Nov. 26, 1940. G. A. HATFIELD 2,223,336

VALVE FOR GAS LIFT PUMPING APPARATUS

Filed Nov. 17, 1937 2 Sheets-Sheet 1

Fig. 1.

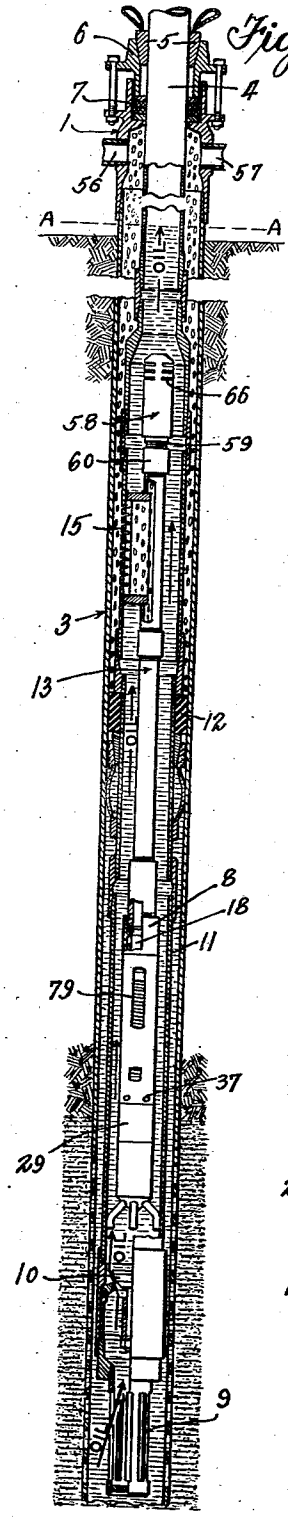


Fig. 2.

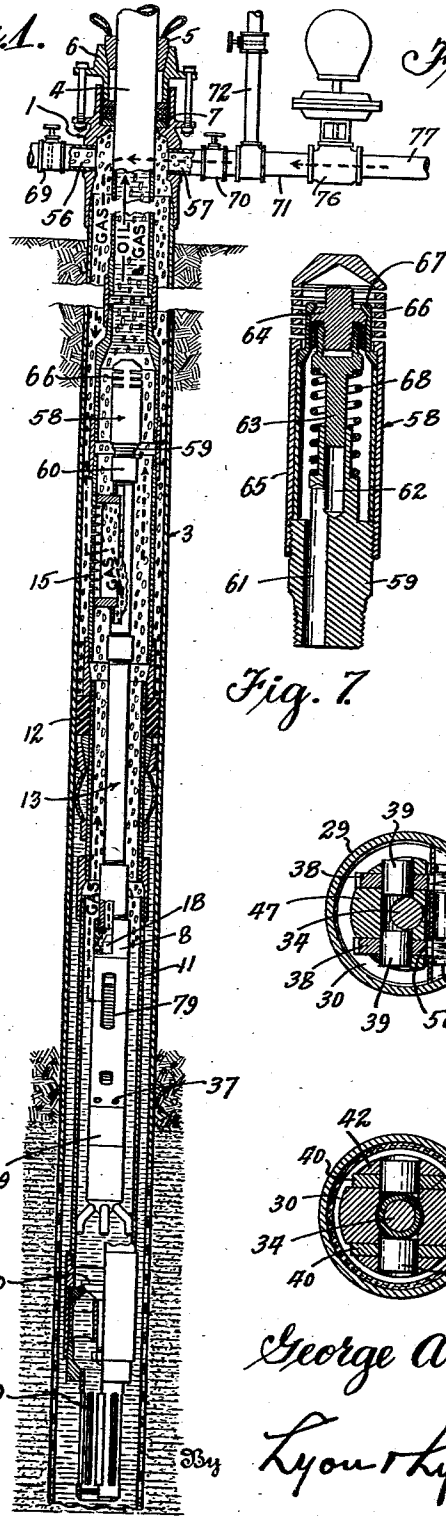


Fig. 7.

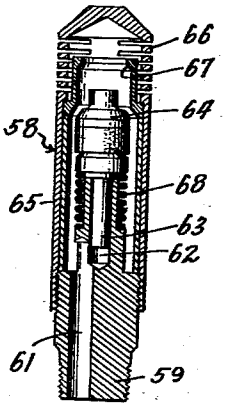


Fig. 8.

Fig. 5.

Fig. 6.

Inventor

George A. Hatfield

By Lyon & Lyon

Attorneys

Nov. 26, 1940. G. A. HATFIELD 2,223,336

VALVE FOR GAS LIFT PUMPING APPARATUS

Filed Nov. 17, 1937 2 Sheets-Sheet 2

Fig. 3.

