

Aug. 31, 1965

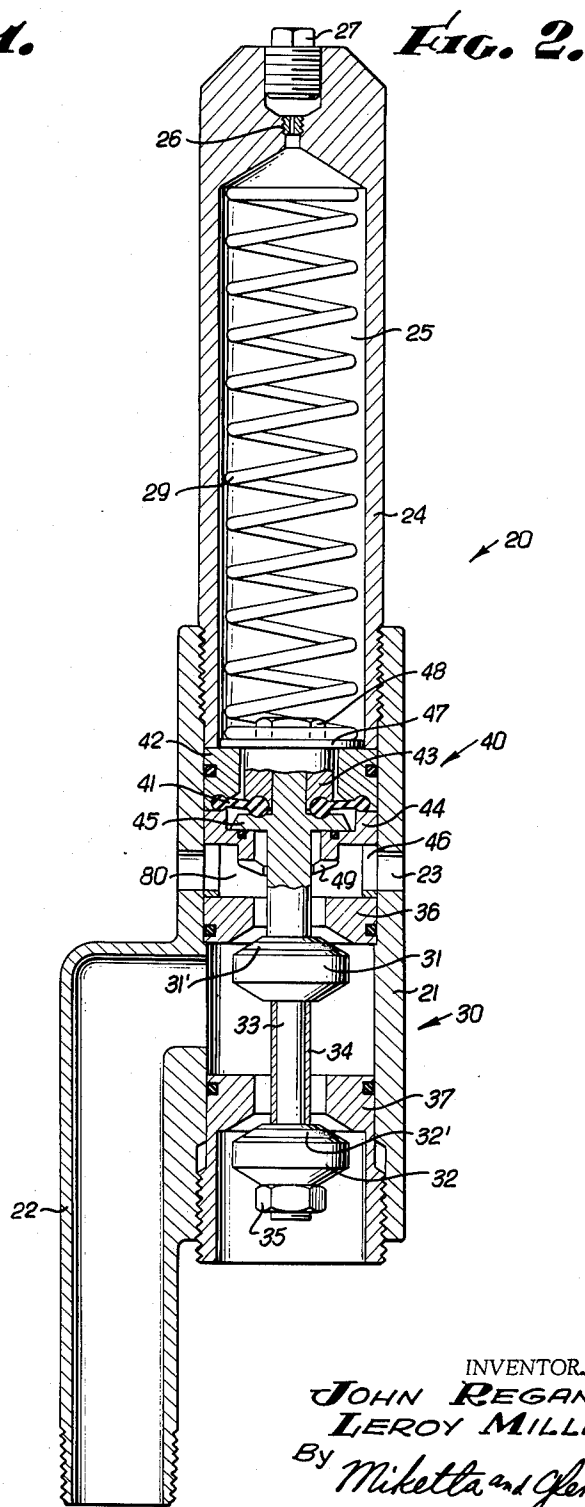
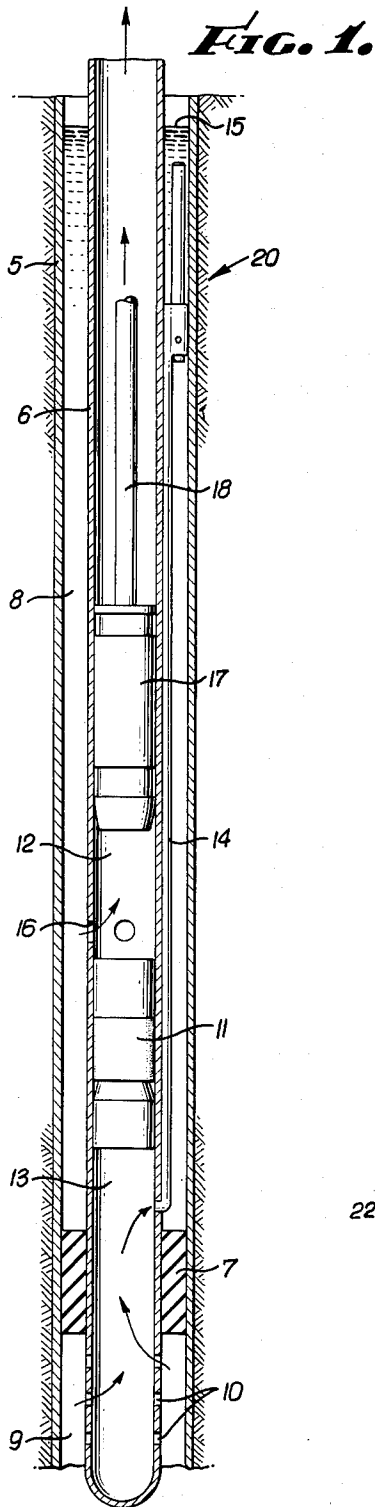
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FLUID FLOW CONTROL APPARATUS

Filed Aug. 13, 1962

3 Sheets-Sheet 1



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FIG. 3.

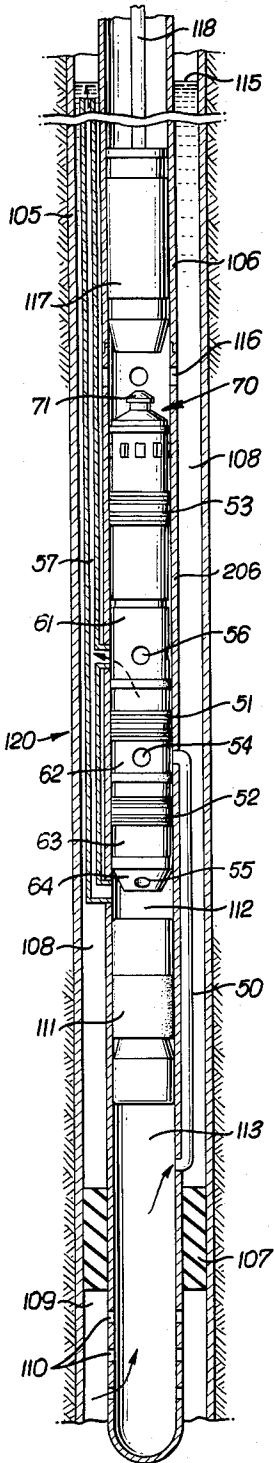


FIG. 4.

