March 9, 1943. G. A. HATFIELD 2,313,066

GAS LIFT DEVICE FOR WELLS

Filed Jan. 8, 1940 2 Sheets-Sheet 1

Fig. 1.

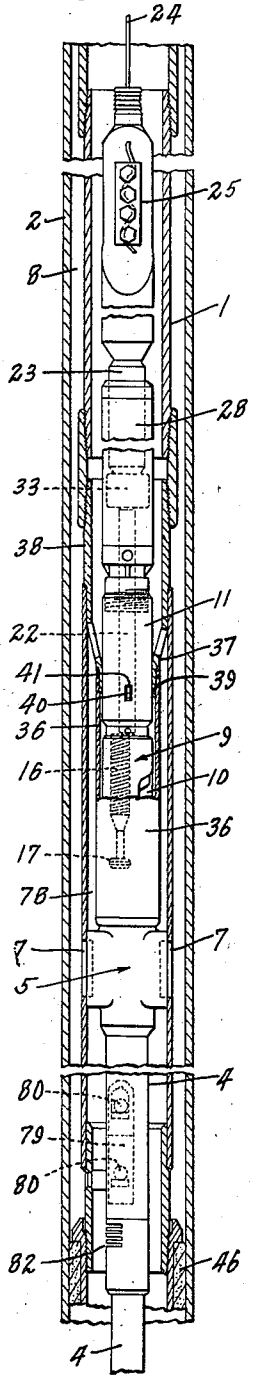
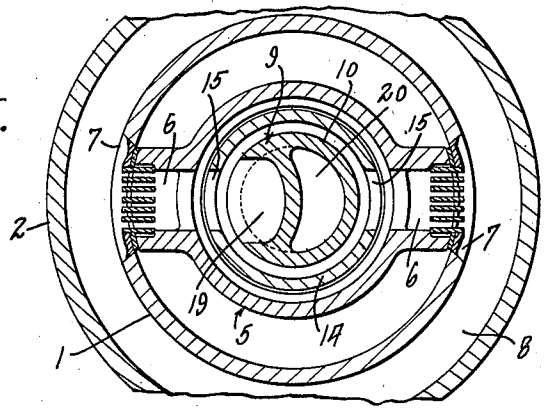


Fig. 5.



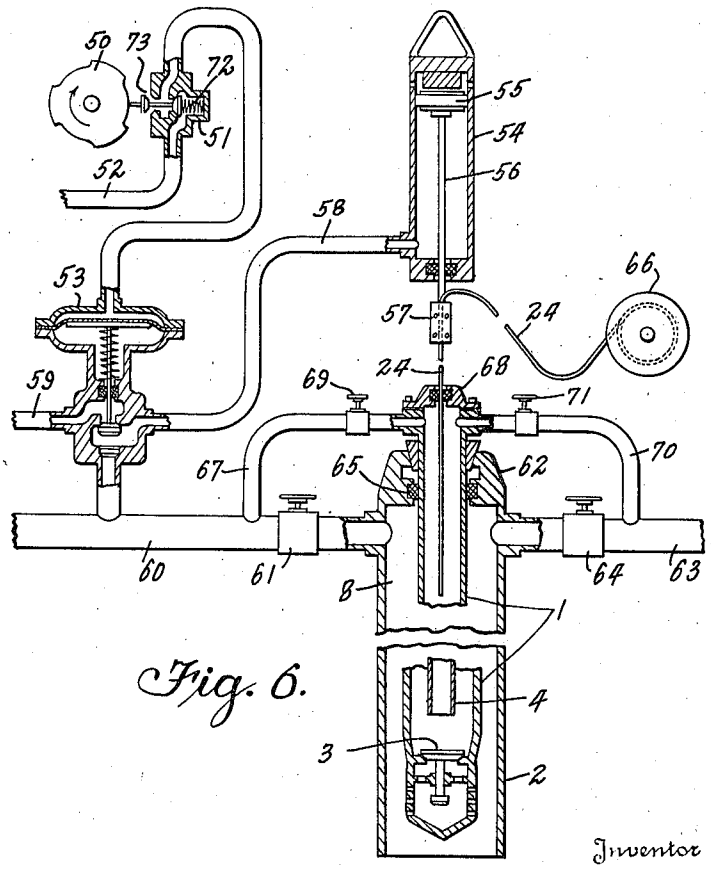


Fig. 6.