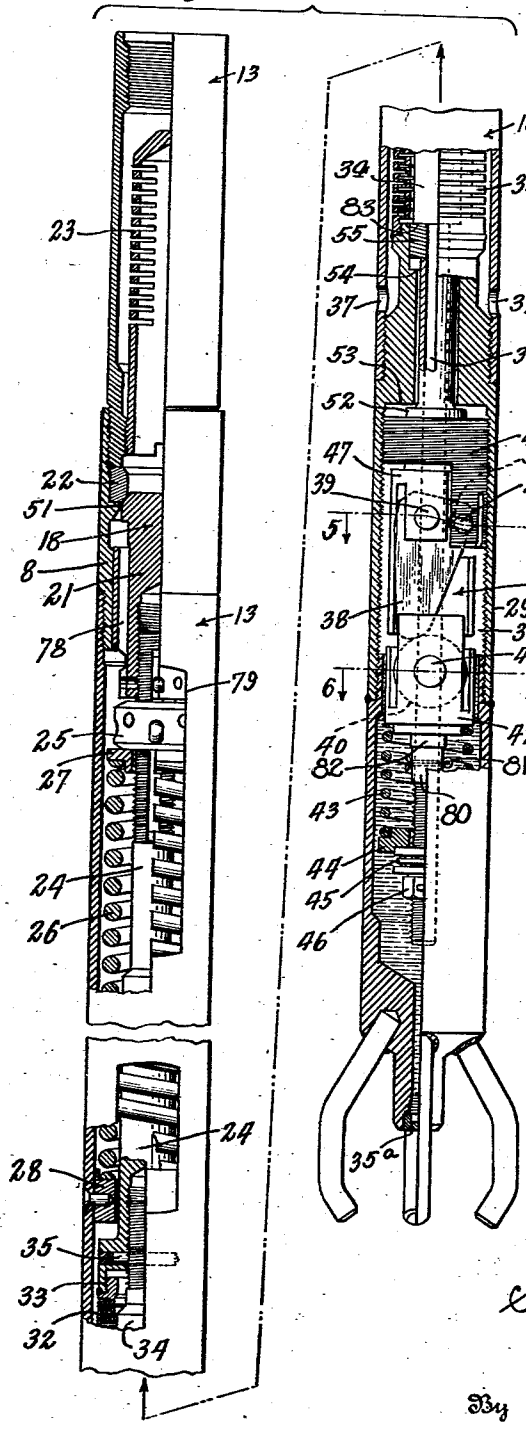


Fig. 4.

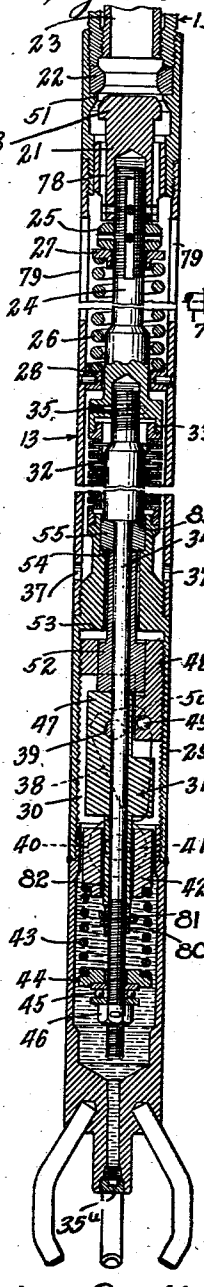
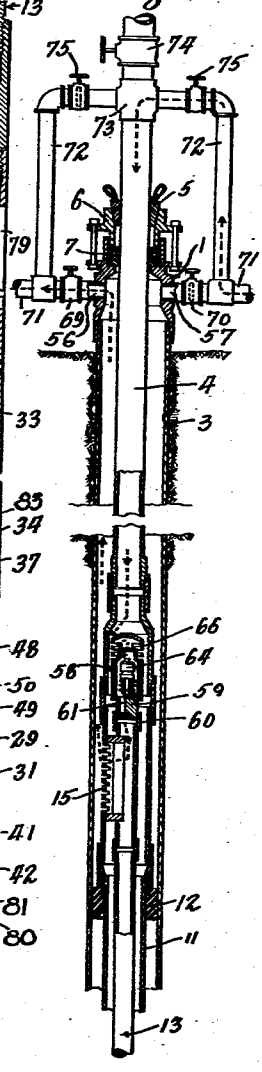


Fig. 9.



