Oct. 15, 1968 T. E. BRYAN 3,405,647

FLOW VALVES

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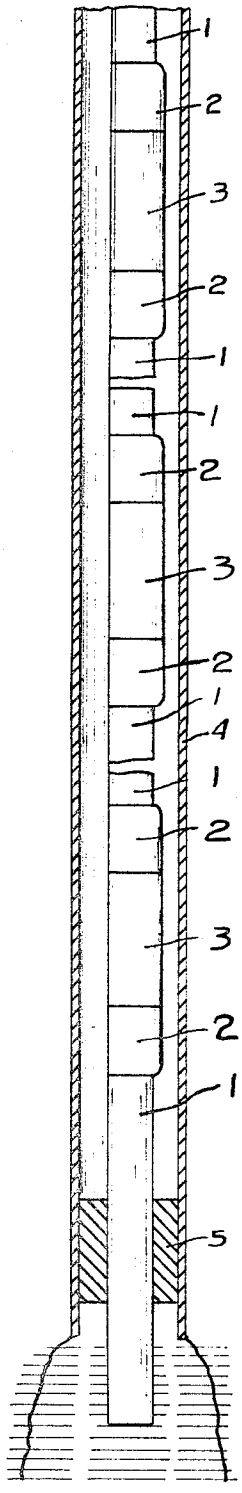


Fig. 1.

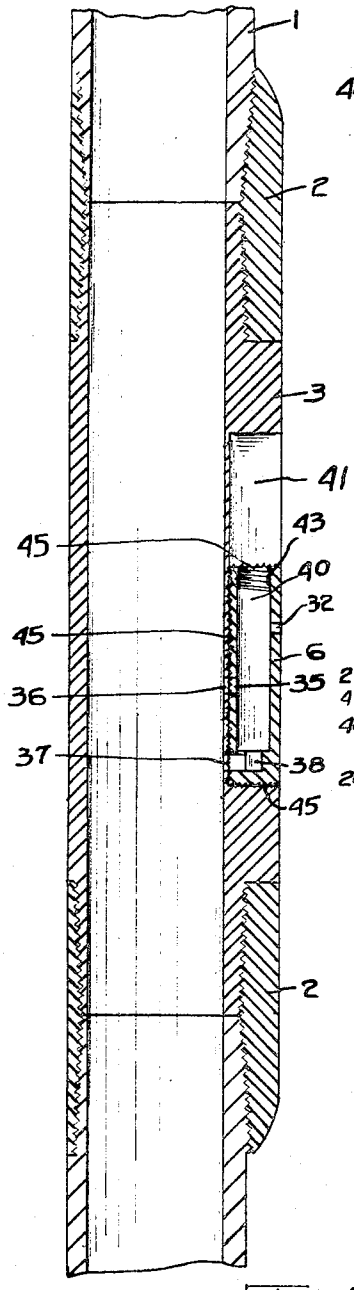


Fig. 2.

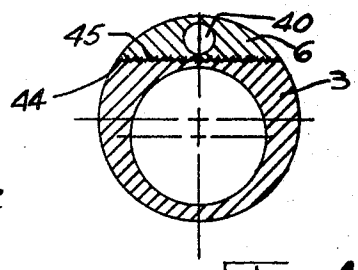


Fig. 4.

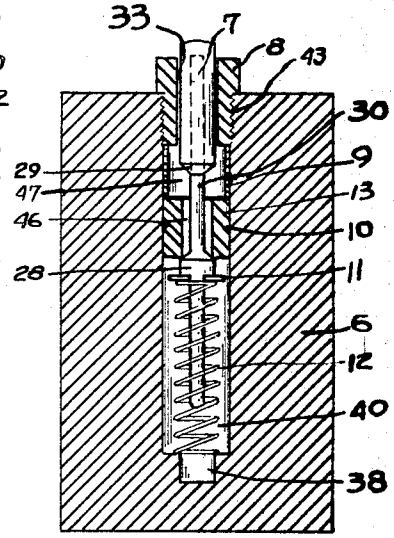


Fig. 3.