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Fig. 2.

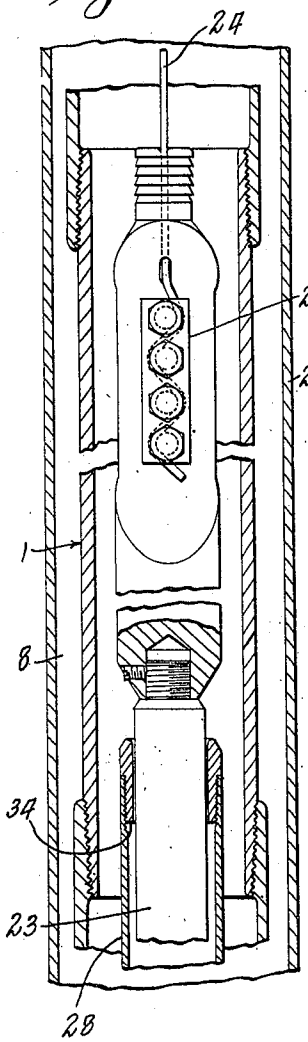


Fig. 3.

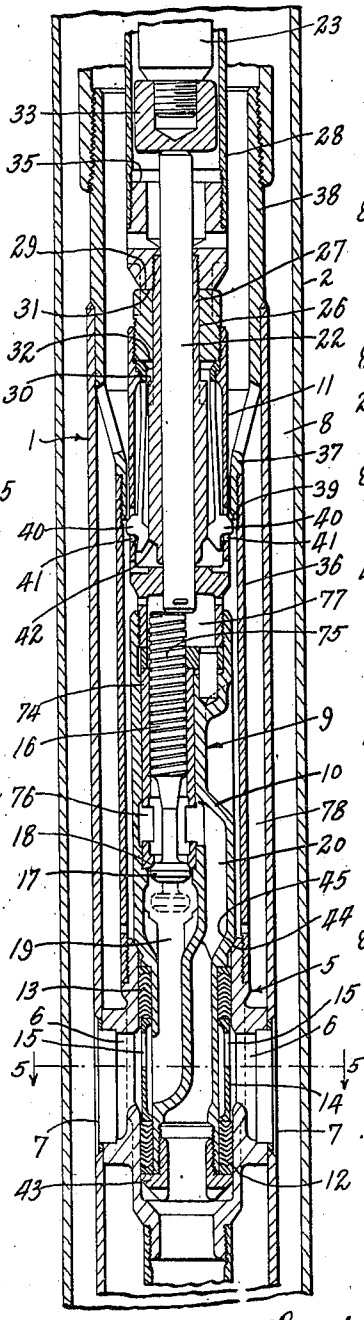
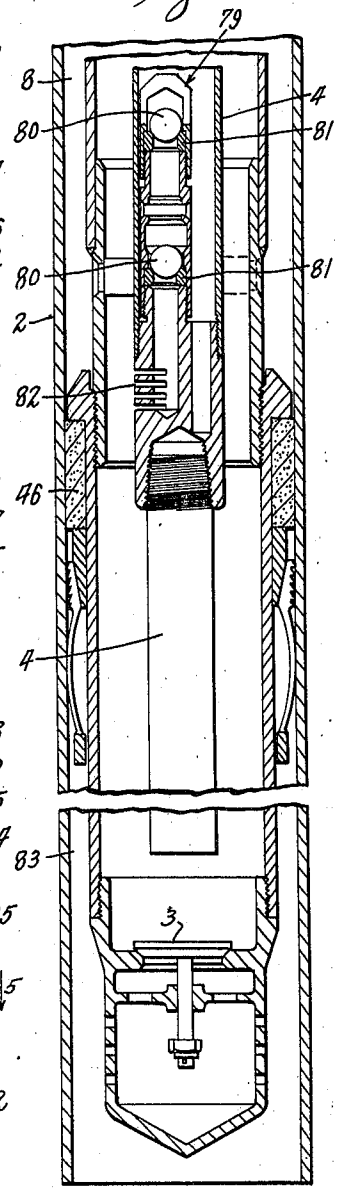


Fig. 4.



