 48. The bellows 124 is enclosed by a sleeve 127 having an inturned upper end 128 which is seated on and may be suitably secured to an external shoulder 129 on the upper head 125. The lower end of the sleeve 127 is also inturned at 130 to engage the lower face of the lower head 123, thereby limiting expansion of the bellows 124. The lower head 123 of the bellows 124 is reciprocable in the sleeve 127 and the lower face thereof is exposed to the fluid pressure surrounding the bellows, which is substantially the fluid pressure obtaining adjacent the lower end of the reservoir 22, so that the bellows is responsive to the fluid pressure obtaining in the reservoir. As will be apparent, if the fluid pressure at the lower end of the reservoir 22 varies from a predetermined value, which corresponds to a predetermined head of the liquid components of the well fluid in the reservoir, the bellows responds to move the valve 103 relative to the annular seat element 102 to vary the rate of flow of well fluid through the passage means 25 into the reservoir. As will be apparent, if the level of the liquid components of the well fluid increases above a predetermined value, the bellows 124 contracts to permit the valve 103 to move toward its closed position, thereby decreasing the rate of flow of well fluid into the reservoir to prevent a further increase in the level therein. The reverse is true when the level falls below the predetermined value. Thus, the bellows 124 serves to maintain the level in the reservoir substantially constant at the predetermined value.

As shown in Fig. 4, the bellows 124 is adapted to be filled through a passage 131 in the upper head 125 and a tube 132 which communicates at its upper end with the lower end of the passage 131 and which extends downwardly into the bellows a predetermined distance, the upper end of the tube 132 being pressed into a bore in the upper head 125. The upper end of the passage 131 serves as a seat for a needle valve 133 which is threaded into a bore in the upper end of the upper head 125 and serves to seal the bellows.

For a reason to be explained in discussing the operation of the present invention, the bellows contains both a liquid 134 and a gas 135, the volume of liquid 134 being at least one-half and preferably three-quarters of the normal volume of the bellows, the remainder of the normal volume of the bellows being equal to the volume of the gas 135 when the exterior of the bellows is exposed to atmospheric pressure. It will be noted that the tube 132 limits the amount of liquid that may be introduced into the bellows 124 so that the proper amount of liquid may be introduced readily, which is a feature. It will be understood that in introducing the liquid into the bellows 124, the bellows cannot be filled with liquid to a level much above the lower end of the tube 132.

Considering the operation of the present invention, it will be assumed that the power and production tubings 12 and 13 have been set in the well with the housing 20 connected to the lower ends thereof, the various components of the installation which are rigidly connected to the housing 20, e. g., the packer 21, etc., being attached thereto prior to setting the tubings in the well. Subsequently, the standing valve assembly 42, which carries the standing valve 48, the valve means 27 and the pressure responsive means 28 is either dropped or lowered through the power tubing 12 and seats on the annular seat element 39.

As is frequently the case, the well fluid level in the casing 10 may be several thousand feet

above the pump inlet apparatus 14 at the time the standing valve assembly 42 is run in in the foregoing manner. If the bellows 124 of the pressure responsive means 28 carried by the standing valve assembly were entirely filled with air at a pressure of, for example, twenty pounds per square inch initially and if it were submerged in, for example, four thousand feet of well fluid after being run in into its operating position, the bellows would be compressed to a volume equal to approximately only 1/100 of its initial volume, which would obviously result in damage to the bellows. On the other hand, assuming that the bellows 124 is initially filled with seventy-five percent liquid and twenty-five percent air under the same conditions and is then run into the well under the same conditions, the bellows is compressed by a factor of only approximately one-quarter of its original volume. This is a reasonable amount and will not result in damage. Consequently, my invention provides a pressure reponsive means which may be run into the well without any possibility of damage from a high external pressure, which is an important feature.

