The present invention relates in general to fluid operated well pumping systems and, more particularly, to an apparatus for removing from the well fluid delivered to the inlet of a fluid operated well pump at least a substantial portion of any gas present in the well fluid to improve the volumetric efficiency of the pump, to minimize raising of the pump due to the presence of gas in the pump cylinder thereof, and to the like, where the present invention embodies improvements on the structure disclosed in Patent No. 2,674,192, granted April 6, 1954 to Clarence J. Coberly, one of the applicants herein.

As general background, the prior patent mentioned discloses an apparatus for delivering relatively gas-free well fluid to the inlet of the pump which includes a casing-type gas anchor providing a reservoir maintained at, or only slightly above, atmospheric pressure, first passage means interconnecting the reservoir and the well in fluid communication for discharging well fluid from the well into the reservoir, second passage means interconnecting the reservoir and the inlet of the well pump in fluid communication, and the reservoir to the inlet of the pump, valve means for regulating flow of well fluid through the first passage means from the well into the reservoir, and pressure responsive means responsive to variations in the level of liquid in the reservoir for operating the valve means mentioned in such a manner as to maintain the level of the liquid in the reservoir below the upper or discharge end of the first passage means so that the well fluid from the well is discharged into the reservoir above the level of the liquid therein. Since the pressure in the reservoir is maintained at, or only slightly above, atmospheric pressure, the pressure of the well fluid flowing through the first passage means into the reservoir is suddenly decreased as the well fluid is discharged into the gas in the reservoir so that the bulk of 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. Thus, the liquid delivered to the inlet of the pump contains a substantially reduced quantity of gas to achieve the results hereinafore outlined.

A primary object of the invention is to provide an apparatus of the foregoing nature wherein the valve means mentioned, which is designated the main valve means hereinafter, is fluid operated and is controlled by a pilot valve means actuated by the pressure responsive means mentioned. With this construction, a force amplifying effect is achieved, the force produced by the pressure responsive means being amplified and applied to the main valve means by the pilot valve means so that a large force for operating the main valve means is obtained without correspondingly increasing the output force of the pressure responsive means, which is an important feature of the invention.

Another and important object of the invention is to provide an apparatus wherein the flow of fluid for operating the main valve means is from a source of clean fluid, at a pressure higher than that of the well fluid, into the well fluid. With this construction, contamination of the pilot valve means and the fluid operated components of the main valve means by the well fluid, which is frequently dirty fluid containing various contaminants, is prevented, which is an important feature of the invention.

Another object of the invention is to provide a construction wherein the pilot valve means is provided with an inlet means communicating with the source of clean fluid and is provided with an outlet means communicating with the well fluid flowing through the aforementioned second passage means, i.e., the passage means leading from the reservoir to the inlet of the pump.

A further object is to provide an apparatus which utilizes as the clean fluid mentioned the operating fluid employed to actuate the engine or motor section of the pump, and preferably the spent operating fluid discharged by such engine or motor section. With this construction, the pressure differential available to operate the main valve means is equal to the difference between the column pressure of the spent operating fluid and the pressure at the inlet of the pump, which is entirely adequate for the purpose.

Another object of the invention is to provide a pilot valve means which operates the main valve means with merely a slight leakage of clean fluid into the well fluid so as to minimize the loss of clean fluid.

An important object is to provide a pilot valve means which includes two throttling means respectively upstream and downstream from and connected in series with the fluid operated components of the main valve means, the pilot valve means including means for respectively increasing and decreasing the flow resistances of the two throttling means simultaneously so that the flow resistances of the two throttling means are balanced against each other. With this construction, when the flow resistance of one throttling means is higher than that of the other, the main valve means is closed, and when the flow resistance of the second throttling means is higher than that of the first, the main valve means is open.