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Patented Mar. 9, 1943 2,313,066

UNITED STATES PATENT OFFICE

2,313,066

GAS LIFT DEVICE FOR WELLS

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Application January 8, 1940, Serial No. 312,833

13 Claims. (Cl. 103—240)

This invention relates to apparatus for use in raising fluid from wells, utilizing gas under pressure as the lifting means.

The invention is particularly directed to such apparatus havng means for positively controlling the flow of the lifting gas into the fluid column.

The principal object of my invention is to provide a valve structure for a gas lift apparatus which can be positioned within a well on a wire line and when positioned will be operated from the surface by means of the wire line.

Another object of my invention is to provide a valve structure for a gas lift apparatus which automatically locks in position when lowered into the well and is so held that displacement thereof due to pressure of the actuating gas is positively prevented.

Another object of my invention is to provide a locking device for such a valve which is so constructed and positioned as to require a greater force for its actuation than the force required to move the valve structure to its operating position whereby it is assured that the valve structure will be fully in position before the locking device is actuated.

Another object of my invention is to provide a sub-surface valve adapted to be operated by means of a wire line to control the flow of actuating gas into a flow string of a gas lift apparatus, and which valve is adapted to be moved into open position by means of the wire line and to be closed by means of the pressure of the actuating gas unassisted by any resilient means such as springs.

Other objects and advantages of this invention it is believed will be apparent from the following detailed description of a preferred embodiment thereof as illustrated in the accompanying drawings.

In the drawings:

Figure 1 is a side elevation partly in vertical section of a gas lift apparatus embodying my invention.

Figure 2 is a fragmental elevation partly in vertical section of the upper section of the apparatus as illustrated in Figure 1, illustrating the same on an enlarged scale.

Figure 3 is a similar elevation mainly in vertical section of the intermediate section of the gas lift apparatus llustrated in Figure 1, on the same scale as Figure 2.

Figure 4 is an elevation mainly in vertical section of the lowermost section of the gas lift apparatus illustrated in Figure 1, upon the same scale as on Figures 2 and 3.

Figure 5 is an end sectional view taken on the line 5—5 of Figure 3.

Figure 6 is a diagrammatic illustration of the actuating gas control means incorporated in my invention.

The apparatus embodying my invention as illustrated in the accompanying drawings in its preferred form includes the well tubing 1 which extends from the surface into the well bore within the casing 2. A standing valve 3, of any suitable or desirable construction, is carried at the lower end of the tubing 1 through which the well fluid to be lifted or raised is admitted. Positioned within the tubing 1 above the standing valve 3 is an inner conduit 4 to the upper end of which there is secured a cross-over member 5. The cross-over member 5 provides the lateral ports 6 in communication with the tubing inlet port 7 providing the gas inlet from the annulus 8 between the tubing 1 and the casing 2.

In order to control the flow of actuating gas from the annulus 8 through the cross-over member, there is provided a valve structure generally indicated at 9, which is mounted above the cross-over member 5.

The valve structure 9 includes a valve body 10 and the lock body 11. The lower end of the valve body 10 is provided with spaced packings 12 and 13 adapted to seal the same within the bore of the cross-over member 5 above and below the lateral ports 6.

The longitudinal spacer 14 which separates the packings 12 and 13 is provided with lateral openings 15 to permit open communication with the ports 6. Mounted within the valve body 10 is a valve plunger 16 having a valve head 17. The valve head 17 is adapted to engage the valve seat 18 under the influence of the pressure of lifting gas admitted into the control valve passage 19 from the annulus 8 through the lateral ports 6 and 15. The valve body outlet passage 20 communicates with the interior of the conduit 4 through the open end 21 thereof into the chamber 83 formed at the lower end of the tubing 1.