Oct. 15, 1968 T. E. BRYAN 3,405,647

FLOW VALVES

Filed Nov. 9, 1966 3 Sheets-Sheet 2

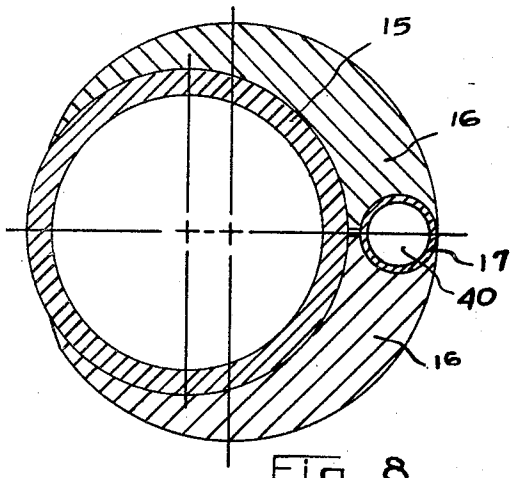


Fig. 8.

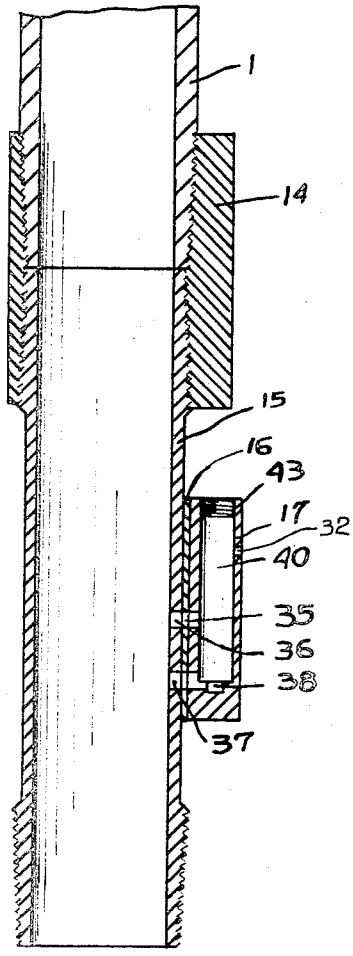


Fig. 6.

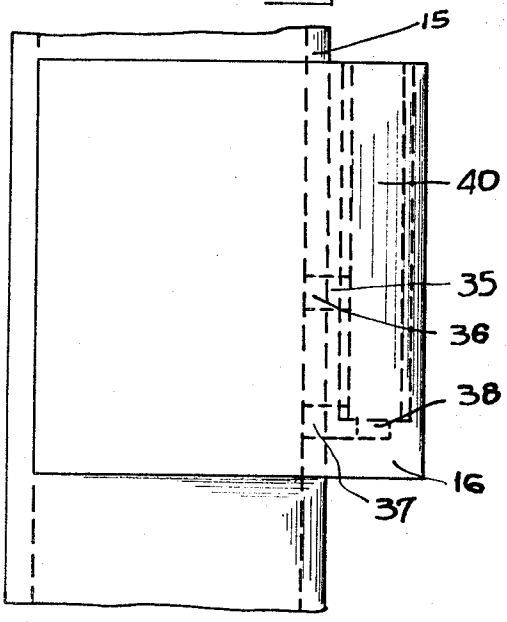


Fig. 7.

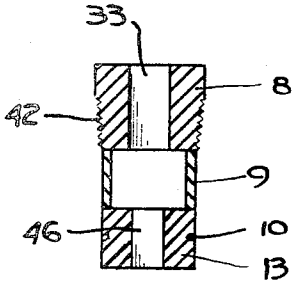


Fig. 5.

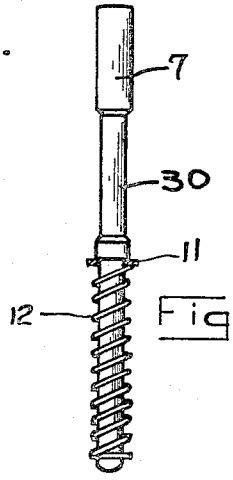


Fig. 14.