Another object of the invention is to provide a pilot valve means which includes a pilot valve body having a pilot valve bore therein and having a pilot valve member reciprocable in the pilot valve bore, the pilot valve body having inlet and outlet means therein in communication with the pilot valve bore at axially spaced points and having port means therein intermediate the inlet means and the outlet means and communicating with the main valve means, the pilot valve member having therein channel means which is adapted to bridge the inlet means and the port means in one extreme position of the pilot valve member and to bridge the port means and the outlet means at the other end of the travel of the pilot valve member. With this construction, the channel means in the pilot valve member does not directly connect the port means mentioned to the inlet means or the outlet means in intermediate positions of the pilot valve member so that flow from the inlet means to the port means and from the port means to the outlet means takes place through slight clearances between the pilot valve member and the wall of the pilot valve bore, such clearances forming the two throttling means mentioned previously. This construction, in effect, merely permits a slight leakage of spent operating fluid into the well fluid to achieve the desired regulation of the liquid level within the reservoir with a minimum loss of operating fluid from the system, which is an important feature.

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 art in the light of this disclosure, may be achieved with the exemplary embodiment of the invention described in detail hereinafter and illustrated in the accompanying drawings, in which:

FIG. 1 is a view, partially in vertical section and on a
reduced scale, showing a fluid operated pumping system which embodies the invention installed in a well;

FIG. 2 is a horizontal sectional view taken along the arrowed line 2-2 of FIG. 1;

FIG. 3 is a view, partially in vertical section and partially in elevation, taken along the arrowed lines 3-3 of FIG. 2;

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

FIGS. 5, 6 and 7 are horizontal sectional views respectively taken along the arrowed lines 5-5, 6-6 and 7-7 of FIGS. 1 and 4; and

FIGS. 8, 9 and 10 are vertical sectional views which duplicate a portion of FIG. 4 on an enlarged scale and which illustrate various operative positions of various components of the invention.

Referring particularly to FIG. 1 of the drawings, the invention comprises a casing 34 which is set in an oil well and the numeral 22 designates a perforated liner which extends below the lower end of the casing, the perforations in the liner being adapted to convey well fluid from a surrounding production formation 24 into the interior of the liner. The casing 20 is provided at its upper end with a casing head 26 from which are suspended supply, return and production tubings 28, 30 and 32, respectively, these tubings being connected at their lower ends to a pump inlet apparatus 34 for a fluid operated oil well pump 36, FIG. 3. The fluid operated pump 36 may be of any suitable construction, such as that shown in Patent No. 2,338,903, granted February 16, 1943 to Clarence J. Coberly, and is shown as being a free pump hydraulically movable through the supply tubing 28 between an operating position wherein it is seated on the pump inlet apparatus 34 and the surface, as disclosed in Patent No. 2,338,903, granted January 11, 1944 to Clarence J. Coberly, the disclosures of these patents being incorporated herein by reference so that a detailed description of the pump 36 is not necessary. Briefly, the pump 36 is moved downwardly through the supply tubing 28 into its operating position by introducing operating fluid, such as crude oil, into the supply tubing above the pump at a sufficient pressure to move the pump downwardly. The pump 36 is removed by introducing operating fluid into the production tubing 32 at a pressure sufficient to move the pump upwardly through the supply tubing 28 to the surface, the manner in which the pressure developed in the production tubing being applied to the lower end of the pump in running the pump 36 out of the well as described hereinbefore. When the pump 36 is in its operating position, its engine section is actuated by operating fluid under pressure conveyed downwardly thereto through the supply tubing 28, the spent operating fluid discharged by the engine section of the pump being discharged into the return tubing 30 at the level of a sealing collar 38 interconnecting the supply and return tubings 28 and 30, and being conveyed upwardly to the surface through the return tubing. The pump 36 includes a pump section which is operated by the engine section of the pump and which discharges fluid from the well into the production tubing 32 as production fluid, the production fluid being conveyed upwardly to the surface by the production tubing.