The opening and closing of the valve 17 thus determines the intervals at which the gas is admitted below the column of well fluid admitted into the tubing 1 through the standing valve 3. In order to control this intermitting action, there is provided an actuating rod 22 which is adapted to engage the upper end of the plunger 16 and to force the valve 17 away from the seat 18. The actuating rod 22 is longitudinally moved under the influence of a weighted

member 23 carried at the end of the actuating cable 24. The cable 24 is connected to the weighting member through the medium of a suitable cable clamp 25.

The weight of the actuating parts, i. e., the weighted member 23 and the sliding rod 22, determines the pressure against which the valve 17 may be opened. For example, the weight of these combined elements may be 300 pounds operating against an effective gas pressure of 200 pounds so that when the weighted member 23 is lowered to move the slide 22 against the plunger 16, the valve 17 will be opened and conversely, when the weighted member 23 is lifted by lifting on the cable 24, the valve 17 may close under the influence of the gas pressure, assuming, of course, that the effective force is sufficient to overcome the weight of the plunger 16, rod 22, and the friction holding these parts against movement. The weight and friction as thus defined may establish the gas pressure which must be present within the annulus 8 before the valve 17 may close, and conversely, this establishes the lower limits of the pressure of the lifting gas which must be established to hold the valve closed to permit the well fluid to flow into the chamber 83.

The lock body 11 is secured to the upper end of the valve body 10 and is provided with a cylindrical bore 26 at its upper end, which is adapted to receive the tubular portion 27 of the mandrel sleeve 28.

The tubular portion 27 is connected with the mandrel sleeve 28 and is slidably mounted within the bore 26 whereby a lost-motion connection is formed between the mandrel sleeve 28 and the valve structure 9.

Shoulders 29 and 30 on the mandrel cooperate with the abutments 31 and 32, respectively, on the lock body 11 to define the limits of movement. During normal operation the mandrel member is supported upon the valve structure 9 with the shoulder 29 in contact with the abutment 31.

The actuating rod 22 is slidably mounted within the mandrel tube 27 and transmits directly the weight of the weight member 23 to the end of the plunger 16. The lower end of the weight bar 23 is provided with an abutment piece 33 confined within the mandrel sleeve 28 and limited in its relative movement by upper and lower stop shoulders 34 and 35, respectively.

A tubular member 36 is connected at its lower end to the cross-over member 5 and at its upper end to a tapered guide 37. The tapered guide 37 is formed as a tapered extension of a connecting member 38 through the medium of which the valve assembly is secured within the tubing 1.

The lower end of the tapered guide 37 provides an annular shoulder 39 under which the spring fingers 40 of the lock body 11 are adapted to engage. The lock body 11 is provided with openings 41 through which the lock fingers 40 extend to engage under the shoulder 39. The engagement thus effected prevents upward movement of the valve 9 under the influence of the pressure-actuating gas, i. e., the lock thus provided prevents the actuating gas from blowing the valve assembly out of position.

The spring fingers 40 are preloaded when assembled into the lock body 11. Under an initial stress tending to move the same inwardly, the fingers 40 are moved out under the shoulders 39 under the influence of the tapered shoulder 42 of the mandrel tube 27. A downward force of predetermined magnitude must be applied before the mandrel head can separate or force outwardly the lug fingers 40 against their tendency to move inwardly.

The valve structure 9 and mandrel member and weight bar 23 are adapted to be lowered into the tubing 1 on the wire line 24. When being lowered into position, the valve structure 9 is suspended from the mandrel member, which is in turn suspended from the weight bar 23.

The packing nut 43 at the lower end of the packing assembly of the packing members 12 and 13 is guided into the tubuluar member 36 by the tapered guide 37. The packing nut 43 is finally guided into central position by the landing stop 44 of the crossover member 5.

Considerable force is required to move the packing members 12 and 13 into position within the bore of the cross-over member 5 and therefore the combined weight of the valve structure 9 and mandrel 27 may not be sufficient to accomplish this purpose. The weight bar 23 is therefore lowered until the abutment piece 33 contacts the shoulder 35 and further downward movement applies part of the weight of the bar 23 to the valve structure 9 with the result that the frictional resistance is overcome and the packing structures 12 and 13 are moved into place.