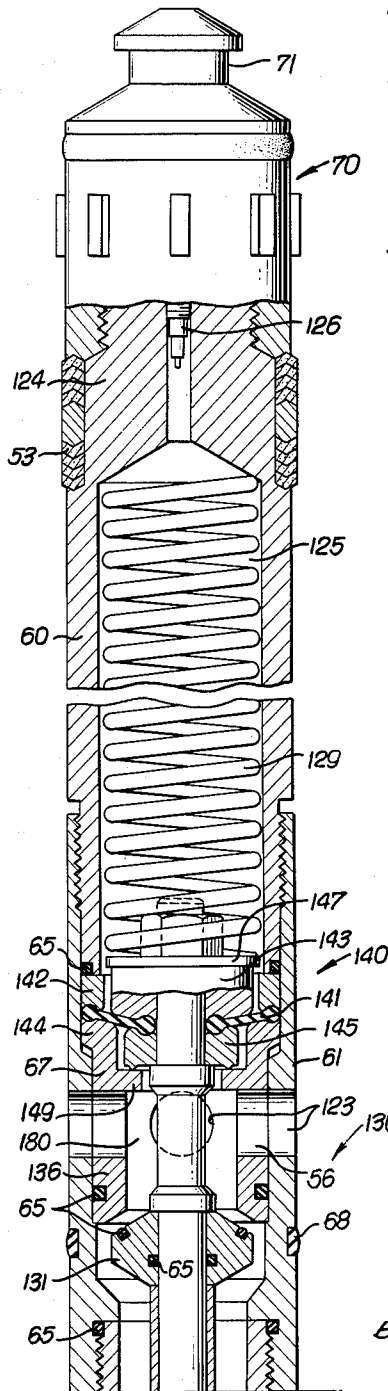
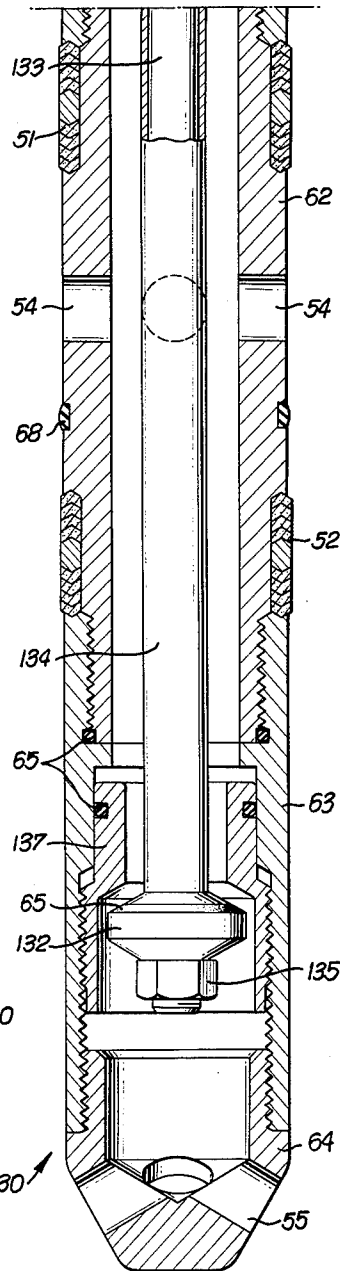


FIG. 4a.



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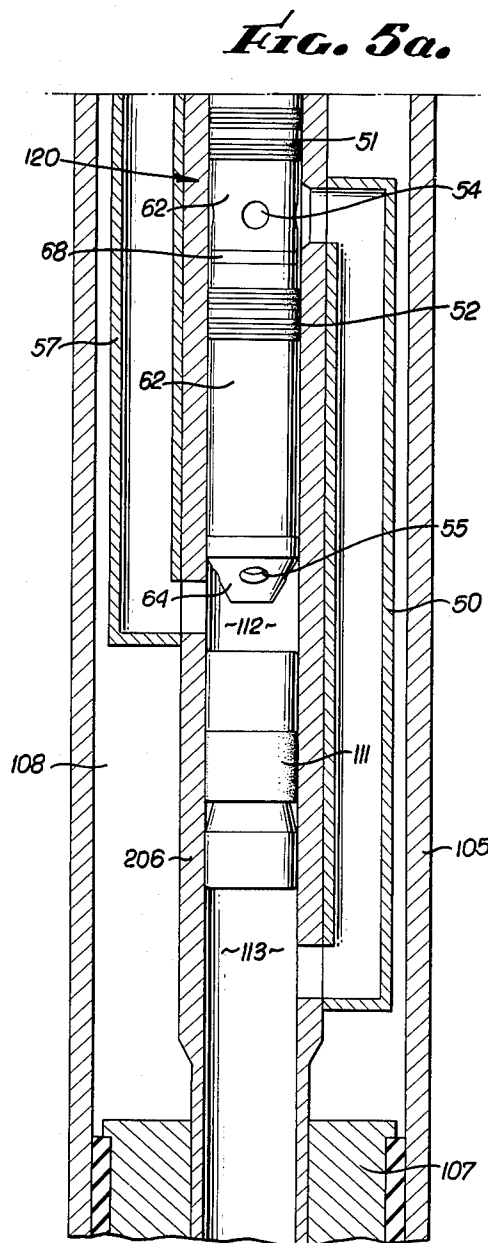
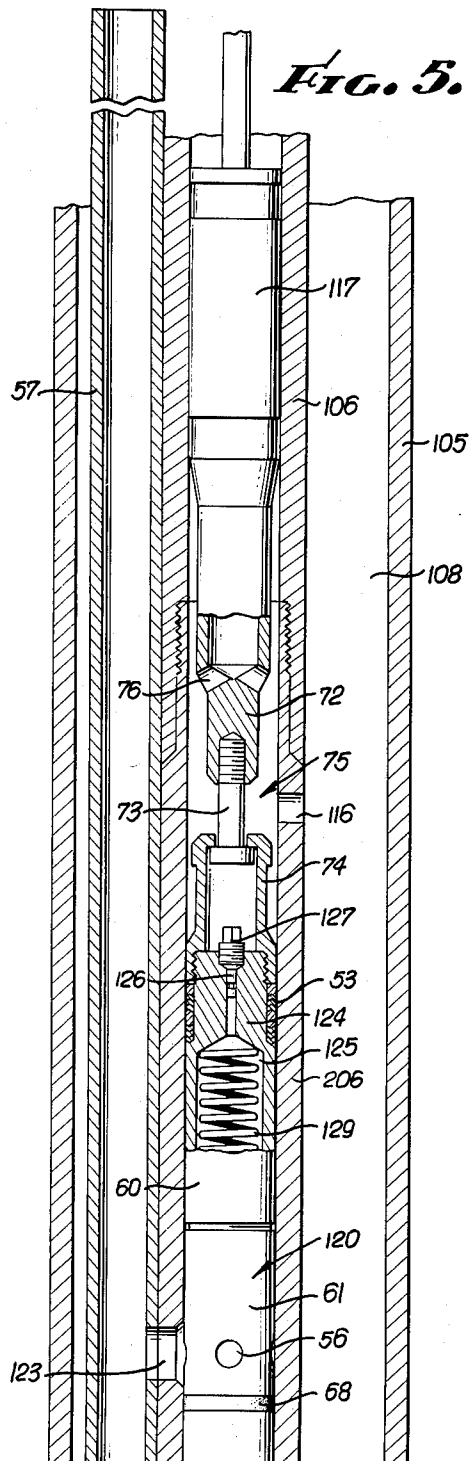
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3 Sheets-Sheet 3