It will be understood that while the pump 36 has been described as a free pump hydraulically movable between the surface and its operating position through the supply tubing 28, the present invention is not limited thereto. For example, the invention is equally applicable to a set pump which is structurally connected to the lower end of the tubing system. Also, while a closed operating fluid system, i.e., one in which the spent operating fluid is returned to the surface independently of the production fluid through the return tubing 30, has been described, the invention is not limited thereto and is equally applicable to an open operating fluid system in which the spent operating fluid and the production fluid are mixed and conveyed to the surface through the same tubing.

Turning now to the pump inlet apparatus 34, it includes a housing 40 which, as best shown in FIGS. 1 and 3, carries a packer 42 engaging the casing 20 and providing above the packer a reservoir 44 in which separation of the gaseous and liquid components of the well fluid takes place, as will be described. This construction provides a so-called gas anchor of the casing type, although it will be understood that the invention is applicable to other gas anchor types.

Relatively gas-free liquid flows from the reservoir 44 through a passage means 46 to an inlet 48 of the pump 36, the reservoir being supplied with well fluid from the well below the packer 42 through a passage means 50, best shown in FIGS. 3 and 4. The passage means 50 is provided at its upper end with a discharge means 52 through which the well fluid is discharged into the reservoir 44. The pump inlet apparatus 34 includes a main valve means 54 which regulates the flow of well fluid into the reservoir 44 through the passage means 50 and includes pilot valve means 56 for operating such main valve means 54, in turn, being actuated by a pressure responsive means 58 which is responsive to variations in the liquid level in the reservoir 44.

The pressure responsive means 58, the pilot valve means 56 and the main valve means 54 cooperate, in a manner to be described, to maintain the liquid level in the reservoir 44 at a point below the discharge means 52 so that the well fluid entering the reservoir through the passage means 50 discharges into gas in the reservoir to obtain maximum gas-liquid separation. As shown in FIG. 1, the casing 20 communicates at its upper end with a pipe 60 through which gas may be drawn off from the casing under the control of a valve 62 to maintain an desired pressure in the casing and in the reservoir 44. Preferably, the pressure in the reservoir 44 above the liquid therein is maintained at, or only slightly above, atmospheric pressure to obtain maximum gas-liquid separation upon discharging of well fluid into the reservoir by the discharge means 52.

Considering the structure of the pump inlet apparatus 34 in more detail now, the housing 40 of the pump inlet apparatus is provided at its upper end with a counterbore 64 into which the lower end of the supply tubing 28 is threaded, as shown in FIG. 3. Adjacent the counterbore 64 is a bore 66 into which the lower end of the production tubing 32 is threaded, the housing 40 being provided with a port 68 which connects the bore 66 to the counterbore 64 so that production fluid discharged from an outlet 70 of the pump section of the valve seating only in the production tubing 32 to be conveyed upwardly thereby to the surface. It will be understood that suitable sealing means, not shown, is provided between the pump 36 and the sealing collar 38 above the outlet 70 to separate the production fluid from the operating fluid, as is well known in the art.

Communicating with the counterbore 64 in the housing 40 is a counterbore 72 in which is disposed an annular seat 74 for a standing valve assembly 76 which carries the main valve means 54, the pilot valve means 56 and the pressure responsive means 58 and which is disposed in a bore 78 in the housing 40 below the annular seat 74. The upper end of the standing valve assembly 76 provides a seat 80 for the lower end of the pump 36. The standing valve assembly 76 includes a tubular housing 82 which forms part of the passage means 46 for delivering relatively gas-free well fluid from the pump 36 of the pump 36, the tubular housing 82 having therein a standing valve 84 which is engageable with a seat 86 to prevent back flow into the reservoir 44. Upward movement of the standing valve 84 is limited by a magnet which holds the standing valve 84 in its seat when the pump 36 is in operation, the standing valve seating only in response to a back flow of fluid sufficient to disengage the
standing valve from the magnet. Normally, such a back flow occurs only when the pump 36 is lifted from its seat 80 in running the pump out of the well.