After the standing valve assembly 42, carrying the valve means 27 and the pressure responsive means 28, has been run in in the foregoing manner and is disposed in its operating position, the fluid-operated, free pump 15 is then moved hydraulically, or otherwise, through the power tubing 12 into its operating position wherein it is seated on the pump seat 16 provided by the standing valve assembly, any fluid in the power tubing below the pump being displaced upwardly through the production tubing 18 because of the fact that the standing valve 48 prevents reverse flow through the passage means 23 leading to the reservoir 22.

Operating fluid under pressure from a suitable source from the surface may then be delivered to the fluid-operated pump 15 through the power tubing 12 to operate the pump, whereupon the pump draws fluid from the reservoir 22 through the passage means 23 and discharges such fluid into the production tubing 13 as production fluid, the production tubing conveying the production fluid upwardly to the surface. If the fluid in the reservoir 22 is initially substantially above the predetermined point for which the pressure responsive means 28 is set, the bellows 124 is compressed to such an extent that the spring 118 closes the valve 103 to prevent any flow of well fluid from the well into the reservoir 22 until such time as the level in the reservoir is reduced to the predetermined value. Thereafter, the pressure responsive means 28 maintains the valve 103 in such a position that the level in the reservoir is maintained at the desired value.

Preferably, the pressure responsive means 28 cooperates with the valve means 27 to maintain the level in the reservoir 22 a substantial distance below the discharge means 26 so that the well fluid entering the reservoir through the passage means discharges into gas, rather than liquid. The well fluid entering the reservoir is discharged against the casing 9 by the discharge means 26 in the manner hereinbefore indicated so as to spread the well fluid over the casing in a thin film which drains downwardly into the body of liquid in the reservoir. This action results in separation of a substantial quantity of the gas in the well fluid from the liquid components thereof so that the gas does not interfere with the operation of the pump 15. As previously discussed, the discharge means 26 preferably discharges the well fluid against the casing 9 tangentially to attain essentially a cyclone separator effect, thereby insuring better gas separation. The distance that the liquid level is maintained below the discharge means 26 by the pressure responsive means 28 and the valve means 27 depends upon the degree of separation desired, which distance probably should not be less than approximately ten feet and might be as much as 100 feet.

It will be understood that the gas pressure in the reservoir 22 above the liquid level therein is desirably maintained at substantially atmospheric pressure by drawing gas off from the casing 9 through the pipe 29. Thus, when the well fluid discharges into the reservoir 22, the pressure thereon has been suddenly reduced at the valve 103 and the gas in solution in the liquid has been liberated therefrom with turbulence so that the amount of gas in the oil is greatly decreased and corresponds approximately to equilibrium conditions at the temperature and pressure in the reservoir.

It is desirable that the liquid level in the reservoir 22 be maintained a substantial distance above the inlet 24 of the pump 15 so that the fluid entering the pump is subjected to a substantial pressure. Consequently, the fluid entering the pump is less than saturated and this tends to prevent or at least minimize liberation of gas in the pump, thereby maintaining a high pumping efficiency.

In order to remove the pump 15 from the well, it is merely necessary to reverse the flow of operating fluid through the system, i. e., to direct the flow of operating fluid downwardly through the production tubing 13, instead of the power tubing 12, by means of a suitable valve mechanism (not shown) on the surface. The operating fluid directed downwardly through the production tubing 13 in this manner enters the power tubing 12 below the pump 15 and acts on an annular area 136 at the lower end of the pump to unseat the pump, the operating fluid pressure thereafter acting on the entire cross-sectional area of the pump to move the pump upwardly through the power tubing 12 to the surface. As will be apparent, the standing valve 48 closes under such conditions to prevent reverse flow through the passage means 23 leading from the reservoir 22.

After the pump 15 has been removed, if it is desired to remove the standing valve assembly 42 from the well for any reason, such as to service or repair the standing valve 48, the valve means 27, or the pressure responsive means 28, this may be accomplished readily by lowering a suitable tool into the power tubing 12 on the end of a wire line to engage the standing valve assembly. Thereafter, the standing valve assembly may be pulled upwardly through the power tubing 12 to the surface.