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FLUID FLOW CONTROL APPARATUS

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11 Claims. (Cl. 103—203)

This invention relates in general to apparatus for removing well fluid from wells employing a reservoir between the tubing and casing walls to receive well fluid preparatory to introduction into a well pump. More particularly, the invention relates to the provision of a reservoir fluid level control device adapted for use in such apparatus for maintaining the level of fluid in such reservoir at a predetermined level.

In recovering oil from oil wells employing a bottom hole pump, it has been found that, because of the high gas saturation of the well fluid frequently encountered, it is difficult to pump the fluid to the surface in its natural state. Also, very high well pressures generally exist in such instances of high gas saturation, making it difficult to handle the fluid in attempting to reduce the gas saturation. One way of handling such high pressure, highly gas saturated fluid, is to introduce the well fluid into a reservoir formed between the casing and tubing walls of the well apparatus under conditions of low fluid pressure, allowing the gas to come out of solution and pass up the casing annulus and the liquid oil to settle to a well pump inlet where it is pumped to the surface. However, when very high well pressures are encountered and the well is very deep, the rush of well fluid into the reservoir may cause the reservoir fluid level to rise several hundreds of feet, creating very high fluid pressures within the reservoir at the point the fluid enters the reservoir. The high pressure at the reservoir inlet tends to retard the separation of gas from the well fluid as it is introduced into the reservoir.

It is, therefore, the principal object of the invention to disclose and provide an apparatus for handling high pressure, highly gas saturated well fluid when introducing such fluid into a well apparatus reservoir.

It is a primary object of the invention to disclose and provide a reservoir fluid level control device for use in an apparatus for removing well fluid from wells employing a reservoir for receiving well fluid preparatory to introduction into a well pump wherein flow of well fluid under relatively high well pressures to the reservoir may be easily controlled in response to changes in the relatively smaller pressures in the reservoir.

It is another object of the invention to disclose and provide a fluid flow control apparatus adapted to balance most of the forces of high pressure fluid flowing there-through through opposed, interconnected valve means wherein such valve means are hydrostatically slightly unbalanced to cause fluid flow through the apparatus to urge said valve means into a closed position under a resultant force thereon considerably less than the total amount of force exerted on said opposed valve means.

It is a further object of the invention to disclose and provide a liquid level control device to control the passage of high pressure well fluid into a well apparatus reservoir which may be disposed in an upper portion of the reservoir, be interconnected with the source of well fluid by vertical passage means extending upwardly within the reservoir and which may be readily operated by changes in the relatively smaller fluid pressures in the upper portion of the reservoir.

It is a still further object of the invention to disclose and provide a well apparatus for recovering well fluid from a well including a reservoir to receive well fluid

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preparatory to introduction into a well pump in which apparatus for controlling the flow of well fluid through valve means therein and pressure sensitive means operable in response to reservoir fluid pressures to operate the valve means may be readily removed from the well apparatus without disturbing the casing and tubing walls of the well apparatus.

Generally stated, the invention contemplates the provision of a fluid control device and associated vertical passage means in a well apparatus having spaced, vertical casing and tubing walls forming a reservoir to receive well fluid under high pressure and high gas saturation. The control device maintains the fluid level within the reservoir at below a predetermined level, maintaining fluid pressures in the reservoir adjacent the outlet of the control at relatively low pressures, promoting the separation of gas out of the well fluid. Vertical passage means convey the well fluid to an upper portion of the reservoir such that the settling liquid or oil may pass downwardly in the reservoir under increasing fluid pressures to the inlet of a deep well pump. The control device may be provided at an upper end of the vertical passage means. The control device preferably comprises a generally cylindrical valve body having an inlet to receive the well fluid under high pressures from the vertical passage means and a pair of outlets vertically spaced on either side of the inlet. Valve means are provided in the body by disposing a pair of axially spaced valve poppets in alignment with a pair of ported valve seats opening to the valve body outlets. Fluid flow through the valve body may thus be directed through opposed valves in generally hydrostatically balanced relation. The opposed valves, however, are preferably so provided that a slight unbalancing of the hydrostatic pressures exerted thereon by the fluid flow is effected. This slight unbalancing of the pressures on the opposed valves does not reduce the ease of operation of the valve means and provides a snap action of the valve means upon opening.

A pressure chamber body is provided on an upper portion of the valve body having an enclosed pressure chamber adapted to receive a charging gas. A lower wall of such chamber, according to the invention, is provided with diaphragm means operably associated with the valve poppets in the valve body. The diaphragm means is adapted to react in response to changes in reservoir fluid pressures under the constant bias of the pressure chamber gas. In addition, a secondary seal may be provided between the diaphragm means and the reservoir fluid to facilitate a snap action operation of the valve when fluid pressure in the reservoir rises above a predetermined value.