As shown in FIG. 4, the bore 78 in the housing 40 communicates at its lower end with a counterbore 98 therein into which is pressed a liner 92. The standing valve assembly 76 includes a tubular housing 94 which is connected at its upper end to the tubular housing 82 and which is disposed in the liner 92 when the standing valve assembly 76 is seated on the seat 74. The tubular housing 94 carries external annular seals, such as O-rings 96, which engage the liner 92 to separate various sets of ports, channels, and the like in the liner and the tubular housing 94 which will be described hereinafter.

Referring to FIGS. 4 and 6, the passage means 46 leading from the reservoir 44 to the pump inlet 48 includes ports 98 in the housing 40, these ports communicating at their outer ends with the reservoir and communicating at their inner ends with an internal annular channel 100 in the housing 40. The annular channel 100 communicates with the interior of the tubular housing 94, when the standing valve assembly 76 is in its operating position, through various radial ports and annular channels which are formed in the liner 92 and the tubular housing 94 and which are collectively designated by the numeral 102. Since these ports and channels are clearly shown in FIGS. 4 and 6 of the drawings, it is unnecessary to apply individual reference numerals thereto. The set of ports and channels designated by the reference numeral 102 is isolated from other, similar sets to be described hereinafter by two of the O-rings 96.

The relatively gas-free liquid in the reservoir 44 flows through the ports 98, the annular channel 100 and the set of ports and channels designated by the numeral 102 into the interior of the tubular housing 94, and then flows upwardly past the standing valve 84 and through the tubular housing 82 into the inlet 48 of the pump 36, the various elements through which the fluid flows from the reservoir to the pump inlet constituting the passage means 46.

The pressure responsive means 58 is disposed in the tubular housing 94 and is exposed to the fluid flowing through the passage means 46 so that it responds to variations in the liquid level in the reservoir 44, it being apparent that the fluid pressure within the tubular housing 94 is substantially equal to the fluid pressure responsive means 58 which corresponds to the head of liquid in the reservoir 44, head being a matter of hundreds of feet, plus whatever pressure is maintained in the reservoir above the liquid, the latter pressure preferably being substantially atmospheric pressure, as hereinbefore pointed out. The pressure responsive means 58 is virtually identical to that disclosed in the aforementioned Patent No. 2,674,192 so that a detailed description herein is unnecessary, the disclosure of such patent being incorporated herein by reference.

Considering the passage means 50 for conveying well fluid from the well below the pump 42 upwardly into the reservoir 44, the pump carries a perforated inlet tube 104 into the interior of which well fluid may flow by way of the perforations therein. Referring to FIG. 4, the well fluid flows from the inlet tube 104 upwardly through the pump 42 and into the lower end of the tubular housing 94 at the lower end of the standing valve assembly 76. The well fluid then flows through the main valve means 54, which will be described hereinafter, and through various generally radial ports and annular channels which are formed in the liner 92 and the tubular housing 94 and which are designated collectively by the reference numeral 106, it being thought unnecessary to describe these various ports and channels in detail since they are clearly shown in FIG. 4 of the drawings. From the set of ports and channels 106, which is isolated by two of the O-rings 96, the well fluid flows into an internal annular channel 108 in the housing 40 and then upwardly through a vertical passage 110 in the housing 40. At its upper end, the vertical passage 110 communicates with the lower end of a pipe 112 threaded into the upper end of the housing 40, this pipe having the discharge means 52 at the upper end thereof. This discharge means is fully described in the aforementioned Patent No. 2,674,192 so that a further description herein is not necessary. The pipe 112 extends upwardly in the reservoir 44 a substantial distance, which distance may be as much as several hundred feet, or more, the liquid level in the reservoir being maintained below the discharge means 52 by the main valve means 54, under the control of the pressure responsive means 58 and the pilot valve means 56, as explained hereinafter. This insures that the discharge means 52 discharges into gas above the liquid in the reservoir 44 to obtain maximum gas-liquid separation.