Oct. 15, 1968 T. E. BRYAN 3,405,647

FLOW VALVES

Filed Nov. 9, 1966 3 Sheets-Sheet 3

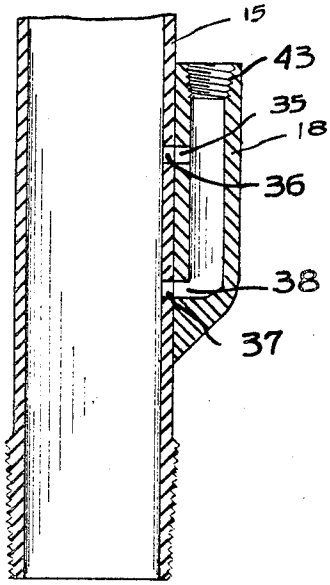


Fig. 10



Fig. 12

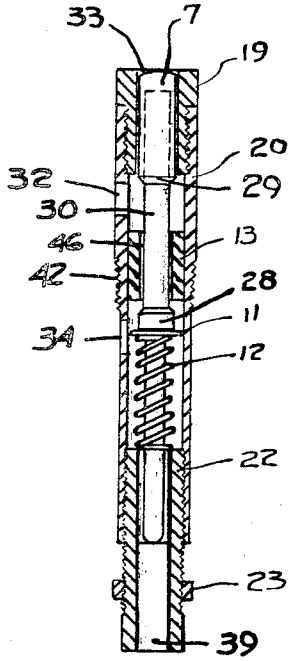


Fig. 9

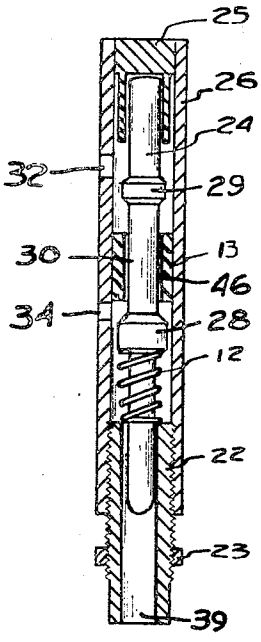


Fig. 11

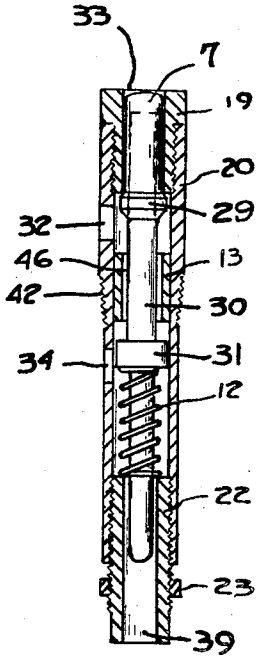


Fig. 13

United States Patent Office 3,405,647
Patented Oct. 15, 1968

3,405,647

FLOW VALVES

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Filed Nov. 9, 1966, Ser. No. 593,118
4 Claims. (Cl. 103—232)

ABSTRACT OF THE DISCLOSURE

An air lift valve means for use in cased oil wells. The valve means has activating surfaces exposed constantly to tubing pressure and casing pressure respectively. The valve is urged to open responsive to the combined forces of tubing fluid and a coil spring and is urged to close by casing pressure. The air lift valve means further comprises check valve means which prevents fluid flow from the tubing to the casing.

This invention relates to flow valves for oil wells for controlling the admission of gas into a column of fluid in a well to aerate the column thereby reducing its weight and aid in lifting the fluid to the surface, or in certain other applications to admit such gas into the column in large quantities at intervals to cause the column or a selected portion thereof to be lifted to the wells surface in a solid piston type flow.

In conventional well installations employing similar devices, the well equipment generally includes a string of relatively small pipe or tubing inserted in a larger pipe or casing positioned within the well bore, either of which may extend to the well bottom. The flow valves are usually spaced along the well tubing at intervals as it is run into the well. Gas or air is then introduced into the annular space between the two strings of pipe at the wells surface and the pressure permitted to rise to a predetermined amount and thereafter as fluid rises in the well and exerts a pressure on an actuating surface of the flow valve thereby opening the valve to admit the gas in the casing to enter the tubing thereby lifting the fluid to the surface.