In an alternative embodiment of the invention, a special tubing nipple is hung on the bottom end of the tubing string in a well apparatus at the approximate location of a bottom hole pump. The tubing nipple has a generally smooth interior and has vertically spaced apertures therein. The vertical passage means in this embodiment are provided in two parts upon the exterior of the tubing nipple, including a primary passage connecting a tubing inlet aperture with the supply of well fluid and a secondary passage connecting two vertically spaced tubing outlet apertures with an upper portion of the reservoir. A fluid level control device, generally as hereinbefore described, may be removably lowered within the tubing nipple, as by a wire line or hung from the bottom hole pump, with its inlet aligned generally with the tubing inlet aperture and the vertically spaced outlets generally aligned with the tubing outlets. Well fluid under high pressure may then rise through the vertical passage means and intermediary, removably disposed control device to an upper portion of the fluid reservoir.

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Further objects and various advantages of our invention will become apparent and a complete understanding of the nature of the invention will be facilitated by the consideration of the following detailed descriptions of an exemplary embodiment of an apparatus for removing well fluid employing the fluid level control device and vertical passage means, according to the invention. Reference will be made to the appended sheets of drawings in which:

FIG. 1 is a vertical sectional view of a well apparatus, including a well fluid receiving reservoir between well casing and tubing string walls employing an exemplary embodiment of apparatus for handling the flow of well fluid into the reservoir, according to the invention;

FIG. 2 is a detail view in section of the liquid level control device of the apparatus for handling the flow of well fluid of FIG. 1;

FIG. 3 is a vertical, sectional view of a well apparatus including a well fluid receiving reservoir between well casing and tubing string walls employing an alternative exemplary embodiment of apparatus for handling the flow of well fluid into the reservoir, according to the invention;

FIGS. 4 and 4a are a detail, sectional view of the removable liquid level control device of FIG. 3; and

FIGS. 5 and 5a are a detail, sectional view of the special tubing nipple and alternative form of vertical passage means employed with the liquid level control device of FIGS. 4 and 4a, but with an alternative means of interconnecting the control device and the well pump.

An exemplary embodiment of the apparatus for removing well fluid from a well including a reservoir fluid level control means, according to the invention, is shown in FIGS. 1 and 2. Referring first to FIG. 1, a well casing member 5 is shown installed in an oil well with a production pipe or inner tubing member 6 extending down through the casing generally concentric therewith. Packing means, such as the packer 7, are provided between tubing 6 and casing 5 at a lower end thereof to seal well fluid below the packer 7 and to form a well fluid receiving reservoir 8 above the packing means. Reservoir 8 extends upwardly from packer 7 in the casing annulus formed between the casing 5 and the inner concentric tubing 6 above packer 7. A lower casing annulus 9 is formed below packer 7 between the inner or production tube 6 and the casing 5, which is open to the well fluid and the high pressures exerted by such fluid. In the embodiment shown, the bottom of tubing 6 is closed to the well and a plurality of ports 10 are provided to allow well fluid to pass from the annulus 9 into the interior of tubing 6. The provision of such ports 10 is optional since the bottom end of tubing 6 could be made open rather than closed, as shown.

Tubing plug 11 is provided in the inner or production tube 6 at a point spaced above the packer 7. Plug 11 is provided to form a pump inlet chamber 12 in the tubing bore above plug 11 and a well fluid receiving chamber 13 in the tubing bore below plug 11.

Passage means are provided to interconnect the reservoir 8 with the well fluid receiving chamber 13 which is open to the well fluid of the well. Such means in the preferred embodiment include a vertical passage or stand pipe 14 which has its lower end connected into an upper portion of chamber 13 at a point thereof between plug 11 and the packer 7. Vertical passage or stand pipe 14 extends upwardly from its lower end between the tubing 6 and casing 5 within the reservoir 8. Passage 14 opens into the reservoir 8 through an aperture at an upper end which is vertically spaced from packer 7 within the reservoir 8 by as much as 100 feet and is preferably relatively near (such as 5 to 10 feet) to a predetermined normal fluid level for the fluid within the reservoir, indicated at 15.

Well fluid with gas in solution enters the casing annulus 9 below packer 7, passes through ports 10 into the well fluid inlet chamber 13 below plug 11, rises due to

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well pressure through the vertical passage means or stand pipe 14 to an upper portion of reservoir 8 where it is discharged into reservoir 8 under relatively low pressure. Gas coming out of solution passes upwardly through the casing annulus. The well fluid settling in the reservoir 8 is drawn through the ports 16 in tubing 6, into the pump inlet chamber 12. Inlet 16 is at a lower portion of the reservoir 8 where higher fluid pressures exist due to the head of fluid in the reservoir. The well fluid is then evacuated by the pump 17 and forced upwardly through tubing 16 to the surface of the well. Pump 17 may be of any conventional form of well pump, as the well known form of fluid operated well pump, employing sucker rods or macaroni tube 18.

The level of the well fluid within reservoir 8 is maintained at a predetermined level above the top opening of the vertical passage means to promote the escape of gases from the well fluid introduced into the reservoir. Means for controlling the reservoir fluid level are provided, such means comprising a liquid level control, indicated generally at 20, according to the invention. It is preferred in the embodiment of FIGS. 1 and 2 to position the liquid level control, indicated generally at 20, within the reservoir and at an upper portion thereof where it is subjected to the reservoir fluid pressures present in the upper portions of the reservoir, rather than at a lower portion of the reservoir where fluid pressures are relatively much higher. Normally, the length of the vertical passage or stand pipe 14 is between about 20 and about 30 feet but it may be as long as 100 feet. The liquid level control valve, according to the invention, may be disposed in this relatively high area of reservoir 8 and be operable by the relatively low reservoir fluid pressures present therein due to the ability of the control to regulate the high pressure well fluid passing therethrough in response to changes in the relatively small fluid pressures in the upper portion of the reservoir.