Referring to Fig. 4, the housing 20 of the pump inlet apparatus 14 is provided with a by-pass passage 140 which communicates at its lower end with the well through the casing packer 21 and which communicates at its upper end with an annular space 141 between the bore 41 and the standing valve assembly 42. The standing valve assembly is provided with a frangible drain plug 142 which is adapted to connect the annular space 141 to the interior of the tube 45. The drain plug 142, which is customarily termed

a "knockout plug," is hollow so that it connects the space 141 and the tube 45 when the inner end thereof is broken off, as by dropping a knockout bar through the power tubing 12. The purpose of this arrangement is to provide a way of draining the tubings 12 and 13 to balance the pressure on the standing valve assembly so that it may be readily pulled with a wire line.

Although I have disclosed an exemplary embodiment of my invention for purposes of illustration, it will be understood that I do not intend to be limited specifically thereto since various changes, modifications and substitutions may be incorporated in such embodiment without departing from the spirit of the invention.

I claim as my invention:

1. In a device of the character described, the combination of: a reservoir for well fluid from a well adapted to produce liquid and gas; passage means having an upper end for connecting said reservoir to the well in fluid communication therewith so as to convey well fluid from the well to said reservoir; valve means in said passage means and including a valve for regulating flow of well fluid through said passage means, said valve having oppositely facing, substantially equal areas; a passage connecting said areas to sources of substantially equal fluid pressures so as to substantially hydraulically balance said valve; and means responsive to variations in the amount of liquid in said reservoir and operatively connected to said valve means for maintaining the liquid level in said reservoir below the upper end of said passage means.

2. In a device of the character described, the combination of: a reservoir for well fluid from a well adapted to produce liquid and gas; passage means having an upper end for connecting said reservoir to the well in fluid communication therewith so as to convey well fluid from the well to said reservoir; valve means in said passage means and including a reciprocable valve having ends of substantially equal areas for regulating flow of well fluid through said passage means; means for exposing the ends of said valve to substantially equal fluid pressures so as to substantially hydraulically balance said valve; and means responsive to variations in the pressure of the well fluid in said reservoir and operatively connected to said valve means for maintaining the liquid level in said reservoir below the upper end of said passage means.

3. In a device of the character described, the combination of: a reservoir for well fluid from a well; passage means for connecting said reservoir to the well in fluid communication therewith so as to convey well fluid from the well to said reservoir; valve means in said passage means for regulating flow of well fluid through said passage means; means including a bellows for actuating said valve means, said bellows containing a liquid and a gas; and means for exposing the exterior of said bellows to the pressure of the well fluid in said reservoir.

4. In a device of the character described, the combination of: a reservoir for well fluid from a well; passage means for connecting said reservoir to the well in fluid communication therewith so as to convey well fluid from the well to said reservoir; valve means in said passage means for regulating flow of well fluid through said passage means; means including a bellows for actuating said valve means, said bellows containing a volume of liquid equal to at least one-half the volume thereof, the balance of said bellows containing a gas; and means for exposing the exterior of said bellows to the pressure of the well fluid in said reservoir.

5. In an apparatus for delivering well fluid to the inlet of a well pump, the combination of: a reservoir for well fluid from a well; passage means for connecting said reservoir to the well in fluid communication therewith so as to convey well fluid from the well to said reservoir; a first seat; pump inlet means adapted to seat on said first seat and providing a second seat for the inlet of the well pump; another passage means connecting said reservoir to said second seat so as to convey well fluid from said reservoir to the inlet of the well pump; and means carried by said pump inlet means for regulating flow of well fluid through said passage means into said reservoir in accordance with variations in the amount of well fluid in said reservoir.