Before considering in detail the main valve means 54 and the manner in which it is operated by the pilot valve means 56 under the control of the pressure responsive means 58, it is convenient to describe the manner in which fluid for operating the main valve means is delivered thereto. As hereinbefore pointed out, the main valve means 54 is operated by clean fluid, preferably the spent operating fluid discharged by the engine section of the pump 36. To achieve this, the return tubing 30 which conveys the spent operating fluid to the surface is extended downwardly from the sealing collar 38 and is threaded at its lower end into the upper end of the housing 40, as best shown in FIG. 3. Communication between the lower end of the return tubing 30 is a vertical passage 114 which communicates at its lower end with an internal annular channel 116 in the housing 40. The annular channel 116 communicates with a wide annular channel 118 within the tubular housing 94 through radial ports in the liner 92 and the tubular housing 94 and an internal annular channel in the liner. The ports and the annular channel just mentioned are designated collectively by the numeral 120, it being unnecessary to specifically apply individual reference numerals thereto since they are clearly shown in FIGS. 4 and 7. The ports and channel identified by the collective reference numeral 120 are isolated from the ports and channels collectively identified by the reference numerals 102 and 106 by two of the O-rings 96.

The channel 118 is located within the structure of the tubular housing 94 by making this housing of concentric inner and outer tubes 122 and 124 suitably secured together, the channel 118 being located between the inner and outer tubes of the tubular housing 94 and being isolated by O-rings 126. As will be apparent, the channel 118, with this construction, always contains spent operating fluid at a pressure equal to the head of spent operating fluid in the return tubing 30, the main valve means 54 being operated by the pressure differential between the pressure of the spent operating fluid in the channel 118 and the pressure of the well fluid being conveyed from the reservoir 44 to the pump inlet 48 and surrounding the pressure responsive means 58, as hereinbefore explained.

Turning now to a detailed consideration of the main valve means 54 with particular reference to FIGS. 8 to 10 of the drawings, it includes a main valve member 130 which is slidable in a tubular guide 132 relative to a main valve seat 134, a O-ring 136 like, on the main valve member providing a fluid-tight seal with respect to the guide. The main valve seat 134 and the main valve guide 130 are disposed in the line of and form parts of the passage means 50 and are held in a counterbore in the inner tube 122 of the tubular housing 94 by a tubular fitting 136 which is threaded into such counterbore and which also forms part of the passage means 50, the fitting 136 also serving to retain the inner and outer tubes 122 and 124 in assembled relationship in a manner which will be apparent from FIG. 4 of the drawings. The main valve member 130 includes a differential-
area piston 138 disposed in a counterbore 140 in the inner tube 122 of the tubular housing 94 and sealed relative thereto by an O-ring, or the like. The lower end of the piston 138 has an area less than that of the upper end thereof, the area of the lower end of the piston being equal to the differential full cross sectional area of the piston and the cross sectional area of the main valve member 130, and the area of the upper end of the piston being equal to the full cross sectional area thereof. The smaller area at the lower end of the piston 138 is constantly exposed to the spent operating fluid pressure in the channel 118 in the inner tube 122 of the tubular housing 94.

The pressure applied to the larger area of the upper end of the piston 138 ranges from the spent operating fluid pressure in the annular channel 118 to the pressure of the well fluid surrounding the pressure responsive means 58, the pressure applied to the pressure responsive means 58 being, as hereinbefore explained, the pressure in the passage 46 leading from the reservoir 44 to the pump inlet 48. The pressure applied to the larger area of the upper end of the piston 138 is determined by the pilot valve means 56 and the control of the pressure responsive means 58, as explained hereinbefore.