Downward movement of the valve structure 9 is limited by the tapered shoulder 45 of the valve body 10 striking the landing stop 44. The spring fingers 40 are preloaded to the extent that they support the weight of the mandrel member plus the additional weight imparted by the weight bar 23 to move the packing 12 and 13 into position. Further weight applied to the mandrel member then deflects the spring fingers 40 outwardly into locking position. For example, the spring fingers 40 may be designed so that a force of at least 200 pounds greater than the weight of the mandrel member is required to deflect them into locking position. This means that the weight bar 23 may impart a force of 200 pounds to move the packings 12 and 13 into position, and this force, together with the weight of the mandrel member and valve structure 9, is entirely adequate. To deflect the spring fingers 40 into locking position, the full weight of the bar 23 (for example, 300 pounds) is then allowed to rest on the mandrel member.

When the valve structure 9 is in its operative position, actuating gas under pressure is admitted into the annulus 8 between the tubing 1 and casing 2. The packer 46 confines the gas within the casing and prevents gas from reaching the production sands. The gas thus admitted enters the port 6 into the inlet passage 19 and when its pressure is sufficient to lift the rod 22, the valve 17 is moved to closed position. Packings 12 and 13 prevent leakage of gas from the port 6 directly into the tubing 1.

The well fluid enters the lower end of the tubing 1 through the standing valve 3 and rises in the tubing 1 until it reaches a normal level somewhere above the packer 46.

When it is desired to raise a slug of the well fluid to the surface, the weight bar 23 is lowered to open the valve 17. Actuating gas then flows down through the valve outlet passage 20 and down through the conduit 4. The standing valve 3 closes due to the increase in pressure above it. The actuating gas then raises the slug of well fluid up through the tubing 1 to the surface. When it is desired to close the valve 17 to termi-

nate the period of intermittent gas lifting, the weight member 23 is lifted and the gas pressure then moves the valve 17 to its closed position. The weight bar 23 and associated parts are made sufficiently heavy to open the valve 17 against the pressure of the actuating gas despite any buoyant effect on the weight bar 23 due to an abnormally high fluid level.

During normal intermitting operations, the weight bar 23 is never raised high enough to bring the abutment piece 33 and shoulder 34 into contact.

As illustrated in Figure 6, a timer 50 is driven from any suitable source of power, not shown. The timer 50 operates a pilot valve 51 of a low pressure gas supply conduit 52. This conduit is connected with a diaphragm valve 53. The diaphragm valve 53 controls admission and discharge of high pressure gas to the actuating cylinder 54.

Arranged for reciprocation within the cylinder 54 is a piston 55 having a piston rod 56. The piston rod 56 is releasably connected to the wire line 24 by means of a clamp 57.

Any suitable or desirable means may be employed for supporting the cylinder 54. The diaphragm actuating valve is mounted in the high pressure supply conduit 58 to control the admission of high pressure gas to the cylinder 54 or its exhaust to an exhaust line 59.

The main pressure supply line 60 is provided with a control valve 61 and is connected with the casing head 62. The opposite branch of the casing head 62 is connected to a discharge conduit 63, and flow through this line is controlled by means of a valve 64. As is customary in such heads, the tubing 1 is packed as indicated at 65 to provide a fluid-tight connection.

The cable 24 is also trained over a suitable drum 66 required for raising or lowering the valve assembly into the well.

A branch conduit 67 connects the high pressure supply line 60 with the tubing head 68. A valve 69 is provided for controlling flow through this branch conduit. A discharge branch conduit 70 connects between the tubing head 68 and the discharge conduit 63 and a valve 71 is also provided for controlling flow through this branch conduit.

During normal operations, the main supply valve 61 and the exhaust branch supply valve 71 are opened. The valves 69 and 64 are closed. Rotation of the timer 50 moves the pilot valve 51 to exhaust gas from the diaphragm valve 53, thus admitting high pressure gas to the cylinder 54 to raise the piston 55 therein. The weight bar 23 is raised closing the valve 17 and cutting off the supply of lifting gas to the conduit 4. This is the position of the parts as indicated in Figure 6.