Inventor

George A. Hatfield

By Lyon & Lyon

Attorneys

Patented Nov. 26, 1940 2,223,336

UNITED STATES PATENT OFFICE

2,223,336

VALVE FOR GAS LIFT PUMPING APPARATUS

George A. Hatfield, Torrance, Calif., assignor to The National Supply Company, Torrance, Calif., a corporation of Pennsylvania

Application November 17, 1937, Serial No. 175,015

14 Claims. (Cl. 137—139)

This invention relates to gas lift pumping apparatus for lifting a fluid such as oil from a well by the use of gas under pressure. This invention is more particularly directed to an improved type of intermitting gas lift device for lifting such fluid which includes an intermitting valve positioned within the well and controlled by fluid pressure from the surface of the well.

An object of this invention is to provide an intermitting valve adapted to be positioned at the bottom of a well and which is operatively sensitive to a single controllable variable.

Another object of this invention is to provide a sensitive remotely controlled intermitting valve for a gas lift which is operative against a substantially constant resistance and which may be automatically and positively actuated by the degree of pressure of the operating gas substantially independently of the fluid formation pressure within the well.

Another object of this invention is to provide a gas lift apparatus including a bottom hole intermitting valve which is actuated by change in pressure in the actuating gas supply conduit without the necessity of employing a supplementary control system in the well.

Another object of this invention is to provide a valve for a gas lift of positive operating characteristics and which is operative without chattering or floating in the gas stream.

Another object of this invention is to provide a cooperating mechanism for an intermitting bottom hole valve for a gas lift, which cooperative mechanism functions to nullify the objectionable increase or decrease of spring pressure on the valve incident to the change in the degree of compression of a controlling spring, and which control mechanism is operative to determine the "spread" between the opening and closing pressures of the valve.

Another object of this invention is to provide an intermitting valve applicable for use in a gas lift system which acts as a gas saver to prevent the loss of operating gas during the interval between its discharge periods and which also is operable during these intervals to permit the well fluid to enter the lift mechanism unimpeded by the pressure of the operating or lifting gas.

Another object of this invention is to provide a gas lift apparatus including a starting valve which is operable not only as a starting valve, but also to clean the gas strainer and gas passage utilized in the regular gas intermitting cycle.

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 diagrammatic elevation partly in longitudinal section of an intermitting gas lift device embodying my invention and illustrating the position of the valves during the filling.

Figure 2 is a view similar to Figure 1 showing the position of the valves during the lifting or discharge.

Figure 3 is an enlarged sectional broken elevation of the gas lift apparatus embodying my invention illustrating the intermitting valve in its closed position.

Figure 4 is a sectional elevation view similar to Figure 3 on a reduced scale illustrating the intermitting valve in its open position.

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

Figure 6 is a sectional end view taken substantially on the line 6—6 of Figure 3.

Figure 7 is a sectional elevation of the starting valve embodied in my invention illustrating the same in closed position.

Figure 8 is a similar sectional elevation of the starting valve illustrating the same in its open position.

Figure 9 is a diagrammatic view illustrating the operation of the starting valve mechanism embodied in my invention.

In the preferred embodiment of my invention as illustrated in the accompanying drawings, 1 indicates a packing head or other supporting device which is positioned at the surface of the well. The packing head at its lower end is secured to the well casing 3, which extends downwardly into the well bore.

The tubing or discharge conduit 4 is supported in any conventional manner upon the packing head 1 and in the particular illustration given, the tubing 4 is shown as supported by means of slips 5 carried by the gland 6 so that the weight of the tubing acts to compress the packing 7 to form a gas-tight seal between the packing head 1 and the tubing 4. The tubing 4 extends concentrically within the casing 3 and at its lower end carries the gas lift mechanism preferably at a position within the well below the normal oil level generally indicated at A. At the extreme lower end of the gas lift device is the oil screen 9 and a standing valve 10.

Supported at the lower end of the tubing 4 is a cylindrical housing 11 which houses and

supports the intermitting gas valve assembly embodying my invention.

In order that the casing 3 may be utilized in the normal operation of the gas lift embodying my invention as the conduit through which the gas is conducted into the lift device, a packer 12 is provided between the casing 3 and the housing 11. The packer 12 is preferably an expansible packer of any suitable or desirable construction which is well understood in this art.

In order to conduct the gas from the casing 3 through the intermitting valve of my invention, a cross-over strainer 15 is provided between the housing 11 and the tubular member 13 of the intermitting gas valve. In Figures 1 and 2 the intermitting gas valve is diagrammatically illustrated at 18 within the tubular member 13.