6. In an apparatus for delivering well fluid to the inlet of a well pump, the combination of: a reservoir for well fluid from a well; a chamber providing a first seat; first passage means communicating intermediate its ends with said chamber for connecting said reservoir in fluid communication with the well so as to convey well fluid from the well to said reservoir; pump inlet means insertable into said chamber and seatable on said first seat, said pump inlet means providing a second seat for a well pump; second passage means communicating at one end with said reservoir and adapted to communicate at its other end with the inlet of a well pump seated on said second seat for conveying well fluid from said reservoir to the inlet of the well pump; valve means carried by said pump inlet means for regulating flow of well fluid through said first passage means into said reservoir; and pressure responsive means carried by said pump inlet means and actuable in response to variations in the amount of well fluid in said reservoir for actuating said valve means.

7. In an apparatus for delivering well fluid to the inlet of a well pump, the combination of: a reservoir for well fluid from a well; a chamber providing a first seat; first passage means communicating intermediate its ends with said chamber for connecting said reservoir in fluid communication with the well so as to convey well fluid from the well to said reservoir; pump inlet means insertable into said chamber and seatable on said first seat, said pump inlet means providing a second seat for a well pump; second passage means communicating at one end with said reservoir and adapted to communicate at its other end with the inlet of a well pump seated on said second seat for conveying well fluid from said reservoir to the inlet of the well pump, said second passage means traversing said pump inlet means; valve means carried by said pump inlet means for regulating flow of well fluid through said first passage means into said reservoir; and pressure responsive means carried by said pump inlet means and exposed to the pressure of well fluid flowing through said second passage means for actuating said valve means in response to variations in the pressure of well fluid flowing through said second passage means.

8. In an apparatus for delivering well fluid to the inlet of a well pump, the combination of: a reservoir for well fluid from a well; a chamber providing a first seat; first passage means communicating intermediate its ends with said chamber for connecting said reservoir in fluid com-

munication with the well so as to convey well fluid from the well to said reservoir; pump inlet means insertable into said chamber and seatable on said first seat, said pump inlet means providing a second seat for a well pump; second passage means communicating at one end with said reservoir and adapted to communicate at its other end with the inlet of a well pump seated on said second seat for conveying well fluid from said reservoir to the inlet of the well pump, said second passage means traversing said pump inlet means; valve means carried by said pump inlet means for regulating flow of well fluid through said first passage means into said reservoir; pressure responsive means carried by said pump inlet means and exposed to the pressure of well fluid flowing through said second passage means for actuating said valve means in response to variations in the pressure of well fluid flowing through said second passage means; and check valve means carried by said pump inlet means for preventing flow through said second passage means into said reservoir.

9. In an apparatus for delivering well fluid to the inlet of a well pump, the combination of: a reservoir for well fluid from a well; a chamber providing a first seat; first passage means communicating intermediate its ends with said chamber for connecting said reservoir in fluid communication with the well so as to convey well fluid from the well to said reservoir; pump inlet means insertable into said chamber and seatable on said first seat, said pump inlet means providing a second seat for a well pump; second passage means communicating at one end with said reservoir and adapted to communicate at its other end with the inlet of a well pump seated on said second seat for conveying well fluid from said reservoir to the inlet of the well pump, said second passage means traversing said pump inlet means; valve means carried by said pump inlet means for regulating flow of well fluid through said first passage means into said reservoir; pressure responsive means carried by said pump inlet means and exposed to the pressure of well fluid flowing through said second passage means for actuating said valve means in response to variations in the pressure of well fluid flowing through said second passage means; check valve means carried by said pump inlet means for preventing flow through said second passage means into said reservoir; a pair of tubings extending downwardly into the well and secured at their lower ends relative to said first seat with one of said tubings substantially aligned with said first seat, said pump inlet means being movable through said one tubing to seat on said first seat; a fluid-operated well pump movable through said one tubing to seat on said second seat, said well pump having an inlet communicating with said other end of said second passage means when said well pump is seated on said second seat, and having an outlet; and third passage means for connecting said outlet to the other of said tubings when said well pump is seated on said second seat.