After the fluid or a part thereof has been evacuated from the well and the pressure within the tubing declines below that pressure at which the valve opened, the valve closes, thus stopping the gas injection to the tubing and it remains closed until the fluid pressure once more rises in the tubing and the action is repeated. A packing element surrounding the tubing and sealing against the casing walls may be employed to prevent the gas under pressure from exerting a pressure against the well formation.

Conventional gas lift valves of the class generally referred to above have heretofore been designed for the purpose, all having certain advantages as well as certain disadvantages. This invention relates to improvements in this type of valves to improve their operation and to correct the disadvantages referred to. Two general types of valves are best known in the art and are commonly referred to as either Bellows operated pressure loaded valves or Differential valves. As indicated, any valve employing a metal bellows which may either be loaded and sealed so as to confine a charge of gas or air therein or thereon to maintain the valve in closed position and requiring a rise in casing pressure to open the valve, is generally referred to as a pressure operated bellows valve. In other types of this valve, they are not loaded but still employ a bellows for the purpose of sealing off the effect of pressures in the well and in combination with a spring, respond to either the effect of casing pressure or from the effect of well pressures or a combination of both. In most instances Bellows valves rely on the loss of pressure in the casing after opening the valve, to close it after dissipating

some of its pressure. In the differential type valve, to which this improvement relates, the opening of the valve relies on the well pressures in the tubing plus the tension of a spring at a given differential of pressure between the casing and the tubing, and closes when the pressure in the tubing declines a predetermined amount.

Unlike the bellows type valve regardless of its mode of operation the differential valve is always maintained in closed position by the gas pressure and opened by a combination of spring tension plus well pressure at any given valve, and only closes upon the decline of well pressures in the tubing.

Thus in differential valves all areas of the valves actuating surfaces are exposed to some pressure; either that of the well pressure in the tubing or the pressure of the gas in the casing, and therefore unlike the bellows valve a spring is not a substitute for a bellows; whatever tension exists in a bellows when compressed interferes with the operation of the valve and exerts a pressure or tension in some direction not required or wanted. Whereas in a differential valve the tension of the spring employed is entirely calculable and necessary for the proper operation of the valve.

The disadvantages referred to heretofore in the operation of differential valves has been in the erratic operation of their closing operation. Designed as they are to be opened by the pressure in the tubing it is obvious that as gas is injected to the flow column at any level and flow is thereby established, friction due to flow is created; this plus the weight of the column above the valve creates a pressure actually greater than at which the valve opened therefore since the valves could not close unless a pressure drop occurred in the tubing all valves would remain open. In valves where the inlet port restricted the entrance of gas to the housing the pressure effective within the valve to close it was constantly declining and therefore unable to close the valve when it should. In the instant valve having an area exposed to the constant pressure in the casing there is no loss of pressure necessary to close the valve and at some level above the point of injection, and due to the wide spacings permitted with this valve, before the column reaches the next valve above, the aeration effect in the column will permit the necessary drop in tubing pressure to close the valve. It is to be understood that in the instant valve spacings between valves along the tubing are at least twice as far as has been possible with valves of this type heretofore. This is made possible by the closing ability of the valve as described.

It is, therefore, an object of this invention to provide an arrangement of valves in a well whereby the fluid confined therein can be lifted to the surface with a minimum of gas and at the greatest efficiency.

It is a further object of this invention to provide an arrangement of valves of the type set forth so that no valves above the one actually operating for the removal of the liquid from the well, will be caused to open by the flowing fluid and admit gas into the tubing.

Still another object of this invention is to provide a mode of operation whereby the opening and closing of the valve is a calculated and predetermined pressure relationship between the tubing and casing pressures.

It is another object of the invention to provide a method of operating differential flow valves whereby all control areas of the valve are exposed to the full and constant pressures of either the gas under pressure or the well fluid pressure in the casing with no pressure drop thru the valve.

A principal object of the invention is to create a new method of controlling the valves operation that permits the valve to close upon a predetermined minimum decline of pressure in the tubing, after the valve opens.