In order to maintain the valve 18 operative against a substantially constant resistance independent of the pressure of the well or formation fluid within the well, an isolated and closed pressure chamber control device is provided which is of a construction and operation which will hereinafter be fully set forth.

In order that the particular construction and operation of the gas lift embodying my invention may be more readily understood, the general operation of such device is illustrated in Figures 1 and 2. In Figure 1 the intermitting valve 18 is indicated as closed and the standing valve 10 as open. Under this condition the oil from the well formation passes through the well screen of the casing 3 and up through the oil screen 9 by the standing valve 10 to fill the housing 11 up to the oil level as indicated at A. Near the end of this interval of operation, the surface valve 76 opens admitting gas under pressure to the casing 3 above the packer 12 and against the upper surface of the valve 18 until sufficient pressure of gas is accumulated above the valve 18 to overcome the constant resistance of the control means provided for the valve 18, at which time the valve 18 opens admitting the gas under pressure into the housing 11 through windows 79 in the tubular member 13, at which time the standing valve 10 closes. The thus trapped quantity or "slug" of oil within the housing 11 and tubing 4 is then forced from the well by the pressure of gas operating upwardly to lift the oil and gas out through the tubing 4. Closing of the surface valve 76 is timed to occur just before the "slug" reaches the surface, so that the actuating gas pressure in the casing 3 quickly bleeds down to closing pressure for the valve 18, as discharge occurs at the surface. After a predetermined period of time has elapsed, the surface valve 76 opens and again admits actuating gas into the casing 3 and the operation is repeated.

The valve 18 is a plunger valve as indicated at 21 and is adapted to control the flow of fluid through the tubular member 13 and out through the discharge port 79 of the tubular member 13. The plunger valve 18 is adapted to seat against a removable seat member 22.

Mounted within the gas passage provided by the tubular member 13 is a gas strainer 23. The plunger valve 18 is fitted to a cylindrical valve sleeve 8.

The plunger valve member 18 is threaded to a valve stem 24 upon which valve stem 24 an adjustable stop 25 is threaded. A compression spring 26 is mounted upon the valve stem 24 to engage a collar 27 at its upper end and to engage a fixed stop 28 at its lower end. It will be obvious that by adjusting the position of the stop 25 along the valve stem 24 that the initial spring load of the spring 26, acting to hold the valve 18 against its seat 22, may be varied as desired.

The tubular member 13 provides an enclosing housing for the intermitting valve, and at its lower end is secured to a housing 29 within which there is provided a constant pressure chamber 30 in which a spring loaded "over-center" device 31 is mounted to control, in connection with a bellows 32 and the compression spring 26, the opening and closing pressures for the valve 18. The bellows 32 is secured as indicated at 33 to the lower end of the stem 24. An extension 34 of the stem 24 is likewise secured at 35 to the stem 24 and extends through the bellows 32 concentrically within the housing 29 and is operatively connected with the "over-center" device 31.

The bellows 32 substantially balances out the fluid pressure exerted upon the underside of the valve 18 so that the operation of the valve 18 may be made independent of variations of the well or formation pressure within the well. The bellows 32 is at its lower end fixed and sealed against the stationary housing 29. The constant pressure chamber 30 formed within the bellows and the housing 29 is sealed at its lower end by means of a sealing plug 35a. The chamber 30 is thus hermetically sealed so that the pressure within the chamber remains constant disregarding the slight changes brought about by changes in temperature and the very slight pressure change caused by the relative movement of the upper end of the bellows 32. The constant pressure chamber 30 thus provides a constant resistance for the valve 18 under all well conditions. This constant pressure chamber 30 extends from the upper end 33 of the bellows 32 down to the sealing plug 35a at the lower extremity of the housing 29. A portion of the lower end of this chamber 30 may contain lubricant, as shown in Figs. 3 and 4, and the remainder of the space within the chamber 30 is filled with air. Since the parts 55 and 29 as well as the parts 52 and 48 are respectively connected by loose, guiding fits, these parts offer no material restriction to the passage of air.

The timer valve 76 may be of the usual construction and is set to open and close at predetermined intervals of time. When this timer valve 76 opens, actuating gas from the supply conduit 77 is admitted into the casing 3 and this gas makes its way through the crossover-strainer 15 and into the member 13 above the valve 18. When a predetermined degree of pressure is reached within the member 13, the plunger valve 18 leaves its seat 22, sliding downwardly in the guide 8. The actuating gas then passes downwardly through the passages 78 in the plunger valve 18, and out into the housing 11 through windows 79. The passages 78 decrease the discharge port area and thereby limit the velocity of gas flow through the valve 18 to a point where the velocity pressure drop through the gas conduits 3 and 13 will not be excessive. This construction also increases the effective area of the valve 18 under conditions of high gas velocity so as to keep it wide open until the pressure in the member 13 above it drops to closing pressure, and in addition assures the initial full opening of the valve 18.