As the timer continues to rotate, the valve 51 is moved against the influence of the spring 72 to close the outlet 73 and admit low pressure gas to the diaphragm valve 53 to move the diaphragm valve to a position to cut off communication between the high pressure conduit 60 and the conduit 58, and to exhaust the conduit 58 through the exhaust conduit 59, permitting the piston 55 to fall in the cylinder 54 under influence of the weight of the weight bar 23 and the cable 24, thereby opening valve 17 and allowing the gas to lift the slug of well fluid through the tubing 1 to the surface.

As the timer 50 continues to rotate, new cycles of operation are initiated. It will be apparent that by the changing of the plate of the timer 50 that the intervals of intermittence of the gas lift operation may be varied to suit the particular conditions encountered. It will thus be apparent that the shape of the disc of the timer 50 and the speed at which it is rotated determines the length of time in which the main gas admission valve 17 will remain opened and closed, respectively.

As will be apparent from Figure 3, the plunger 16 is slidably mounted within a sleeve 74 carried in the valve body 10. A spiral groove 75 traverses the full length of the plunger 16 and in effect constitutes a small passageway of considerable length; thus when the valve 17 is open, a pressure differential exists between the pockets 76 and 77 at the opposite ends of the groove 75 and therefore a limited leakage of gas will occur through the groove 75 from the pocket 76 to the pocket 77. This pressure difference always exists when the valve 17 is open because the actuating gas must travel from the pocket 76 down through several hundred feet of conduit 4 and then back up the same distance through the annulus 78 within the tubing 1 to the pocket 77.

The relative great length and small cross-sectional area of the groove 75 prevents high velocity of gas therethrough and hence no cutting action occurs. This limited leakage is effective, however, in preventing the accumulation of foreign matter in the pocket 77 or along the sliding surface between the valve plunger 16 and the sleeve 74; thus the valve plunger 16 may freely move between open and closed positions without any tendency to stick.

In the event the fluid in the well should reach an abnormally high level, the pressure of the actuating gas might not be sufficient to raise the fluid to the surface through the tubing 1, owing to the great length of the slug which is formed. The length of this slug can be materially shortened by using the casing 2 as the discharge conduit in place of the tubing 1, as the cross-sectional area of the annulus 8 between the tubing 1 and the casing 2 is materially greater than the cross-sectional area of the tubing passage. In order to permit this action to take place, provision is made for flowing the well through the casing 2 in the event of an abnormally fluid level as, for example, may form when the well has been shut down for some time and it is desired again to commence flowing operations.

In order to permit this blowing off of the well, starting valves 79 are provided in the conduit 4 below the valve structure 9. The starting valves 79 are substantially duplicates and each may include a ball 80 and a cooperating seat 81. The valves 79 are arranged in tandem so that they operate in unison. They remain closed during normal operation but when actuating gas is admitted into the tubing, they open to permit flow upwardly through the inner conduit 4. When it is desired to initiate reverse or "blow-off" flow, the valves 61 and 71 at the well head are closed and the valves 69 and 64 are open. Thus gas is admitted into the tubing 1 and is impressed on the top of the fluid column standing in the tubing, thereby closing the standing valve 3.

The gas pressure moves the fluid downwardly through the openings in the tapered guide 37, down through the annulus 78 and through the inlet screen 82. The fluid then moves upwardly through the starting valve 79 and through the conduit 19 and valve 17. The valve 17 remains open because the pressure above it is greater

than the pressure below it. The fluid, after passing the valve 17, passes downwardly through the passage 19 and out through the lateral port 6 into the casing 2. When the slug reaches the surface, the connections at the well head are reversed and normal intermitting operations as controlled by the wire line 24 may be commenced.

Having fully described my invention, it is to be understood that I do not wish to be limited to the details herein set forth, but my invention is of the full scope of the appended claims.

I claim:

1. In combination with a device for raising liquid from a well, including a tubing, a lateral opening in said tubing near the lower end thereof in communication with a source of gas under pressure, of a valve structure in said tubing having a valve adapted to control the flow of gas through said opening, releasable lock means adapted to secure said valve structure in operative position, a wire line having a weight suspended therefrom and positioned within the tubing, means at the top of the well associated with the wire line for controlling downward movement of the weight under influence of gravity, and cooperating parts associated with the weight whereby downward movement of said weight acts sequentially to actuate said lock means and to open the valve.