Another important object of the invention resides in a new method of controlling the closing operation of the valve whereby increased spacings between valves may be employed.

Other objects and advantages of this invention will become apparent from the following description taken in connection with the accompanying drawings. It is to be understood that the said drawings and descriptions are by way of illustration and example only and this invention is to be limited only by the prior art and by the appended claims.

In the drawings;

FIG. 1 is an assembly view of the preferred construction of the device in place within a well.

FIG. 2 is a view in vertical cross section illustrating the construction of the valve supporting chamber **3**, together with the means of mounting the valve housing **6** thereon and showing the special coupling **2** for connection to the tubing **1** at either end.

FIG. 3 is an enlarged view in vertical cross section of the valve housing **6** and the preferred form of the flow valve therein.

FIG. 4 is a view in cross section of the chamber **3** together with the valve housing welded in place thereon at **45**, and showing the receptacle **40** therein for receiving the valve assembly. The vertical center line of the fitting as well as the center line of the off-set bore hole are indicated by the cross lines.

FIG. 5 is a cross sectional view of the valve parts making up the valve assembly adapted to be installed in the bore **40** in the housing. The valve stem part shown in elevation in FIG. 14 forms a part of this assembly.

FIG. 6 is a view in cross section of another form of a valve supporting fitting together with the valve assembly housing **17** attached thereto.

FIG. 7 is a side elevation view of the valve housing assembly shown in FIG. 8, in place on the sub nipple in FIG. 6.

FIG. 8 is a horizontal cross section view of the valve housing assembly shown in FIG. 7 together with the valve receiving receptacle shown in place surrounding the sub nipple; parts **16** are separate units and fitted around the sub and welded thereto.

FIG. 9 is a vertical cross section of a modified form of the flow valve shown in FIG. 3 adapted to be installed in the assembly illustrated in FIG. 10.

FIG. 10 is a view in cross section of a sub-nipple adapted to receive the modified forms of the flow valve shown in FIGS. 9 and 13 both of which operate in accordance with the invention.

FIG. 11 is a view in cross section of a prior valve not part of the invention and shown only by way of illustrating the important difference in operation though the difference in construction of the claimed invention are not great. As in all differential valves the mode of operation is the only difference possible; similarity of construction to accomplish the purpose form a part of all such valves.

FIG. 12 is a vertical view of the top of FIG. 11 illustrating the solid plug (**25**) fitted into the valve housing.

Referring now specifically to FIG. 1 it will be seen in the well illustrated there is a tubing, extending into the well at or near the well formation, the valve supporting Chamber and its joining parts **2–3**, are shown attached to the tubing above and below, a casing **4** surrounds the tubing and extends into the well bore to the top of the well formation, a packing element **5** attached to the tubing and sealing against the walls of the casing forms a gas chamber in the annulus of the casing thereabove. Suitable connections (not shown) will be made at the top of the well for introducing pressure gas to the annular casing chamber. Likewise, suitable connections (not shown) will be made at the surface for the discharge of oil and gas from the tubing.

In FIG. 2 and referring to the parts illustrated it is to be noted that the chamber **3**, provides an unobstructed fluid passageway therethru in vertical alignment with the tubing above and below, and is joined to the tubing by special fitting **2**. The vertical passage thru the chamber for oil is bored off-set from a vertical center line of the fitting whereby one wall is of thicker proportions than the opposite wall and that in the thicker section of the wall, a transverse slot is formed in the exterior wall providing a flat seating surface for the valve housing **6**. The housing **6** after being put in position on the seating surface it is welded in position as in **45**. A vertical groove **41** is formed in this thicker wall section extending upwardly from the housing **6** approximately a distance of one and one half inches which provides an indentation within the wall so that the valve parts shown in FIGS. 5 and 14 may be installed in the bore **40** of the housing after it has been attached to the chamber as above. Threads **43** in the top of the bore **40** accommodate the threaded valve stem guide **8**.