In order to bring the plunger valve 18 quickly to its full open position and to compensate for the velocity pressure drop which occurs when the gas begins to flow through the opening created by the opening of the valve 18, the effective area of the bellows 32 is made slightly larger than

the effective area of the seat 22. This difference between effective areas is, however, maintained small enough so that the formation pressure of the well in the annulus within the tubular member 13 will not materially affect the opening pressure of the valve 18.

It will be obvious that while the constant pressure chamber 30 and construction as hereinabove set forth produces the desired sensitivity for the valve 18, that there results upon opening movement of the valve 18 an increase in force tending to close the valve due to the compression of the spring 26. The longitudinal contraction or compression of the bellows 32, accompanying the opening movement of the valve, tends to compress the air in the chamber and acts similarly to the spring 26 to further increase the upward force on the plunger valve 18 as it moves downwardly to open position. This effect of the spring 26 and bellows 32 is contrary to the desired characteristics of valve sensitivity and I therefore provide a means to counteract this objectionable feature incident to the necessary movement of the bellows 32 and spring 26 and which means also provides for the desired difference in degree of actuating gas pressure at opening and closing of the valve 18. This means I have heretofore referred to as the spring-loaded "over-center" device 31. The spring-loaded "over-center" device 31 is mounted and housed within the constant pressure chamber 30. The device 31 includes a pair of cam members 38 which are pivotally mounted on pins 39 carried by the cam holder 47. The cam holder 47 is secured upon the extension 34. The cams 38 are adapted to engage a pair of cam rollers 40, which cam rollers 40 are pivotally mounted upon pins 41 of a cam roller carrier 42. The cam roller carrier 42 is resiliently supported to move longitudinally of the extension 34 by means of a spring 43, which spring 43 is at its opposite end engaged with an adjustable stop 44 carried by the extension 34. The stop 44 is mounted upon a thrust bearing 45, the position of which thrust bearing 45 along the extension 34 is made adjustable by means of the nut 46 threaded to the extension 34. The cam roller carrier 42 is formed with parallel slots in which the cam rollers 40 are mounted. The cams 38 are mounted within corresponding slots formed in the cam holder 47, which is mounted upon the extension 34.

A nut 80 threaded upon the lower end of the extension 34 and held in place by a pin 81 serves to clamp the sleeve 82, cam holder 47, stop member 52, and collar 55 in end-to-end relation against the shoulder 83 formed on the extension 34. Each of these parts so clamped is thereby secured in position upon the extension 34. Hence the cam holder 47 moves with the extension 34 and valve 18.

In order to actuate the cams 38, there is provided within the housing 29 a stationary yoke 48 which carries an off-center actuating pin 49 which is positioned off-center with respect to the axis of the extension 34.

The cams 38 are provided with notches 50 which form a sliding fit with the pin 49 so that when gas pressure acts on the valve 18 to move it downwardly, that is, to open position, the extension 34 will move downwardly with the valve and relatively to the stationary yoke 48 so that the cams 38 will pivot about the pins 39 and fulcrum about the relatively stationary pins 49, and the lower ends of the cams 38 will thereby be caused to move over the crest of the cam rollers 40 from the position as indicated in Figure 3 when the valve 18 is closed to the position as indicated in Figure 4 when the valve 18 is opened. The respective slots within which the cam members 38 and the cam rollers 40 are mounted maintain the cam rollers and cams in alignment.

It will be obvious from the foregoing that the action of this "over-center" device 31 is such as to require a greater force to start its motion than is required at any other point during its travel and therefore once the valve 18 starts to move, the resistance offered by the "over-center" device 31 immediately decreases and the valve 18 will move quickly either to its fully open or to its fully closed position by the action of spring 43. It will be obvious from inspection of Figures 3 and 4 that as the cams 38 pass over the cam rollers 40 in passing from one position to the other, that the action of this "over-center" device is equal and opposite during its movements occasioned by both the opening and closing of the valve 18 and that the spring 43 exerts pressure in the same general direction to effect both the quick opening and the quick closing of the valve.

The adjustment provided for the spring 43 by the adjustment nut 46 enables a variation of the amount of force required for the extension 34 to move the cams 38 over center on the cam rollers 40. The upward force of the extension 34 required to move the cams 38 from the position shown in Figure 4 to that shown in Figure 3 need not necessarily equal to the downward force required to move the cams 38 in the opposite direction. From Figures 3 and 4 it will be obvious that the shape of the lower ends of the cams 38 could be proportioned to require upward and downward forces of different magnitude.