Reservoir fluid level control, indicated generally at 20 and as shown in detail in FIG. 2, is provided with a main valve body 21 having a side inlet tube 22. Inlet tube 22 is adapted at its lower end to be attached to the upper end of vertical passage means 14 and introduces the well fluid passing upwardly through such passage means into a generally central portion of the cylindrical open ended body 21. A plurality of ports 23 in the walls of body 21 above the inlet tube 22 allow the well fluid passing upwardly through passage means 14, inlet tube 22 and the body 21 to pass into the reservoir 8, as well as through the lower open end of body 21. A pressure chamber body 24 is provided at an upper end of valve body 21, removably attached to body 21 by a threaded connection thereto, forming a pressure chamber 25 therein adapted to be precharged with gas. Pressure or diaphragm chamber 25 may be precharged through the dill core 26, at an upper end of body 24. A pipe plug 27 seals such upper end as a safety measure to retain the charge within chamber 25 and to keep external pressure out should the well pressure cause a reservoir pressure exceeding the charging pressure. Such charging pressures are normally about 150 pounds per square inch. The precharging of chamber 25 acts as a diaphragm biasing means to maintain the valve means, indicated generally at 30 and the diaphragm means indicated generally at 40, in an open position allowing the passage of well fluid from inlet tube 22 through the ports 23 and the lower open end of body 21 into reservoir 8, as subsequently described. When the fluid pressure in the reservoir 8 in the upper portion thereof near the normal reservoir fluid level rises sufficiently to overcome the bias of such precharging, the valve means 30 close, preventing further flow of well fluid into reservoir 8. Valve means 30 are retained closed until the pump 12 removes sufficient fluid from reservoir 8 to lower the fluid pressure within the reservoir by returning the level of reservoir fluid to the predetermined normal level indicated at 15 in FIG. 1.

Valve means are disposed within reservoir 8 below the normal fluid level in the reservoir and are interconnected between the vertical passage means 14 at its upper end or aperture and the reservoir 8. Such valve means, indicated generally at 30, include an upper poppet 31 and a lower poppet 32 axially spaced apart upon a stem 33 by a poppet spacer 34. A nut 35 threadably attached to the stem 33 maintains the poppets in such spaced relation upon the stem 33. Stem 33 passes through a pair of spaced opposed ports formed in an upper valve seat 36 and an adjustable lower valve seat 37 which is threadably received in the lower portion of body 21. Sealing means, such as an O-ring seal or preferably a molded rubber, are provided on the valve seats 36 and 37, respectively, as shown in FIG. 2 to prevent the passage of sand and fluid between the seats and the body 21. Similarly, a sealing means, preferably of molded rubber are provided on the upper surface of each of the poppets 31 and 32 as shown in FIG. 2 at 31' and 32', respectively. Valve poppet 31 is disposed below the upper ported valve seat 36, being between or inwardly of the two valve seats. Valve poppet 32 is disposed below the lower ported valve seat 37, being below or outwardly of the spaced ported valve seats. Therefore, well fluid under high pressure passing from inlet tube 22 into the interior of body 21 attempts to force the upper poppet closed and lower poppet open, effecting a general balancing of the high well fluid pressures. The well fluid then passes from the interior of body 21 at the inlet 22 through the upper ported valve seat 36 into the discharge chamber 80 opening to reservoir 8 through ports 23 and through the lower ported valve seat 37 into the reservoir 8.

Preferably, the effective hydrostatic pressure exerted on the poppets 31 and 32 by the well fluid within body 21 is slightly unbalanced to provide a resultant closing force on the poppets due to well pressure. If the poppets 31 and 32 are provided identically with identical molded rubber sealing means 31' and 32', the valve will be perfectly hydrostatically balanced when closed. We have found that by providing a slightly larger sealing means 31 (having a greater surface area than the bottom sealing means 32) than means 32, a slight unbalancing of the valve means may be attained. Thus, when in a closed position, the valve means is held closed by the well fluid pressure in body 21, but under a considerably smaller force than the total force being exerted on the valve means by the well fluid.

An upper portion or head of stem 33 is associated with diaphragm means, indicated generally at 40, to cause the opening and closing of the valve means, indicated generally at 30, to be responsive to fluid pressure within the reservoir 8 as determined by the liquid level within reservoir 8. Diaphragm means, indicated generally at 40, may include the diaphragm 41 retained between a pair of upper retainer rings, outer retainer ring 42 and inner retainer ring 43, and a pair of lower retainer rings, lower retainer ring 44 and valve stem retainer ring 45. The outer (upper and lower) retainer rings 42 and 44, are fixedly held within body 21, upper outer ring 42 abutting the body 24 at its upper portion and outer lower retainer ring 44 abutting a perforated spacer ring 46 fixedly held within body 21 by the upper ported valve seat 36. Seat 36 may rest on a ledge formed in the body 21. Upper inner retaining ring 43 and the diaphragm means, indicated generally at 40, are biased downwardly by the precharged gas within chamber 25. Spring means 29 are provided to also bias the ring 43 downwardly. Such spring means are optional and are provided to cause the valve to open should the gas pressure accidentally bleed off from the pressure chamber 25. A washer 47, positioned on upper inner retaining ring 43 by a nut 48 threadably attached to the upper end of stem 33, transmits the spring bias to the stem 33.

Slotted guide means 49, depending from lower outer

retaining ring 44 may be provided to guide the stem in its vertical movement between open and closed positions.

Diaphragm 41 forms a primary seal between the pressure chamber 25 and the fluid discharge chamber 29, the diaphragm reacting to variances in pressure between the two chambers. A secondary seal is effected between the lower inner retaining ring 45 formed in the stem 33 and the lower outer retaining ring 44. When the valve is in the open position as shown in FIG. 2, a smaller area on the valve stem ring 45 is exposed to the reservoir pressure than when the valve is open and the lower surface of the diaphragm is exposed. Thus, the valve is given a snap action as soon as the pressure in chamber 29 reaches a point which causes a break in the secondary seal effected between the ring 45 and the ring 44. Since the actuating pressure acts on the larger surface of diaphragm 41, effecting a greater force on stem 33, than that on ring 45.