Referring now to FIG. 3 and especially to the part **6**, the valve housing there is a bore **40** therein extending downwardly to a depth necessary to match up the ports **35** and **38** with the ports **36–37** thru the side walls of the chamber **3**, forming outlets for gas into the interior of the chamber and thence into the tubing. A gas inlet port **32** shown clearly in FIG. 2, admits the gas in the casing to the interior bore of the housing. It is to be noted that the port **32** is of small capacity, calculated to be the amount necessary to establish flow up the tubing economically, but in any event its capacity is less than the capacity of bore **46** surrounding the valve stem **30** which forms a passage for gas traveling towards the tubing when the valve is open and affords a passage for back pressure of the oil in the tubing to the dome **47** of the valve. The inlet (**33**) bore thru the guide plug **8** has only a limited capacity around the stem section **7** as this member has a sliding fit therethru, and the combined capacity of this port and port **32**, as above must be less than the port **46** as described. The purpose of this arrangement will become apparent later in the description of the operation of the valve. Within the bore of the housing **6**, a valve stem **30** and **7** slidably operates longitudinally thru the guide plug **8** at the top of the valve stem and the seat **13**, the clearance around the stem **30** in the bore **46** provides a passage for gas thru the valve as above and affords communication with the interior of the chamber **3** and the tubing thru the large ports **35–36–37–38**. These ports have a combined capacity much greater than the inlet ports to the valve assembly so that regardless of the amount of gas admitted to the assembly the pressure therein will always reflect the oil pressure in the tubing; below the seat **13** when the valve is closed and above and below **13** when the valve is open; that is when valve member **29** is in contact with seat **13** the valve is closed; when it is raised off of seat **13** the valve is considered open. An O ring groove **10** surrounds the seat **13** forming a seal with the inner walls of bore **40**. Valve member **28** positioned on the stem below the seat **13** is an automatic check valve to prevent back flow from the tubing into the casing in the event the pressure in the tubing exceeds that of the casing during periods of inoperation of the well. A compression spring **12** surrounds the lower portion of stem **30** resting on the bottom of bore **40** exerts a pressure upward against a washer **11** which may be a part of member **28** or a separate part; the spring assists the oil pressure from the tubing working against the bottom exposed surfaces of the stem to open the valve. Little if any pressure is required of the spring when the member **28** is in contact with the seat **13**.

The top of stem **30** or member **7** is of the same diameter as the outer seating edge of seat **13**, and the same diameter valve members **28** and **29** to maintain an absolute balance of pressures thruout the valve members. The member **7**, which can be termed a piston, operates longitudinally thru the port **33** of the guide plug **8** and extends into the zone of casing pressure unrestricted by ports

whereby the full effect of the casing pressure is always applied on the area of the top exposed to that pressure and therefore is constant and unaffected by pressure conditions within the groove. The entire valve assembly of parts made up of FIGS. 5 and 14 consisting of the spring, stem, spacer, seat and guide plug are contemplated to be installed in the bore **40** of the housing **6** either prior to attaching the housing member to the chamber **3** or afterwards. The stem consists of two parts; the member **7** and the stem **30**. Member **7** has a bored hole therethru for receiving the top of stem **30** which is press fitted there into after the seat member **13** has been fitted around the stem **30**. After the stem **30** with the seat in place there around, the spring and stem are inserted in the bore **40**, the seat being of a diameter to be press fitted therein. Then the spacing ring **9**, is dropped into place and the guide plug screwed into the threads **43** of the bore **40** in the housing.

In FIG. 4 the housing **6** is shown in position attached to the chamber **3** and welded as shown at **45** or it could be attached by bolts (not shown). The exterior circumference of the housing is rounded to conform to the arc of the circumference of the chamber **3**. The off-set bore of the chamber is indicated by cross lines and the center line of the fitting is indicated thereabove.

In operation, after the valve assembly including the housing **6** have been attached to the chamber **3** and installed in the well as in FIG. 1 the valve assembly will be in position as shown in FIG. 3 with the lower valve element **28** seated against the seat **13** preventing back flow from the tubing to the casing; after the tubing has been run in the well and the packer seated against the casing walls, gas under pressure is introduced into the annulus of the casing at the wells surface thereby creating a column of gas above the oil level standing in the well.