The operation of this "over-center" device 31 has three principal functions, namely:

(1) To compensate for the force change of the spring 26 incident to the movement of the valve 18;

(2) To compensate for a similar force change in the bellows 32 incident to the movement of the valve 18, and

(3) To provide a further force requirement in addition to that for the compensations above set forth in order to determine the pressure difference of the operating gas between the opening and closing of the valve 18.

In the operation of this device it will be noted that the valve 18 opens when the resultant downward force of the gas pressure exceeds the upward force due to the combined effect of the spring 26 and bellows 32 plus the resistance offered by the "over-center" device 31. Similarly the valve 18 does not close until the resultant downward force of the gas pressure is less than the upward force due to the combined effect of the spring 26 and bellows 32 minus the resistance offered by the "over-center" device 31.

In some wells having low bottom hole formation pressure and requiring a housing 11 large in diameter but short in length, the pressure in the well and around the valve 18 at the time of opening of the valve may be, for example, only one-fourth of the pressure of the actuating gas above the valve 18. Furthermore, the well fluid around the valve 18 may be very light and foamy so as to offer little resistance to the incoming actuating gas. It is to be understood that this condition may occur only at the time of the opening of the valve and does not exist once the fluid has left the housing 11 and entered the tubing 4, for by this time, due to the tubing 4 being of lesser

capacity per foot than the housing 11, the "slug" of fluid being lifted will have lengthened out and will offer a back pressure in proper proportion to the pressure of the actuating gas.

It can thus be seen that in this instance the pressure and inertia characteristics of the fluid around the valve 18 may influence its action in opening.

While the combination of the "over-center" device 31 and the slightly greater effective area of the bellows 32 over that of the valve seat 22 will usually effect instant full opening of the valve, yet in such an extreme case as above outlined, it is desired to provide for a supplementary opening action. Although the structure adapted to provide this supplementary action does not affect the predetermined degree of pressure at which the valve will open or close, it does aid in the instant full opening of the valve 18 once it has started to open. In order to provide for this instant opening of the valve 18 under such adverse and unusual cases as above outlined, there is provided around the valve periphery a restriction 51 which, when the valve 18 starts to open, causes the actuating gas to work over an artificially increased effective diameter until the valve is substantially half way through its travel and can then complete its opening unaided. It will be obvious that the restriction 51 has sufficient passage area to allow for ordinary leakage past the valve seat 22 without effect.

In order to permit of assembly and replacement of the valve seat 22, it is preferable to provide within the structure an emergency stop 52 which engages shoulder 53 to limit the upward movement of the extension 34. Unlimited movement of the extension 34 would result in injury to the bellows 32.

A stop shoulder 54 engages the lower face of a collar 55 formed on the extension 34 and serves to limit downward movement of the extension 34, stem 24 and valve 18. Movement in the upward direction is normally limited by the valve 18 engaging its seat 22.

It will be obvious from the foregoing that the ports 37 provided in the tubular member 13 are so positioned as to prevent accumulation of foreign matter within the member 13.

In order to provide for the starting of the well after the well has been allowed to stand idle for some time, or for the purpose of cleaning the cross-over strainer 15, I provide a starting valve 58. In either of the cases above mentioned, the fluid within the well may have filled both the tubing 4 and the annulus within the casing 3 to a height considerably above that reached during normal operation. A further condition where high fluid head may occur in the well is when the application of the gas in one conduit transfers its well fluid to the other conduit. Since the annulus within the casing 3 is of greater cross-sectional area than the tubing 4, adding the well fluid in the tubing 4 to that standing in the annulus within the casing 3 raises the fluid head a lesser amount than would be the case when the gas pressure is applied in the annulus within the casing 3 and the well fluid contained therein is added to that in the tubing 4. In addition, when applying gas pressure within the tubing 4 and through the starting valve 58, it is not necessary to lift the well fluid from the chamber formed within the housing 11 below the strainer 15 as would be the case if gas pressure were applied as in the direction of normal operation. Hence it will be obvious that the initial "slug" can be raised to the surface with a minimum of gas under pressure.

The starting valve 58 includes a plug 59 which is threaded to the collar 60 at the upper end of the tubular member 13. The plug 59 is formed with a gas passage 61. The upper end of the plug 59 is provided to form a guideway 62 for the stem 63 of a plunger valve 64. Secured to the plug 59 is a sleeve 65 which is closed at its upper end and formed below its upper end to provide a gas strainer 66. Mounted within the sleeve 65 is a valve seat 67 against which the plunger valve 64 seats. Interposed between the plug 59 and the valve plunger 64 is a spring 68 normally acting upwardly to maintain the plunger valve 64 upon its seat 67.