In operation, the control apparatus is lowered into the casing annulus down through the well fluid standing therein. As the apparatus is lowered, the increase in fluid pressure exerted through ports 23 on the bottom of diaphragm 41 tends to close the valve poppets upon their respective seats. After insertion of the packing means 7 causing well fluid to pass through the tubing annulus 13 and vertical passage means 14, the well fluid pressure in body 21 tends to keep the valve poppets 31 and 32 closed as well as diaphragm means 40. As well fluid is pumped from the reservoir formed between the tubing and casing walls, the pressure on the outer surface of diaphragm 41, acting through ports 23, decreases until the pressures on either side of diaphragm 41 are equalized. However, further reduction of the reservoir pressure is required to allow the pressure in the pressure chamber 25 to move the diaphragm 41 and poppets 31 and 32 due to the unbalancing thereof. When the effect of the unbalancing is overcome, the poppets 31 and 32 will snap open since once the poppets are unseated, the unbalancing of the hydrostatic pressures on the sealing means 31 and 32 is lost. Thus, a quick positive action of the valve is attained upon opening. Also, we have noticed a slight elongation of the stem 33 between the poppets when very high well pressures are encountered which causes the lower poppet to be unseated. By unbalancing the effective hydrostatic pressures upon the poppets as hereinbefore described, the poppets are urged upwardly under higher well fluid pressures in body 21, compressing the seal 31 more, and maintaining seal 32 closed even where a slight elongation of the stem 33 occurs. When the fluid level in the reservoir increased to an undesirable height, increasing the pressure exerted on the previously described primary sealing means of the diaphragm means 40, the valve will snap closed as previously explained.

An alternative exemplary embodiment of the apparatus for removing well fluid from a well, including a reservoir fluid level control device, according to the invention is shown in FIGS. 3, 4, 4a, 5 and 5a. In the prior exemplary embodiment of FIGS. 1 and 2, the fluid level control, indicated generally at 20, cannot be brought to the surface for servicing without pulling the tubing, a very costly operation. In the embodiment of FIGS. 3, 4 and 5, the fluid level control device, indicated generally at 120, is adapted to be readily removed from the well without removing the tubing string 106. In general, this is accomplished by suspending the fluid level control from the deep well pump and providing a special tubing nipple on the bottom end of the tubing string, as described hereinafter. The fluid level control and tubing nipple can also be run on wire line tools to be set below the pump and retrieved with a wire line after the pump has been pulled.

Referring first to FIG. 3, the fluid level control, indicated generally at 120, may be provided with a conven-

tional lockdown assembly, indicated generally at 70. The lockdown assembly serves to hold the fluid level control in position within the generally smooth inner surfaced tubing string when in lowered position and may be provided with a wire line fishing deck 71 adapted to facilitate removal of the control means by dropping a wire line thereon and raising it. Alternatively, a direct rigid connection between the bottom end of the pump 117 and control means can be provided such that removal of the pump 117 by pulling up the sucker rods or macaroni tube 118 extending from the pump to the surface, will concurrently remove the control means, indicated generally at 120. Preferably, the connection between the pump and control means is flexible and may be provided as shown in FIG. 5 with a slip joint, indicated generally at 75.

Referring again to FIG. 3, a well casing member 105 is shown installed in an oil well with a production pipe or inner tubing string 106 extending down through the casing generally concentric therewith. Packing means, such as the packer 107, are provided between the tubing string 106 and the casing tube 105 at a lower end thereof to seal well fluid below the packer 107 and to form a well fluid receiving reservoir 108 above the packing means, as in the embodiment of FIGS. 1 and 2. A lower casing annulus 109, formed below packer 107 between the inner or production tubing string 106 and the casing 105, is open to the well fluid at relatively high well pressures. The bottom end of the production tubing string 106 may be closed to the well with a plurality of ports 110 as shown in FIG. 3 or it may be left open to receive well fluid into the well fluid receiving chamber 113 formed within the inner tubing string 106 below the tubing plug 111. In the exemplary embodiment of FIGS. 3, 4 and 5, the inner tubing bore 112 above the tubing plug 111 is adapted to receive the fluid level control means, indicated generally at 120, and the deep well pump 117, as best shown in FIG. 3. Both the deep well pump 117 and the fluid level control means, indicated generally at 120, may be withdrawn from the tube 5 and reinserted therein without disturbing the positioning of the production tubing string 106.

Vertical passage means are provided to interconnect the reservoir 108 with the well fluid. Such means in the present exemplary embodiment comprise a primary vertical passage, such as bypass pipe 50, adapted to interconnect the chamber 113 and control means, and a secondary vertical passage, such as the stand pipe 57, to interconnect the control means with reservoir 108.

In operation, the well fluid passes from chamber 113 through primary vertical passage means, as bypass pipe 50, into the fluid level control means, indicated generally at 120, and then upwardly through the secondary vertical passage means, as stand pipe 57, to an upper portion of reservoir 108 where the entrapped gases may escape under conditions of relatively low fluid pressure, the upper end of the secondary passage means being relatively near the normal fluid level 115 in reservoir 108. The primary and secondary passages thus provide a vertical passage means as in the embodiment of FIGS. 1 and 2 except that the valve means of the present removable control device is disposed in an intermediary portion of the passage means, rather than at an upper portion.

According to the invention, the vertical passage means may be provided on a special tubing nipple 206 shown in detail in FIGS. 5 and 5a. Special tubing nipple 206 is adapted to be secured to the lower end of the tubing string 106 at about the location therein that the pump 117 is to be positioned, as shown in FIG. 5. The tubing nipple 206 is provided with the plug 111 forming tubing bore chamber 112 above and the tubing bore chamber 113 below and is adapted to be lowered into the packing means 107. The bypass pipe 50, or primary passage means, is secured to the side of nipple 206 with a lower end communicating with tubing bore chamber 113. The upper end of the bypass pipe, passing around the plug

111, opens into a valve inlet chamber defined by the packing means 51 and 52, the control device and the interior of tubing nipple 206. Such valve inlet chamber is in fluid communication with the valve inlet ports 54 regardless of the positioning of the ports provided only that the packing means 51 and 52 straddle the outlet or upper end of the bypass pipe 50.