Assuming the fluid level to be at the level of the topmost valve at the start of operations. The gas pressure in the casing will depress the fluid and by transferring it into the tubing thru the lower valve or other suitable opening in the tubing near its lower end, raise it to a higher level. As the fluid level in the casing drops and the space above it continuously replaced with gas under pressure, as the top valve is uncovered and exposed to the gas in the casing, the pressure is applied to the member **7** of the valve and starts it moving downward thus opening the valve assembly so as to admit gas into the tubing; this operation will continue until the level of the fluid in the casing uncovers the next valve, at which time, depending upon the tension of the spring, the top valve element **7** together with the balance of the stem unit is depressed so as to make contact with seat **13** thus closing this valve. As previously set forth, this closing action is the result of either aeration of the fluid column to a point where the pressure in the tubing is less than at which the valve opened or due to the evacuation of the fluid at the well head. This differential valve closing operation is a preselected relationship of tubing pressure and casing pressure prior to installing the unit in the well. As the second valve is uncovered and operation occurs from this point as above, the fluid in the casing will continue to transfer into the tubing as above, and so on until the casing is emptied of fluid, and depending upon the pressure maintained in the casing, the lower valve or any one above having sufficient submergence of well flud now rising from the well bore in the tubing will re-open and inject gas to the tubing and reestablish flow up the tubing as rapidly as the well input fluid rises to a height necessary to create a pressure sufficient to open the valve.

Explaining the closing operation of the valve as above in more detail, as the top valve is uncovered and pressure is admitted into the valve assembly through the ports **32–33** the pressure in the casing is constantly applied to the top of element **7** thus maintaining a constant pressure downward to close the valve. At the same time back pressure from the tubing entering the ports **35–36–37–38** are effective within the valve assembly upon the lower end of the valve stem and the under side of valve element **28**, urging the stem upward; likewise since the area through the seat member bore around the valve stem permits the transfer of this tubing pressure to be fully effective within the dome of the valve assembly the back pressure from the tubing applies against the lower face of valve element **29** and on the upper face of valve element **28**, since these areas are identical the back pressure has no effect to move the valve in either direction and the net pressure of the back pressure to hold the valve open, or rather resist the closing of the valve is applied against the lower end of the valve stem and the under side of element **28**. Referring now to the area of the top of element **7** which is equal to the areas just described, exposed to the gas pressure, the pressures within the valve and the effect of pressures are maintained in constant relationship with each other and the slightest drop in tubing pressure is reflected instantly within the valve and the stem moves to close the valve accordingly. In addition to the back pressure resisting the closing of the valve is the spring, to a degree preset to control the differential opening of the valve.

The description of the closing operation of the valve as set forth, will be better understood by considering the opening operation and the conditions prevailing within the valve assembly with the valve closed. Under static conditions between cycles of operation, as oil rises in the tubing, the back pressure from the tubing enters the valve assembly thru the ports **35–36–37–38** as explained, and surrounds the lower valve parts and is effective on the areas of the various valve elements described to urge the valve upwardly to open the valve. Like in the closing operation this pressure is effective thru the bore of the valve seat and applies against the lower face of element **29**, but in the same manner as described, this effect of pressure downward on the upper face of valve element **28**, offsets any influence of the back pressure between the valve elements to move the valve in either direction, and the only area effective to respond to the back pressure is the lower end of the stem and the lower face of valve element **28**.

The tension of the spring having been pre-set, when the oil rises in the tubing to a sufficient height and its pressure becomes effective within the valve assembly and their combined pressure equals or slightly exceeds the effect of casing pressure on element **7**, the valve rises and disengages the element **29** from the seat and gas now entering ports **32–33** begins to pass downwardly thru the port in the seat and exits thru the ports **35–36–37–38** into the tubing. Thus the pressure within the valve assembly is maintained in proper balance to accomplish its function whether the valve is open or closed. It should be noted here that the gas entering the valve assembly thru ports **32–33** into the dome of the assembly encounters the back pressure from the tubing as set forth and raises the pressure within the dome only to that extent necessary to establish flow thru the bore of the seat and thence up the tubing; the pressure within the valve assembly therefore remains the reflected back pressure from the tubing and the injected gas has no effect to disturb the relationship of pressures as described.