Referring to Figure 9, it will be seen that the openings 56, 57 of the packing head 1 are provided with valves 69 and 70 mounted within the gas conduits 71, through which the gas is conducted to the openings 56 and 57. Conduits 72 extend upwardly and connect to a cross 73 mounted in the tubing 4. The tubing 4 is provided with a valve 74 above the cross 73. Mounted in the conduits 72 are control valves 75.

In this structure as thus described, when the well fluid has accumulated within the well to an abnormal height, or when it is desired to clean the strainer 15, gas under pressure is admitted into the tubing 4 from its upper end by proper manipulation of the valves 69, 70, 74 and 75. The pressure of this gas is sufficient to open the starting valve 58, thereby forcing the well fluid above it into and through the cross-over strainer 15, and up through the annulus within the casing 3 and out the valved opening 57. As soon as the first "slug" of well fluid reaches the surface and passes out the outlet 57, valve connections at the head of the well are reversed to admit the gas into the casing 3 through the valve 70, at which time the valve 58 closes and the regular intermitting cycle is commenced.

It will be obvious from the foregoing that by locating the starting valve 58 in the position indicated, that there is provided a method and means by which the gas strainer 15 may be cleaned as hereinabove set forth.

The expression "over-center" as utilized in the specification and in the claims designates a device which may be of the snap-action character and wherein the valve actuating element includes an operating or snap-action means which, when passing over- or off-center is operable to maintain the actuating device in the off-center position. Thus the over-center device is a device having the operating characteristics in this specific illustration as defined in this specification.

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. A valve assembly of the character described comprising in combination a housing having an opening therein, a valve member mounted within the housing and adapted to close the opening, means within the housing including a resilient means acting along a certain axis to yieldably urge said valve member toward its closed position upon the valve member being moved adjacent its closed position, said resilient means acting in the same direction along the same axis to maintain the valve member in its open posi-

tion upon said valve member being moved adjacent its open position.

2. A valve assembly of the character described comprising in combination a housing having an opening therein, a valve member mounted within the housing and adapted to close the opening, means carried by the housing and adapted to urge the valve member toward the closed position, additional means within the housing including a spring means acting along a certain axis to yieldably urge said valve member toward its closed position upon the valve member being moved adjacent its closed position, said spring means acting in the same direction along the same axis to maintain the valve member in its open position upon said valve member being moved adjacent its open position.

3. A valve assembly of the character described comprising in combination a housing having an opening therein, a valve member mounted within the housing and adapted to close said opening, said valve being movable to open position, an element adapted for oscillatory movement and being operatively connected with the valve member, means operatively associated with said oscillatory element including a resilient means acting along a certain axis, said resilient means being adapted to yieldably maintain said valve member in its closed position upon the valve member being moved to its closed position, said resilient means acting in the same direction along the same axis to yieldably maintain the valve member in its open position upon the valve member being moved to its open position.

4. In a device of the class described, the combination of a housing having an opening therein, a valve member mounted within the housing and adapted to close the opening, resilient means carried by the housing and adapted to urge the valve member toward the closed position, an element operatively connected with said valve member and adapted to have an oscillatory movement relative to a certain axis, additional means including a spring operatively associated with said element and acting yieldably to rotate it about said axis in one direction when the valve member is adjacent its closed position, said additional means also acting yieldably to rotate said element about said axis in a counter direction when the valve member is adjacent its open position, the axis of said spring and the direction of force applied by said spring remaining unchanged for all operative positions of said valve member.

5. A valve assembly of the character described, comprising in combination a housing having a valve seat secured therein, a valve member mounted within the housing and adapted to engage the seat to form a seal, spring means carried by the housing and adapted to urge the valve member toward said seat, additional means within the housing including a resilient means acting along a certain axis to yieldably urge said valve member into engagement with said seat upon the valve member being moved to its seat-engaging position, said resilient means acting along the same axis to maintain the valve member in a retrieved position upon the valve member being retrieved from said seat.

6. In a pressure actuated valve of the class described, the combination of a housing having an opening therein, a valve member mounted within the housing and adapted to close the opening, conduit means adapted to supply gas under pressure to said housing for urging said valve member to open position, a spring adapted to urge the valve member toward its closed position against the pressure of the gas, means within the housing adapted to yieldably urge said valve member toward its closed position upon the valve member being moved adjacent its closed position, and acting to maintain said valve member in its open position upon said valve member being moved adjacent its open position, said means also acting to counteract the force change of said spring incident to movement of the valve member from one position to the other, and said means further acting to control the difference between the degree of gas pressure at which the valve will open and the degree of gas pressure at which the valve will close.