The secondary vertical passage means, as stand pipe 57, may be disposed on the special tubing nipple 206 as shown in FIG. 5a with its lower end communicating with the tubing bore chamber or valve outlet chamber 112 to receive fluid flow from valve outlet ports 55. The upper exhaust ports 56 on the control means exhaust into a chamber formed within nipple tube 206 between the control means, packing means 51 and vertically spaced packing means 58. This valve outlet chamber is in fluid communication with the secondary vertical passage means or stand pipe 57 at a point vertically spaced above the lower end of pipe 57. Such spacing is generally equal to the spacing between ports 56 and 55 on the control means. The upper end of stand pipe 57 carries the well fluid well above tubing ports 116 in the tubing nipple 206 directly below the pump 117. Well fluid in reservoir 108 may thus pass into the interior of the tubing nipple 206 at a point in the tubing string 106 well below the normal liquid level 115 of the reservoir liquid.

Connector means to attach the liquid level control to the bottom of pump 117 may be provided such as the slip joint connecting means shown generally at 75 in FIG. 5. A pump nipple 72 depending from pump 117 may be provided with a key member 73 adapted to slip into the housing 74 disposed upon the top portion of the control means indicated generally at 120. Pump inlet ports 76 are provided in pump nipple 72, as shown in FIG. 5, to withdraw well fluid from the interior or bore of tubing nipple 206 above the packing means 53 and pump it to the surface.

Referring now to FIGS. 4 and 4a, the alternative exemplary embodiment of a fluid level control means, according to the invention and as shown generally at 120 in FIG. 3, is provided with a body assembly including a pressure chamber and a generally cylindrical valve body. Such valve body may include an upper valve body portion 61, a center valve body portion 62, a lower valve body portion 63 and a bottom nose portion 64.

Pressure chamber body portion 60 is provided in an upper end of the body assembly, removably attached thereto by a threaded connection, and forms a pressure chamber 125 therein adapted to be precharged with gas as in the embodiment of FIGS. 1 and 2. A drill core 126 at the upper end of pressure chamber body 124 and a pipe plug 127 sealing such upper end are provided for introducing gas into the chamber 125. In addition to the precharged gas within chamber 125, acting as a diaphragm biasing means to maintain the valve means indicated generally at 130 and a diaphragm means indicated generally at 140 in an open position, spring means 129 may be provided to hold the valve in an open position should the gas within chamber 125 be accidentally evacuated. Spring means 129 are optional.

Valve means, indicated generally at 130, include an upper poppet 131 and a lower poppet 132 axially spaced apart upon a stem 133 by a poppet spacer 134. A nut 135 threadably attached to the lower end of stem 133 maintains the poppets in assembled relation upon stem 133. Stem 133 passes through a pair of spaced, opposed ports formed in an upper valve seat 136 and an adjustable lower valve seat 137 which is threadably received in the lower valve body portion 63 of the control body assembly. Sealing means, such as the O-rings 65, are provided on the valve seats 136 and 137, poppets 131 and 132 and at the junctures between the various body assembly body portions as shown in FIGS. 4 and 4a. In addition, sand seal means 68 are preferably provided above the packing means as indicated in FIG. 4a to stop sand from packing

between the control device and the inner bore of tubing nipple 206. If allowed to settle in these areas, the sand would tend to freeze the control into the tubing nipple making it impossible to remove it to the surface.

Well fluid entering the ports 54 in the central valve body portion 62 from the bypass pipe 50 pass both upwardly and downwardly within the control body assembly, producing a slightly unbalanced hydrostatic pressure upon the poppets 131 and 132 as in the first embodiment disclosed. The well fluid then passes from the interior of the control body assembly through the upper ported valve seat 136 into a discharge chamber 180 opening to the reservoir 108 through the ports 123 and vertical passage means 57 and downwardly through the lower ported valve seat 137 opening into the reservoir 108 through the ports 55 of lower nose body portion 64 and the vertical passage means 57.

The upper portion or head of stem 133 is associated with diaphragm means, indicated generally at 140 as in the embodiment of FIGS. 1 and 2, to cause the opening and closing of the hydrostatically balanced valve means, indicated generally at 130, in response to variations in the fluid pressure within reservoir 108 as determined by the liquid level, indicated at 115, within the reservoir. The diaphragm means may include the diaphragm 141 retained at its outer edges between a pair of opposed outer retainer rings 142 and 144. The inner portions of diaphragm 141 are maintained between a pair of opposed inner retainer rings 143 and valve stem retainer ring 145. Ring 142 abuts at its upper surface on the pressure chamber body 60 while lower outer ring 144 abuts at its lower portion against a ledge formed within the upper valve body portion 61. It should be noted that in the embodiment of FIGS. 4 and 4a, the lower outer retainer ring 144 includes integrally formed stem guide portions 149, a lower perforated ring portion and upper valve seat 136. Thus, the lower retainer ring 44, slotted stem guides 49, perforated spacer ring 46 and upper ported valve seat 36 of the embodiment of FIGS. 1 and 2 is provided in an integrally formed unit 67 in the embodiment of FIGS. 4 and 4a. Upper inner retaining ring 143 is biased downwardly by the precharged gas within chamber 25 and the optional spring means 129 abutting against the washer 147 positioned between the spring 129 and ring 143. As in the embodiment of FIGS. 1 and 2, diaphragm 141 forms a primary seal between the pressure chamber 125 and the fluid discharge chamber 180, the diaphragm reacting to variances in pressure between the two chambers. A secondary seal is also effected between the lower inner retaining ring 145 mounted on the stem 133 and the lower outer retaining ring portion 144 of unit 67. Thus, a snap action is given to the valve means as in the embodiment of FIGS. 1 and 2.

From the foregoing detailed descriptions of exemplary embodiments of the apparatus for handling high pressure, high gas saturated well fluid and the reservoir liquid level control device employed therein, it may be seen that such well fluid is easily introduced into the well apparatus reservoir in readily controlled amounts maintaining the liquid level of the reservoir at a predetermined level. In addition, the flow of fluid through the valve means of the control device is hydrostatically balanced so that actuation of the valve means may be readily and easily accomplished by the pressure sensing device, operating under the force of relatively low reservoir pressures upon the diaphragm means. Further, in the alternative exemplary embodiment, the hydrostatically balanced valve means, pressure sensing means, etc. of the control device may all be removed from the well apparatus without disturbing the casing and tubing string walls, including the tubing nipple and vertical passage means provided thereon.