Unlike other valves of the differential type employing a single nozzle exposed to the tubing pressure wherein when the valve opens, and gas pressure is confined within the valve assembly at all times, the pressure within the assembly is that of the gas and not the oil and the nozzle now becomes exposed to the gas pressure and is responsive thereto and thus after opening, the gas pressure may be operating against itself, applied on the top of the valve to close it and upward on the nozzle to keep it from closing thus working to prevent the valve from closing. As a matter of fact the main objection of the differential type valves in the past has been the difficulty of obtaining a closing that was dependable and has led to the practical abandonment of this type of valve.

This illustrates the importance of the improvements

sought by this invention and it will be seen that a means has been provided for carrying out all the objects and advantages claimed, therefore, I claim:

1. A gas injection valve in combination with a string of well tubing extending into a well bore, well casing surrounding said tubing affording an annular gas chamber containing gas under pressure, a housing unit spaced apart on said tubing and forming a part thereof having communication therethru with the interior of said tubing at either end, means mounted exteriorly on said unit for supporting said injection valve, a passage for gas thru said unit affording communication between said tubing and said casing, a ported valve seat positioned within said passage, a movable valve element slidably operable longitudinally thru said seat, opposed closure elements on said movable element forming contacts for said seat in either direction of movement for controlling passage of gas thru the seat, a ported guide plug positioned at one end of the passage affording communication with the casing and the interior of said valve, a portion of the movable valve element extending thru the guide plug and exposed to the pressure in the casing whereby said pressure is fully applied thereto urging it in a direction to close the passage thru the seat, valve means on the movable element exposed to the corresponding pressure in the tubing within the valve whereby said pressure is effective thereon to move it in a direction to open the passage thru the seat and a spring cooperatively arranged with the movable element urging it in a direction to open the passage to permit gas to enter the tubing.

2. In combination with an automatic flow valve, a casing in a well forming a pressure chamber, tubing in said casing adapted to receive oil from the well, a valve supporting housing on the tubing, a passage for gas thru the housing for admitting gas from the casing to the interior of the tubing, valve means mounted within the passage for controlling the admission of gas to the tubing, ports in the housing for admitting gas to said valve means, a portion of said means extending thru the housing and exposed to the gas in the casing, said valve means being responsive to the pressure in the casing to move in a direction to interrupt the admission of gas to the tubing thru the passage, additional valve means within the housing, exposed to the pressure in the tubing and acted thereupon to urge said valve means in a direction to open the passage and means to maintain the full and corresponding oil pressure in the tubing within said housing surrounding said valve means when the passage is open.

3. In combination with an automatic well flowing device, casing in an oil well forming a chamber for gas under pressure, tubing therein open at the bottom to receive oil from the well and open at the top for the discharge of oil, spaced apparatus on said tubing for admitting gas under pressure in the casing to the oil in the tubing to eject it consisting of a valve supporting housing, a gas admission valve in said housing, means on said valve exposed constantly and at the corresponding pressure to the oil in the tubing for actuating said means to open and admit gas from the casing to the tubing, a portion of said admission valve exposed to the pressure in the casing whereby the said pressure is constantly applied thereon to urge the valve to a closed position, a spring associated with said admission valve resisting the closing of said valve and a valve means within the housing forming a part of the admission valve preventing back flow from the tubing to the casing.

4. In combination, a casing in a well forming a chamber for gas under pressure, tubing in the casing adapted to receive oil from the well, spaced valve units on said tubing for admitting gas from the casing to the interior of the tubing, a hollow bored housing member mounted exteriorly on said unit forming a passage for gas from the casing to the tubing, valve means in the passage actuated by the pressure in the casing to close the passage, additional valve means forming a part of said first means responsive to the oil pressure in the tubing for opening the passage, said means exposed to the full and corresponding pressure in the tubing when the passage is open or closed and a spring assisting the oil pressure to open the passage to admit gas to the tubing.

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