2. In combination with a device for raising liquid from a well, including a conduit having a lateral opening at a point in the well, of a valve structure adapted to be lowered through the conduit into operative position adjacent said lateral opening, a valve in said valve structure adapted to control flow through said lateral opening, means for actuating said valve including a weighted tool suspended in the conduit by means of a wire line, cooperating parts on the valve structure and conduit offering certain resistance incident to final insertion of said valve structure into operative position, releasable lock means adapted to secure said valve structure in operative position, means at the top of the well associated with the wire line for controlling downward movement of the weighted tool under influence of gravity, and cooperating parts associated with said tool whereby downward movement of said tool acts sequentially to move said valve structure into operative position against said resistance and to actuate said lock means.

3. In combination with a device of the class described, including a tubing, of a valve structure removably mounted in the tubing near its lower end, lock means for releasably securing said valve structure in operative position within the tubing, a mandrel member slidably mounted with respect to said valve structure and adapted to actuate said lock means, a weighted tool suspended in said tubing on a wire line and having a lost motion connection with said mandrel member, means connected to said wire line for reciprocating said tool within the limits of movement of said lost motion connection, a valve in said valve structure adapted to be actuated by normal movement of the tool within such limits, and cooperating means on the mandrel member and valve structure whereby upward movement of the tool in excess of the upper limit sequentially acts to move the mandrel member to release the lock means and then to withdraw said valve structure from its operative position within the tubing.

4. In combination with a device for raising liquid from a well, including a conduit, of a valve structure adapted to be lowered through the conduit into operative position at a point in the well, sealing means on said valve structure adapted to seal between said conduit and said valve structure when the latter is in operative position, a weighted tool suspended in the conduit by means of a wire line, a portion of the weight of said tool being adapted to move said sealing means into place upon the valve structure being lowered into the conduit, releasable lock means adapted to be actuated by said weighted tool whereby said valve structure may be secured in operative position, said lock means being pre-loaded to the extent that a greater proportion of the total weight of the tool is required for its actuation than that required for moving the sealing means into place.

5. In combination with a device for raising liquid from a well, including a conduit, of a valve structure adapted to be lowered through the conduit into operative position at a point in the well, cooperating parts on the valve structure and conduit offering certain resistance incident to final movement of the valve structure into operative position, a weighted tool suspended in the conduit by means of a wire line, a portion of the weight of said tool being utilized to overcome such resistance whereby the valve structure may be moved into its operative position, releasable lock means adapted to be actuated by said weighted tool whereby said valve structure may be secured in place in the conduit, said lock means being preloaded to the extent that a greater proportion of the total weight of the tool is required for its actuation than that required for moving the valve structure into place.

6. In combination with a device for raising liquid from a well, including a conduit having a lateral opening at a point in the well, of a valve structure adapted to be lowered through the conduit into operative position adjacent said lateral opening, axially spaced sealing means on said valve structure adapted to seal above and below said opening between said conduit and said valve structure, a valve in said valve structure adapted to control flow through said lateral opening, means for actuating said valve including a weighted tool suspended from the surface, a portion of the weight of said tool being adapted to move said sealing means into place upon the valve structure being lowered into the conduit, releasable lock means adapted to be actuated by said weighted tool whereby said valve structure may be secured in operative position, said lock means being preloaded to the extent that a greater proportion of the total weight of the tool is required for its actuation than that required for moving the sealing means into place.

7. In combination with a device for raising liquid from a well, including a valve housing positioned within the well and having a passageway for gas under pressure, of a valve means in said housing adapted to control the flow of gas through said passageway, said valve means including a stationary sleeve member having a cylindrical bore and a cylindrical plunger member mounted for sliding movement within said bore, a spiral groove traversing the contacting surface of one of said members and adapted to permit limited leakage of gas when the valve is open, whereby accumulation of foreign matter between said members may be prevented, and mechanical means adapted to move the plunger member relative to the sleeve member.