Having thus described the invention in detail by reference to exemplary embodiments thereof and noting that other modifications, embodiments, alternatives and refinements thereof may be made within the scope of the inven-

tion, what is claimed and new and desired to be secured by Letters Patent is:

1. In an apparatus for removing well fluid from a well including spaced, vertical casing and tubing walls forming a reservoir to receive well fluid preparatory to introduction into a well pump, the provision of:

vertical passage means interconnecting said reservoir with well fluid from said well, said passage means extending upwardly in said reservoir above the pump and opening into said reservoir at an upper portion thereof below a normal fluid level;

valve means associated with said passage means to control flow of fluid into said reservoir; and

pressure sensitive means responsive to changes in fluid level in said reservoir to operate said valve means to closed position upon the rise of well fluid above a predetermined level within said reservoir.

2. The apparatus of claim 1 wherein said valve means is disposed within said reservoir at an upper end of said vertical passage means below the normal fluid level in said reservoir and said pressure sensitive means is disposed in said reservoir above said valve means.

3. The apparatus of claim 1 wherein said valve means comprises:

a valve body having an inner chamber and two aligned spaced ports opening said chamber to said reservoir; a valve stem through said aligned ports associated at one end with said pressure sensitive means;

a pair of valve poppets on said stem, axially spaced apart thereon to cooperate with said ports, one of said poppets being on the inner side of one of said ports and the other of said poppets being on the outer side of the other of said ports.

4. The apparatus of claim 3 wherein the effective hydrostatic pressure receiving area of said one poppet is greater than that of said other poppet when said poppets are in closed position.

5. The apparatus of claim 1 wherein said pressure sensitive means comprises:

a pressure chamber body mounted on said valve means and receiving an upper portion of said valve stem; diaphragm means associated with said upper portion of said valve stem;

passage means interconnecting one side of said diaphragm means with said reservoir; and means within said chamber body to bias said diaphragm against fluid pressure of said reservoir exerted on said one side of said diaphragm.

6. A device for introducing well fluid into a deep well pump, comprising:

a casing member; an inner, generally concentric tubing member; packing means between said tubing and casing to seal well fluid below said packing means and form a well fluid receiving reservoir above said packing means; a plug in said tubing above said packing means; a deep well pump in said tubing above said plug and communicative with said reservoir;

passage means interconnecting said reservoir with well fluid in said well, said passage means including a vertical passage interconnected at its lower end with said tubing at a point between said plug and packing means, extending upwardly between said tubing and casing within said reservoir and opening into said reservoir at an upper aperture vertically spaced above said packer means, plug and pump;

valve means disposed within said reservoir below a normal fluid level in said reservoir and interconnected with said passage means upper aperture; and means within said reservoir for controlling said valve in response to changes in the level of fluid in said reservoir to maintain a predetermined normal fluid level.

7. A device as in claim 6 wherein said valve means comprises:

a valve body having an inner chamber and two aligned

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- spaced ports opening said chamber to said reservoir;
 a valve stem through said aligned ports associated at
 one end with said pressure sensitive means; and
 a pair of valve poppets on said stem, axially spaced
 apart thereon to cooperate with said ports, one of
 said poppets being on the inner side of one of said
 ports and the other of said poppets being on the outer
 side of the other of said ports and where well fluid
 pressure in said valve means is hydrostatically un-
 balanced on said poppets.
8. A device as in claim 6 wherein the pressure sensi-
 tive means comprises:
 a pressure chamber body mounted on said valve means
 and receiving an upper portion of said valve stem;
 diaphragm means associated with said upper portion
 of said valve stem;
 passage means interconnecting one side of said dia-
 phragm means with said reservoir; and
 means within said chamber body to bias said diaphragm
 against fluid pressure of said reservoir exerted on
 said one side of said diaphragm.
9. In the apparatus of claim 1, the provision of a tub-
 ing nipple at a lower end of the tubing walls having a plu-
 rality of vertically spaced apertures therein and wherein
 said vertical passage means includes primary and second-
 ary passages mounted on sides of said nipple and said hy-
 drostatically balanced valve means is removably received
 within said nipple intermediate said primary and second-
 ary passages.
10. A device for introducing well fluid into a well pump,
 comprising:
 vertical spaced casing and tubing walls forming a res-
 ervoir therebetween for receiving well fluid from a
 well;
 a pump disposed between a lower portion of said tub-
 ing walls and communicative with a lower portion
 of said reservoir;
 vertical passage means interconnecting said reservoir
 with well fluid from said well, said passage means
 extending upwardly in said reservoir above said pump
 and opening into said reservoir at an upper portion
 thereof but below the normal fluid level in said reser-
 voir;
 valve means disposed within said reservoir at said up-
 per portion being below the normal fluid level in

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- said reservoir and interconnected with said passage
 means; and
 pressure sensitive means in said reservoir and asso-
 ciated with said valve means adapted to operate said
 valve to maintain a predetermined level of fluid with-
 in said reservoir.
11. In an apparatus for removing well fluid from a deep
 well including spaced, vertical casing and tubing walls
 forming a reservoir to receive well fluid preparatory to
 introduction into a deep well pump removably disposed
 within said tubing walls, the provision of:
 a tubing nipple depending from a lower end of said
 tubing wall, said tubing nipple having vertically
 spaced apertures in a side wall thereof;
 vertical passage means associated with said tubing nip-
 ple to interconnect said reservoir with a source of well
 fluid through said tubing nipple side wall apertures;
 valve means removably receivable within said tubing
 nipple having inlet and outlet means for alignment
 with said tubing nipple side wall apertures when said
 valve means is received within said tubing nipple,
 said valve means controlling fluid flow through said
 vertical passage means between said source of well
 fluid and said reservoir when removably received
 within said tubing nipple; and
 fluid pressure sensitive means removably receivably
 within said tubing nipple and associated with said
 valve means for operating said valve means in re-
 sponse to changes in the level of well fluid in said
 reservoir, said tubing nipple having aperture means
 in a side wall thereof communicating fluid pressure
 of said reservoir to said fluid pressure sensitive means
 when said fluid pressure sensitive means is received
 within said tubing nipple.

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