10. In a pump inlet device, the combination of: a reservoir; a pump inlet body having first and second passages therethrough, said first passage having an outlet end connected to said reservoir and said second passage having an inlet end connected to said reservoir, said second passage having an upper, outlet end and having at its outlet end a seat for a lower, inlet end of a pump; valve means carried by said body for regulating flow through said first passage; said pressure responsive means carried by said body and exposed to fluid pressure in said second passage for actuating said valve means.

11. In a pump inlet device, the combination of: a pump inlet body having first and second passages therethrough, said second passage having an upper, outlet end and having at its outlet end a seat for a lower, inlet end of a pump; reservoir means for connecting said passages in series; valve means carried by said body for regulating flow through said first passage; and pressure responsive means carried by said body and exposed to fluid pressure in said second passage for actuating said valve means, said pressure responsive means including a bellows containing a liquid and a gas and having its exterior exposed to fluid pressure in said second passage.

12. In a pump inlet device, the combination of: a pump inlet body having first and second passages therethrough, said second passage having an upper, outlet end and having at its outlet end a seat for a lower, inlet end of a pump; valve means carried by said body for regulating flow through said first passage; pressure responsive means carried by said body and exposed to fluid pressure in said second passage for actuating said valve means; and check valve means carried by said body for preventing flow in one direction through said second passage.

13. In a pump inlet device, the combination of: a pump inlet body having first and second passages therethrough connected by a reservoir; valve means carried by said body for regulating flow through said first passage; pressure responsive means carried by said body and exposed to fluid pressure in said second passage for actuating said valve means; and a pump seat encompassing one end of said second passage.

14. A pump inlet device, comprising: first and second passages; reservoir means for connecting said passages in series; valve means for regulating flow through said first passage; and pressure responsive means for actuating said valve means, said pressure responsive means including a bellows containing a liquid and a gas and having its exterior exposed to fluid pressure in said second passage.

15. In a fluid-operated well pumping system, the combination of: power and production tubings set in a well; a reservoir enclosing the lower ends of said tubings; passage means communicating at one end with the well and at its other end with said reservoir for conveying well fluid from the well to said reservoir, said passage means including a third tubing in said reservoir beside said power and production tubings; a fluid-operated pump actuable by an operating fluid under pressure delivered thereto through said power tubing, said pump having an inlet communicating with said reservoir and an outlet communicating with said production tubing; and means for regulating flow of well fluid through said passage means into said reservoir in accordance with variations in the amount of well fluid in said reservoir.

16. In a device of the character described, the combination of: a reservoir for well fluid from a well; and passage means for connecting said reservoir in fluid communication with the well to convey well fluid from the well to said reservoir, said passage means communicating with said reservoir in a zone above the bottom of said reservoir through discharge openings in said passage means, said discharge openings being dis-

posed adjacent and being directed toward a wall of said reservoir and the axes of said discharge openings making acute angles with said wall so that the well fluid impinges substantially tangentially on said wall.

17. A pump inlet device according to claim 12 including means for biasing said check valve means open.

18. A pump inlet device according to claim 12 including magnetic means for biasing said check valve means open.

19. A pump inlet device according to claim 8 including means for biasing said check valve means open.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
495,074	Vail et al.	Apr. 11, 1893
497,295	Action	May 16, 1893
515,703	Birkeny	Feb. 27, 1894
1,195,253	Nashlund	Aug. 22, 1916
2,179,481	Coberly	Nov. 14, 1939
2,338,903	Coberly	Jan. 11, 1944
2,347,768	Crites	May 2, 1944
2,446,680	Walton	Aug. 10, 1948
2,489,665	O'Leary	Nov. 29, 1949
2,597,198	Staggs et al.	May 20, 1952