As will be apparent, the main valve member 130 may occupy various positions, ranging from closed through partially open to fully open, depending upon the pressure applied to the upper end of the piston 138 by the pilot valve means 56 and under the control of the pressure responsive means 58. For example, if the pilot valve means 56 applies the spent operating fluid pressure in the channel 118 to the upper end of the piston 138, the main valve member 130 is closed, as shown in FIG. 10, assuming that the well fluid pressure applied to the lower end of the main valve member 130 is less than the spent operating fluid pressure applied to the equal area at the upper end of the piston 138, which normally is the case. On the other hand, if the pressure applied to the upper end of the piston 138 is reduced to that of the well fluid surrounding the pressure responsive means 58, the main valve member 130 is moved to its fully open position, as shown in FIG. 9 of the drawings. The main valve member 130 may also assume various partially open positions intermediate its closed and fully open positions, such as the intermediate position shown in FIG. 8 of the drawings, when the fluid pressure applied to the upper end of the piston 138 by the pilot valve means 56 is such that the main valve member and its piston are hydraulically balanced with the main valve member in such partially open position. Considering the pilot valve means 56, it includes a pilot valve member 150 connected to and reciprocable by the pressure responsive means 58 as the liquid level in the reservoir 44 varies. The pilot valve member 150 is reciprocable in a bore 152 in a pilot valve body 154 disposed in a bore 156 in the inner tube 122 of the tubular housing 94.

The pilot valve body 154 is restrained in the bore 156 by an annular flange 158 and a nut 160 respectively engaging annular shoulders on the inner tube 122 at opposite ends of the bore 156. To reduce the axial length of the pump inlet apparatus 34, the pilot valve body 154 extends into the piston 138 of the main valve member 130, such piston being cup shaped to receive the pilot valve body. Also, as FIG. 9 shows, the pilot valve body acts as a stop defining the fully open position of the main valve member 130 when retracted.

The pilot valve body 154 and the inner tube 122 of the tubular housing 94 are provided therein with an inlet means 162 which connects the annular channel 118 to the pilot valve bore 152 adjacent the upper end of the pilot valve bore. The inlet means 162 is made up of various radial ports and annular channels in the pilot valve body 154 and the inner tube 122 which are clearly shown in FIGS. 8 to 10 of the drawings and which there-
the outlet means 164 in intermediate positions of the pilot valve member 150 through a slight clearance between the pilot valve member and the pilot valve bore 152 on the opposite side of the outlet throttling means 176, this clearance being of the same order of magnitude as the clearance previously mentioned and constituting an outlet throttling means 176. Again, the flow resistance offered by the outlet throttling means depends on the position of the pilot valve member 150, increasing to a finite maximum as the pilot valve member moves further out, and decreasing again as the outlet means 176 and 178 move together, the flow resistance produced by one throttling means decreases as the flow resistance produced by the other increases, and vice versa. Thus, the flow resistances of the throttling means 176 and 178 and, consequently, the leakages therefrom, are balanced against each other, one increasing as the other decreases, and vice versa.

Elaborating on the foregoing somewhat, if the liquid level in the reservoir 44 rises slightly, the pressure responsive means 58 act to move the pilot valve member 150 upwardly a corresponding increment. This reduces the distance between the channel 174 in the pilot valve member 150 and the inlet means 162 and simultaneously increases the distance between the channel 174 and the outlet means 164. Consequently, the pressure applied to the annular area of the pilot valve member 130 toward its seat 134 sufficiently to restore the liquid level in the reservoir 44 to its prescribed value.

The foregoing balancing of the flow resistances of and the leakages through the inlet and outlet throttling means 176 and 178 against each other results in very sensitive and accurate control of the fluid pressure applied to the upper end of the piston 138 rises to move the main valve member 130 toward its seat 134 sufficiently to restore the liquid level in the reservoir 44 to its prescribed value.

As will be apparent from the foregoing discussion, there is a constant, slight flow or leakage of spent operating fluid from the annular channel 118 through the pilot valve means 56 and 58, which can occur through the main valve without 54 controlled thereby into the well fluid in the tubing housing 94 around the pressure responsive means 58. Consequently, the pilot valve means 56 and the portion of the main valve means 54 controlled thereby are constantly exposed to a flow of clean fluid which prevents the entry of possibly contaminated well fluid. This washing action is important since it prevents the entry into the pilot valve means 56 and the portion of the main valve means 54 controlled thereby of contaminants which might cause damage.