8. In combination with a device for raising liquid from a well, including a valve housing posi-

tioned within the well and having a passageway for gas under pressure, of a valve means in said housing adapted to control the flow of gas through said passageway, said valve means including a stationary sleeve having a cylindrical bore and a cylindrical plunger mounted for sliding movement within said bore, a spiral groove traversing the surface of the plunger and adapted to permit limited leakage of gas when the valve is open, whereby accumulation of foreign matter between the plunger and sleeve may be prevented, and mechanical means adapted to move the plunger relative to the sleeve.

9. In a sub-surface valve for controlling flow of gas between a casing and a tubing, the combination of a valve housing, a sleeve member in said housing provided with a cylindrical bore, a cylindrical plunger member adapted for vertical sliding movement within said bore, a downwardly facing seating surface associated with said housing, said plunger member having a part associated therewith adapted to contact said seating surface to form a seal upon upward movement of said plunger member, a spiral groove traversing the contacting surface of one of said members and adapted to permit limited leakage of gas in an upward direction upon downward movement of the plunger member, whereby accumulation of foreign matter between said members may be prevented.

10. In a sub-surface valve for controlling flow of gas between a casing and a tubing, the combination of a valve housing, a sleeve in said housing provided with a cylindrical bore, a cylindrical plunger adapted for vertical sliding movement within said bore, a downwardly facing seating surface associated with said housing, said plunger having a part associated therewith adapted to contact said seating surface to form a seal upon upward movement of said plunger, a spiral groove traversing the contacting surface of said plunger and adapted to permit limited leakage of gas in an upward direction upon downward movement of the plunger, whereby accumulation of foreign matter between said sleeve and plunger may be prevented.

11. In a gas lift device for wells, the combination of a conduit extending into the well and having a well fluid inlet valve near its lower end, a tube positioned within said conduit and having its lower end terminating above said fluid inlet valve, the tube and conduit cooperating to form an annular accumulation chamber for well fluid around the tube and within the conduit, a packer forming a seal between the conduit and the tube, a lateral opening in the wall of the tube at a point above the position of the packer, a control valve assembly adapted to be lowered from the surface through said conduit into operative position above said annular accumulation chamber, means to deliver a pressure fluid into the conduit and through said lateral opening to said valve assembly, a valve operatively included in said assembly and adapted to control flow of pressure fluid to said accumulation chamber, and means including a wire line extending from the surface adapted to control the operation of said valve.

12. In a gas lift device for wells, the combination of a control valve assembly positioned within the well bore, an upper pair of concentric conduits extending upwardly from the position of said valve assembly to the surface, the inner conduit being adapted for eduction of fluid from the well and the outer conduit being adapted to deliver fluid under pressure to said control valve assembly, a lower pair of concentric conduits extending downwardly from said control valve assembly and defining between them an accumulation chamber for well fluid, the control valve assembly being adapted to be lowered from the surface through one of said conduits to position above said accumulation chamber, the outer conduit of the lower pair having a well fluid inlet valve near its lower end, a lateral port in the wall of the inner conduit of the upper pair opening directly into the fluid pressure conduit, a passageway formed through said control valve assembly communicating with said lateral port and one of the conduits of the lower pair to permit passage of pressure fluid, a pressure fluid valve operatively included in said control valve assembly and adapted to control flow of pressure fluid through said passageway, means including a wire line extending from the surface and adapted to control the operation of said pressure fluid valve, and means providing communication between the other conduit of the lower pair and the inner conduit of the upper pair for passage of well fluid.

13. In a well flowing device of the class described, the combination of a well casing, a tubing within the casing and adapted to convey well fluid from the well, means for injecting fluid under pressure into the well casing, a packer forming a seal between the casing and tubing, a lateral opening in the wall of the tubing at a point above the position of the packer, a valve structure adapted to be lowered into said tubing and having cooperating parts adapted to form a sealed connection with the inner end of said opening, means including a valve associated with said valve structure adapted to convey fluid under pressure admitted through the lateral opening to a point in the tubing substantially below the position of the lateral opening, and means including a wire line suspended from the top of the well for mechanically actuating said valve.

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