7. A valve assembly of the character described, comprising in combination a stationary member having an opening provided therein for the passage of a fluid under pressure, a movable member mounted within the stationary member and adapted to close the opening, an expansible chamber operatively associated with said members, and means confined within said expansible chamber acting to yieldably urge said movable member toward its closed position upon the movable member being moved adjacent its closed position, said means also acting to yieldably urge said movable member toward its open position upon the movable member being moved adjacent its open position.

8. A valve assembly of the character described, comprising in combination a stationary member having an opening therein, a movable member mounted within the stationary member and adapted to close the opening, means normally acting to urge said movable member toward its closed position, an expansible chamber operatively associated with said members, and additional means confined within said expansible chamber acting to yieldably urge said movable member toward its closed position upon the movable member being moved adjacent to its closed position, said additional means also acting to yieldably urge said movable member toward its open position upon the movable member being moved adjacent to its open position, said expansible chamber being adapted to contain lubricant for said additional means.

9. In a device of the class described, the combination of, a housing, valve means in said housing comprising an opening and a valve member adapted to close the opening, conduit means communicating with said opening and adapted to supply fluid under pressure for urging said valve member to open position, resilient means adapted to urge said valve member toward its closed position against the pressure of the fluid, means forming a substantially constant pressure chamber within said housing including a bellows disposed axially of said housing and having one end sealed with said housing and the other end sealed with said valve member, said valve member being adapted to move to its open position against the action of said resilient means upon the pressure differential between said conduit and said chamber reaching a predetermined magnitude.

10. In a device of the class described, the combination of, a housing adapted to be positioned in a well bore, valve means in said housing comprising an opening and a valve member adapted to close the opening, conduit means communicating with said opening and adapted to contain a fluid under pressure for urging said valve mem-

ber to open position, means forming a substantially constant pressure chamber within said housing including a bellows disposed axially of said housing and having one end sealed with said housing and the other end sealed with said valve member, whereby said valve member may be moved from open position to closed position and vice versa by the degree of pressure in said conduit.

11. In a device of the class described, the combination of, a housing adapted to be positioned in a well bore, valve means in said housing comprising an opening and a valve member adapted to close the opening, conduit means communicating with said opening and adapted to contain a fluid under pressure for urging said valve member to open position, means forming a substantially constant pressure chamber within said housing including a bellows disposed axially of said housing and having one end sealed with said housing and the other end sealed with said valve member, whereby said valve member may be moved from open position to closed position and vice versa by the degree of pressure in said conduit, additional means within said chamber acting to yieldably urge said valve member toward its closed position upon the valve member being moved adjacent its closed position, said means also acting to yieldably urge said valve member toward its open position upon the valve member being moved adjacent its open position.

12. In a device of the class described, the combination of, a housing adapted to be positioned in a well bore, a valve seat in said housing, a plunger slidably mounted axially of said housing and adapted to engage said seat to form a fluid seal, a depending extension secured to said plunger, conduit means communicating with said housing above said valve seat and adapted to contain gas under pressure for urging said plunger to open position, means forming a substantially constant pressure chamber within said housing below said valve seat, said means including a bellows disposed axially of said housing and having its lower end sealed with said housing and its upper end sealed with said extension, the effective diameter of the fluid seal being substantially equal to the effective diameter of the bellows, whereby said valve plunger may be actuated by the degree of pressure in said conduit substantially independently of formation pressure within the well bore.

13. In a device of the class described, the combination of a housing having a valve seat therein, a valve slidably mounted within the housing and adapted to contact the seat to form a seal, said valve having a valve stem attached thereto extending axially of the housing, means associated with the valve stem and the housing adapted to resist axial movement of the valve in either direction, said means including a spring carried on said valve stem and extending axially of said housing.

14. In a device of the class described, the combination of a housing having a valve seat therein, a valve slidably mounted within the housing and adapted to contact the seat to form a seal, said valve having a valve stem attached thereto extending axially of the housing, means associated with the valve stem and the housing adapted to resist movement of the valve away from said seat, said means including a cam pivotally secured with respect to said valve stem, cooperating elements on said cam and said housing acting to impart pivotal movement to said cam upon axial movement of the valve and valve stem away from said seat, and means including a spring supported on said valve stem adapted to resist pivotal movement of the cam.

GEORGE A. HATFIELD.