Considering the general operation of the invention, it will be assumed that the various fixed components of the well installation, such as the supply, return and production tubing 28, 36, and 32, the housing 40 and the packer 42 are all in place. Subsequently, the standing valve assembly 76, which carries the standing valve 84, the main valve means 54, the pilot valve means 56 and the pressure responsive means 58, is either dropped or lowered through the supply tubing 28 and seats on the annular seat 74 therefrom. As explained in the aforementioned Patent No. 2,674,192, the pressure responsive means 58 is so constructed that it can be run into the well without any possibility of damage even with a high well fluid level in the casing 20 when the standing valve assembly is run in.

After the standing valve assembly 76 has been run in and is disposed in its operating position, the fluid operated free pump 36 is circulated in the supply tubing 28 into its operating position wherein it is seated on the pump seat 80 provided by the standing valve assembly 76, any fluid in the supply tubing below the pump being displaced upwardly, preferably through the production tubing 32, since the standing valve 84 prevents back flow into the well.

Operating fluid under pressure is then delivered to the pump 36 through the supply tubing 28 to operate the pump, wherein the pump draws fluid from the reservoir 44 through the passage means 46 and discharges such fluid as production fluid into the production tubing 32, which conveys the production fluid upwardly to the surface. If the liquid level in the reservoir 44 is initially substantially above the predetermined point for which the pressure responsive means 58 is set, the pressure responsive means causes the pilot valve means 56 to close the main valve means 54 until such time as the liquid level in the reservoir is reduced to the predetermined value. Thereafter, the pilot valve means 56, under the control of the pressure responsive means 58, maintains the main valve member 130 in a position such as to maintain the liquid level in the reservoir at the desired value. As previously pointed out, the liquid level in the reservoir 44 is maintained well below the discharge means 52 so that the discharge means discharges into gas to obtain maximum gas-liquid separation.

In order to remove the pump 36 from the well, it is merely necessary to introduce operating fluid under pressure into the production tubing 32 in this manner enters the supply tubing 28 below the pump 36 and first acts on an annular area at the lower end of the pump to unseat the pump, thereafter acting on the entire cross sectional area of the pump to move the pump upwardly through the supply tubing to the surface. As will be apparent, the standing valve 84 closes under such conditions to prevent back flow.

After the pump 36 has been removed, if it is desired to remove the standing valve assembly 76 from the well also for any reason, this may be accomplished readily by lowering a suitable tool through the supply tubing 28 on the end of a wire line to engage the standing valve assembly. Thereafter, the standing valve assembly 76 may be pulled upwardly through the supply tubing 28 to the surface. Whenever it is desired to remove the standing valve assembly 76, the tubing system is preferably drained first to balance the pressure on the standing valve assembly so that it may be pulled readily with a wire line. Considering how this is accomplished, the housing 40 of the pump inlet apparatus 34 is provided with a bypass passage 180, FIG. 4, which communicates at its lower end with the well through the packer 42 and which communicates at its upper end with an annular space 182 between the housing 40 and the standing valve assembly 76. The standing valve assembly is provided with a detachable drain plug 184 which, when broken, connects the annulus 182 to the interior of the tubing housing 82 above the standing valve 84 so that the tubing system may drain. The drain plug 184 may be broken in any suitable manner, as by dropping a knock out bar through the supply tubing 28.

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

We claim:

1. In an apparatus for delivering well fluid from a
well to the inlet of a well pump in the well, the combination of: a reservoir in the well; first passage means interconnecting said reservoir and the well in fluid communication for conveying well fluid from the well to said reservoir; second passage means interconnecting said reservoir and the inlet of the well pump in fluid communication for conveying well fluid from said reservoir to the inlet of the well pump; fluid operated main valve means in said first passage means for regulating flow of well fluid through said first passage means from the well to said reservoir; pilot valve means in fluid communication with said main valve means for operating said main valve means; and means responsive to variations in the level of liquid in said reservoir and connected to said pilot valve means for operating said pilot valve means.

2. In an apparatus for delivering well fluid from a well to the inlet of a well pump in the well, the combination of: a reservoir in the well; first passage means interconnecting said reservoir and the well in fluid communication for conveying well fluid from the well to said reservoir; second passage means interconnecting said reservoir and the inlet of the well pump in fluid communication for conveying well fluid from said reservoir to the inlet of the well pump; fluid operated main valve means in said first passage means for regulating flow of well fluid through said first passage means from the well to said reservoir; pilot valve means in fluid communication with said main valve means for operating said main valve means; and means responsive to variations in the level of liquid in said reservoir and connected to said pilot valve means for operating said pilot valve means.

3. In combination: a fluid operated well pump in a well having an inlet for well fluid from the well; means providing a source of clean operating fluid for conveying operating fluid under pressure downwardly in the well to said pump and for conveying spent operating fluid upwardly in the well from said pump; a reservoir in the well; first passage means interconnecting said reservoir and the well in fluid communication for conveying well fluid from the well to said reservoir; second passage means interconnecting said reservoir and said inlet of said pump in fluid communication for conveying well fluid from said reservoir to said inlet of said pump; fluid operated main valve means in said first passage means for regulating flow of well fluid through said first passage means from the well to said reservoir; pilot valve means in fluid communication with said main valve means for operating said main valve means; means intermediate said inlet means and said outlet means; and means for operating said pilot valve means.

5. In an apparatus for delivering well fluid from a well to the inlet of a well pump in the well, the combination of: a reservoir in the well; first passage means interconnecting said reservoir and the well in fluid communication for conveying well fluid from the well to said reservoir; second passage means interconnecting said reservoir and the inlet of the well pump in fluid communication for conveying well fluid from said reservoir to the inlet of the well pump; fluid operated main valve means in said first passage means for regulating flow of well fluid through said first passage means from the well to said reservoir; pilot valve means in fluid communication with said main valve means for operating said main valve means; and means responsive to variations in the level of liquid in said reservoir and connected to said pilot valve means for operating said pilot valve means.

6. In an apparatus for delivering well fluid from a well to the inlet of a well pump in the well, the combination of: a reservoir in the well; first passage means interconnecting said reservoir and the well in fluid communication for conveying well fluid from the well to said reservoir; second passage means interconnecting said reservoir and the inlet of the well pump in fluid communication for conveying well fluid from said reservoir to the inlet of the well pump; fluid operated main valve means in said first passage means for regulating flow of well fluid through said first passage means from the well to said reservoir; pilot valve means in fluid communication with said main valve means for operating said main valve means; and means responsive to variations in the level of liquid in said reservoir and connected to said pilot valve means for operating said pilot valve means.

7. In combination: a fluid operating means having a chamber for conveying well fluid from the well; fluid operated main valve means in said second passage means for regulating flow of well fluid through said second passage means from the well to said reservoir; pilot valve means in fluid communication with said main valve means for operating said main valve means; and means responsive to variations in the level of liquid in said reservoir and connected to said pilot valve means for operating said pilot valve means.

8. In combination: a fluid operating means having a chamber for conveying well fluid from the well; fluid operated main valve means in said second passage means for regulating flow of well fluid through said second passage means from the well to said reservoir; pilot valve means in fluid communication with said main valve means for operating said main valve means; and means responsive to variations in the level of liquid in said reservoir and connected to said pilot valve means for operating said pilot valve means.
member having therein channel means which extends axially thereof a distance less than the axial spacing of said inlet means and said outlet means, but greater than the distances between said port means and said inlet means and said outlet means, whereby said channel means is incapable of bridging said inlet means and said outlet means, but is adapted to bridge said inlet means and said port means and is adapted to bridge said port means and said outlet means; and means connected to said pilot valve member for operating said pilot valve means.